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Brief Contents

Abstract

This thesis comprises four empirical essays on environmental and development economics. In the first chapter, we examine to what extent individual and contextual level factors influence individuals to contribute financially to prevent environmental pollution. We find that rich people, individuals with higher education, as well as those who possess post-materialist values are more likely to be concerned about environmental pollution. We also observe the country in which individuals live matter in their willingness to contribute. More precisely, we find democracy and government stability reduce individuals' intention to donate to prevent environmental damage mainly in developed countries. The second chapter deals with the relation between economic growth and environmental degradation by focusing on the issue of whether the inverted U-shaped relation exist. The study discloses no evidence for the U-shaped relation. However, the empirical result points toward a non-linear relationship between environmental degradation and economic growth, that is, emissions tend to rise rapidly in the early stages with economic growth, and then emissions continue to increase but a lower rate in the later stages. The third chapter investigates the long-run as well as the causal relationship between energy consumption and economic growth in a group of Sub-Saharan Africa. The result discovers the existence of a long-run equilibrium relationship between clean energy consumption and economic growth. Furthermore, the short-run and the long-run dynamics indicate unidirectional Granger causality running from clean energy consumption to economic growth without any feedback effects. The last chapter of this thesis concerns with convergence of emissions across Canadian provinces. The study determines convergence clubs better characterizes Canadian's emissions. In other words, we detect the existence of segmentation in emissions across Canadian provinces.

Keywords: World Value Survey; Multilevel modelling; WTP; Environmental Kuznets Curve; CO2 emissions; Economic development; Clean energy; Cross-sectional Dependence; Structural breaks; Club convergence; clustering; Canadian provinces

Résumé

Cette thèse comporte quatre essais et porte sur les questions fondamentales sur la relation entre l'environnement et le développement économique. Le premier chapitre cherche à identifier les déterminants individuels et contextuels qui affectent la volonté de contribuer des gens à la lutte contre la pollution environnementale. Nos résultats révèlent que les individus riches, les personnes éduquées ainsi que les personnes possédant des valeurs post-matérialistes sont plus susceptibles d'être préoccupées par la pollution environnementale. On remarque que la caractéristique du pays de ces individus affecte leur volonté à contribuer. Ainsi, dans les pays à forte démocratie avec une forte stabilité gouvernementale, les individus sont réticents à faire des dons pour prévenir les dommages environnementaux. Le deuxième chapitre examine la relation entre la croissance économique et la dégradation de l'environnement en s'interrogeant sur la relation U inversée de Kuznets. Nos résultats empiriques ne révèlent aucune preuve de ladite relation. Cependant, nous notons l'existence d'une relation non linéaire entre la croissance économique et la dégradation de l'environnement. Les émissions ont tendance à augmenter à un rythme plus rapide dans les premiers stades de la croissance économique puis dans les dernière étapes, cette hausse persiste mais à un rythme plus lent. Le troisième chapitre étudie la relation de causalité de long terme entre la consommation d'énergie propre et la croissance économique dans un groupe de pays de l'Afrique subsaharienne. Le résultat révèle l'existence d'une relation d'équilibre à long terme entre la consommation d'énergie propre et la croissance économique. En outre, la dynamique de court terme et de long terme indiquent une relation de causalité à la Granger unidirectionnelle de la consommation d'énergie propre vers la croissance économique sans aucun effet rétroactif. Le dernier chapitre de cette thèse cherche à investiguer sur la convergence des émissions de gaz entre les provinces canadiennes. L'étude montre que les émissions de gaz des provinces canadiennes sont caractérisées des convergences de clubs. En d'autres termes, on détecte l'existence d'une segmentation des émissions entre les provinces canadiennes.

Mots-clés: World Value Survey; Modélisation multi-niveau; WTP; Courbe de Kuznets environnementale; Émissions de CO2; Développement économique; Énergie propre; Dépendance transversale; Ruptures structurelles; Club convergence; clustering; Provinces canadiennes

General introduction

The process of industrialization, which originally started in the United Kingdom in the middle of the 18th century, has clearly transformed nations forever. This industrial revolution brought about many societal and economic changes. It shifted societies from agrarian economies into industrial ones. The establishment of large-scale industries that succeeded the industrialization process resulted in large-scale urbanization, technological innovations, trade liberalization, wealth accumulation, higher paying jobs and, of course, better living standards.

Much has changed in the wake of industrialization, particularly with the rapid evolution of technology and the emergence of a global economy. Nowadays, nations around the world are attaining ever higher levels of economic growth through heavy exploitation of natural resources and increasing industrial production, resulting in continually higher rates of energy consumption. The rush to achieve better standards of living has played a major role in the rapid increase in anthropogenic emissions of greenhouse gases, particularly over the last few decades. Where industrialization brings improvements and creates economic opportunities, it also presents challenges. The challenges include poor air quality, higher temperatures, higher sea levels, stronger and more frequent storms, extreme weather conditions, increasing number of droughts, food and water shortages, forced migrations, and species extinctions.

According to a recent assessment report by the Intergovernmental Panel on Climate Change, 2014 (IPCC), relative to the pre-industrial era, carbon dioxide concentrations have increased by over 40 percent, driven largely by the process of industrialization and associated fossil fuel combustion. During the 21st century, global anthropogenic emissions have continued to increase, with larger absolute increases occurring between 2000 and 2010 than in any decade previously. According to the same report, in 2010, global greenhouse gas emissions had increased by 31% relative to their

1990 level. Combined global land and ocean average surface temperature increased by 0.85 Celsius during the 21st century, snow cover decreased by 1.6% per decade, and sea level rose by 0.19 centimeters. It has been predicted that global average temperature will continue to rise, snow and ice will continue to melt, and sea levels will continue to rise throughout the 21st century.

These negative consequences of environmental pollution have drawn a lot of attention on a global scale. There is strong belief now that the upsurge in global temperatures observed over the previous decades is mostly a result of higher atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). A majority of climate scientists agree that the earth is deteriorating at a fast rate, climate change is largely due to human activities, not naturally occurring phenomenon, and that the consequences of this may severely impact our well-being and the economy. Furthermore, climate scientists add that the escalating industrial activity has an impact on living standards and on the long-term global economic growth. There is scientific evidence today that poor air quality has direct impact on human longevity. Using data on 22,902 subjects from the American Cancer Society cohorts, Jerrett et al (2005) showed that chronic health effects and specificity in cause of death are associated with within-city gradients in exposure to $PM_{2.5}$ (fine particulate matter). Aunan and Pan (2004) also confirmed that poor air quality has severe impact on human morbidity and mortality. Moreover, it can be argued that poor environmental conditions reduce long run economic prosperity through negative effects on health and labour supply which in turn diminish productivity. As the magnitude of these issues is brought to public attention, environmental awareness is developing. Governments and public across the globe have become increasingly aware of the need to reduce our environmental footprint. As well as ecologic areas of study, these concerns have attracted researchers' interest in economics, sociology and other fields interested in investigating the determinants of pollution emissions and to understand the steps society can take, either individually or collectively to mitigate these effects.

The societal bases of public concern related to environmental quality

It is difficult to trace back the origin of human concern for environmental factors, but there was a general, well-established belief that the modern concept of environmental concern grew its roots in the 20th century, with the first efforts to conserve natural resources, the beginning protests against air pollution, and the campaigns against fossil fuel combustion.

Environmental activism has surfaced at various times, for various reasons and in various forms, but the scale of activism shown by the environmental organization Greenpeace has been unprecedented. As a movement, Greenpeace has hundreds of millions of adherents around the world, the organization is expanding and spreading into other forms of environmental protection. The rise of environmental movement and social movements has ignited the debate around what motivates individuals to engage in environmental protection groups. The existing literature posits that socio-economic and demographic characteristics of individuals might explain their involvement in environmental concerns. Some authors went as far as claiming that in general women show more care for the environment than men (Bord and O'Connor, 1997; Franzen and Meyer, 2010; McCright, 2010). Yet, others working in the field found that women, married, and those have at least one child are more likely to engage in action toward environmental protection, due to the social responsibility effects (Hunter et al, 2004). There is strong believe that educated individuals are more likely to be concerned about environmental issues than non-educated, because they have better understanding about the consequences environmental problems may bring (Olli et al., 2001). Besides, studies such as, Franzen and Meyer (2010), Kemmelmeier et al. (2002) and Franzen and Vogl (2013) found that wealthier individuals are more likely to be greener than poorer ones. Additionally, Inglehart (1990) argued that individuals' values and personal beliefs may explain to certain extend their involvement in environmental protection. However, at the country level, it is claimed that country wealth is behind cross-national variation in environmental concerns. The existing literature explains all these hypotheses by three main theories: the post-materialist values thesis, the affluence hypothesis and the global environmentalism theory.

In the early 1990s, Inglehart has advanced a theory of global modernization stating that as societies develop and become more prosperous, people depart from the core goals of materialistic values, such as physiological sustenance and improvement of economic conditions, toward more so-called contemporary values such as political freedom, self-expression and environmental protection.

Inglehart's (1990) thesis has inspired an impressive amount of empirical research to test the hypothesis in both industrialized and developing countries. The post-materialislism claim has been challenged by many researchers. A number of studies reveal that citizens in both developed and developing countries unveil high degree of concern for the environment (Brechin and Kempton, 1994; Dunlap, Gallup, and Gallup, 1993; Dunlap and Mertig, 1995). In response, Inglehart revises his original thought by distinguishing among concern for the environment due to subjective environmental values and objective environmental problems. He adds that environmental concerns in developing countries can be explained mainly by the need to overcome severe local environmental conditions, such as air pollution and lack of clean drinking water prevailing generally in developing countries. A second line of studies related to environmental concern emerges and advocates that environmental quality rises with the level of affluence (Diekmann and Franzen, 1999; Franzen, 2003; Kemmelmeier et al. 2002).

Though, public support for the environment should be seen as a global phenomenon, emerging from multiple sources, such as direct exposure to environmental degradation resulting from industrialization, trade liberalization, quality of institutions, rather than being determined solely by a particular result of post-materialism values or of a country's wealth.

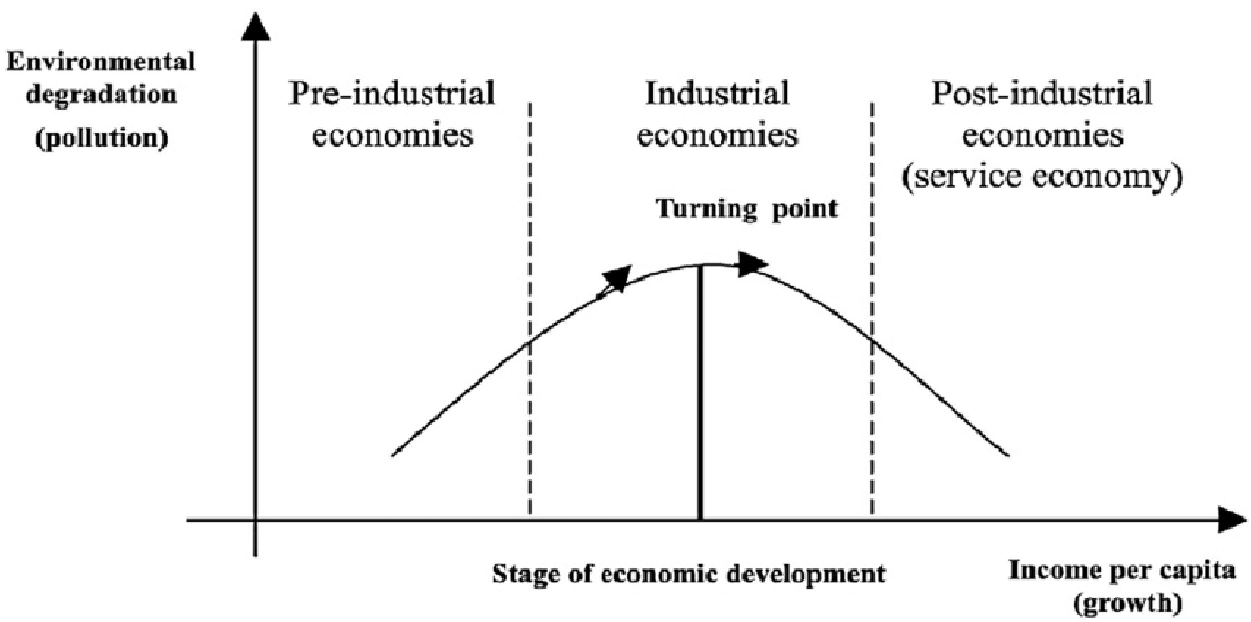
With the recent increase in environmental degradation, the world has seen environmental groups multiplied and environmental protests intensified. Violent public demonstrations at WTO meetings were partly as a consequence of environmental concerns related to trade liberalization (Brunnermeier and Levinson, 2004). Irrespective of the public's support for the environment, the questions that everyone should ask is, what are factors behind individuals' involvement in environmental protection and whether individuals' financial contribution for the cause of the environment may change the future development of emissions trajectories and/or fundamentally change the ability to mitigate. Clearly, deep-rooted public concern in environmental protection may shape and reshape public policies in significant ways.

The Environmental Kuznets Curve

It is well recognized that a worldwide change in attitude is essential to create balance between economic growth and the protection of the environment. This worldwide concern has sparked great interests over the past three decades to study the link between economic growth and environmental pollution. In an article prepared for a conference concerning the North American Free Trade Agreement (NAFTA), and talks focused on the impact of this agreement on changes to the production of pollutants, Grossman and Krueger (1991) brought up the concept of an Environmental Kuznets Curve (EKC)[1]. Basically, Grossman and Krueger (1991) studied the development of production of sulfur dioxide, smoke and suspended particulates in industrial zones of a dozen countries and found that for two pollutants (sulfur dioxide and smoke), concentrations increase with

[1] A clause in the NAFTA assumes that there will be a cross-border transfer of environmentally challenging production from the US and Canada to Mexico.

per capita GDP at low levels of national income, but decrease with GDP growth at higher levels of income. Their findings have attracted broad attention of economists and policy analysts due to their importance in policy implementation. Then, Grossman and Krueger (1995) and the World Bank Paper by Shafik and Bandyopadhyay (1992) popularized the idea. By using a simple empirical approach, Grossman and Krueger (1995) tested different pollutants across countries and found that in countries with low GDP per capita concentration of dangerous chemical substances initially increased, but after a certain level of income, concentration was falling. If the hypothesized relationship was found to hold true across countries, rather than being a threat to the environment, economic growth would be the means through which sustainable economic development can be achieved, as depicted in Figure 0-1 below:



Source: Panayotou (1993)

Figure 0-1. The Environmental Kuznets Curve

The issue of whether environmental degradation increases or decreases has been examined on a wide variety of pollutants, including automotive lead emissions, deforestation, greenhouse gas emissions, toxic waste, and indoor air pollution[2]. The relationship has been examined with different econometric approaches, including higher-order polynomials, fixed and random effects, splines, semi- and non-parametric techniques, and different patterns of interactions and exponents. Additionally, studies have focused at cross-country and at regional levels. The general conclusion emerging from these analysis is that the turning points differ across countries. For some countries the turning points occurs at the highest income level, or even no turning points at all, for some others pollutants, it appears to increase steadily with income. As a matter of fact, the empirical evidence is rather mixed.

Nonetheless, theoretically several studies seem to provide explanation for the income–pollution path. There are two basic competing views with respect to the relationship: the first view states that economic growth is harmful to the environment (Meadows et al, 1972), while the second argues that technological process and economic growth improve environmental quality (Panayotou, 1993; Brock and Taylor, 2005). According to Brock and Taylor (2005), as an economy grows the scale of all activities increases proportionally, pollution will increase with economic growth. But when economic activity shifts from energy-intensive industries to cleaner ones, emissions fall through the composition effect and then as investments in environmentally-friendly technology become more effective, sustainable development is achieved. Others share this view. In a short paper in the Policy Forum section of Science, Arrow et al. (1995) advance that environmental quality generally worsens during the initial phases of economic growth but when societies have attained relatively more advanced stages of economic growth, they tend to give greater attention to environmental quality through either market mechanisms or regulatory policies. However, they cautioned against interpreting the EKC as implying that the international and national environmental problems

[2] These indicators became the most widely used approximation of environmental quality.

accompanying economic growth would be resolved through autonomous processes specific to each country. On the other hand, Lopez (1994) shows that the EKC can be explained by preferences of economic agents. He argues that if preferences are homothetic, an increase in income leads to higher consumption, which in turn cause an increase in output will eventually cause higher pollution. But if preferences are nonhomothetic, along with rising income individuals may desire to consume less and thereby cause less pollution, depending upon the relative risk aversion between consumption and environmental quality. Another theoretical approach that could contribute to the foundation of the EKC assumes that environment is a luxury good, which implies if income increases by 1%, the demand for environment quality increases by more than 1%. In a case of European Union (EU) countries, McConnell (1997) showed that environment quality is a normal good with income elasticity of demand slightly higher than one.

As mentioned above, many studies have tested the relationship between economic growth and environmental quality using various environmental indicators, countries, regions, sectors and adopting more sophisticated econometric techniques, but empirical results are far from conclusive. Many scholars advocate that the main reasons for the discrepancy in the results can be attributable to among others thing, the properties of the data used and the methodology applied. Other factors might also impact the nature of the relationship, for instance, the degree of liberalization of the economy, the environmental regulation within the country, the historical development of the land, the natural endowment of the country as well as the effect of weather conditions. As such, not accounting for these variables into the relationship could distort the pollution-income path[3]. Therefore, to properly assess the pollution-income dynamics, the need for proper indicators to reflect

[3] The common feature to most previous econometric studies of the growth–environmental relationship are GDP per capita and its square treated as explanatory variables. The GDP variable represents the scale of economic activity while its square represents those aspects of the economy that do not change as GDP grows.

environmental quality as well as an appropriate methodology is required. Without a relevant methodology the EKC hypothesis remains a subject of ongoing debate. In view of these limitations, some researchers were cautious in interpreting the results and begun to call for mitigation through regulations (Dasgupta et al, 2002).

The Mitigation Strategies

Due to the global nature of the problem of greenhouse gas emissions, there is today wide consensus that in order to address the problem of climate change, international coordination is required. Over the past four decades or so, the international community had made significant efforts to address the issue of climate change. Actions towards this direction started with the 1972 discussion of the United Nations Conference on the Human Environment held in Stockholm, then materialized twenty years later with the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) to negotiate greenhouse gas emissions reduction. A more concrete example of these international negotiations is the Kyoto Protocol, which represents the first significant international agreement toward greenhouse gas emissions reduction. The Kyoto Protocol defined legally binding emission commitments for industrialized countries and market mechanisms for mobilizing the most cost effective mitigation options worldwide. Under the Kyoto protocol, most developed countries committed to reduce their total greenhouse gas emissions by an average of 5% relative to 1990 levels by 2012. In 2011, a new round of negotiations started aiming to define a new binding climate agreement applicable to all countries, this process yielded to the recent Paris Climate Agreement. The Paris Agreement sets a new objective aiming to limit the global average temperature increase to 1.5 degree Celsius above pre-industrial levels. These objectives are attainable only if countries agree to curb emissions resulting from the combustion of fossil fuels, as emissions steaming from these sources contribute significantly to the increase in greenhouse gases concentrations[4].

With a growing global population, competitiveness among nations and grappling with the issue of environmental problems, countries need to shift from fossil fuels to less earth-damaging sources of energy in order to meet their increasing energy demand[5]. As alternative to fossil fuels, renewable energy technologies is seen as viable energy sources since it lower carbon intensity, while improved energy efficiency can lower emissions.

With the recent increase in energy prices and way to find response to global climate change, economies start to promote the development of renewable energies such as biofuels, wind and solar energies. As such, in 2011 alone, renewable energy provided 14.0% of the world energy demand and the trend is upward sloping. By 2015, 19.3% of the global energy demand come from renewable energy (Sawin et al, 2017). According to a recent report of European Environment Agency (EEA) the use of renewable energy has cut the European Union's carbon footprint by 10%. While renewable energy seems to be a major contributor to climate change mitigation. The link between renewable energy consumption and economic growth is less understood.

In a group of industrialized countries, more specifically, Tugcu et al (2012) use a panel of G7 countries for 1980–2009 period to investigate the long run and causal relationship between renewable energy and economic growth. They found that renewable consumption matters for economic growth. Similarly, Bhattacharya et al (2016) assess the effects of renewable energy consumption on the economic growth of 38 top renewable energy consuming countries. After

[4] In 2012, fossil fuels accounted for 84% of worldwide energy consumption and about 2/3 of global greenhouse gas emissions can be attributed to the supply and use of energy from fossil fuels.
[5] Developing countries were not placed under any mandatory obligation but were encouraged to access better technology in order to curb their greenhouse gases.

controlling for cross-sectional dependency of the data and solving for heterogeneity issue, they found clear evidence that renewable energy consumption has a significant positive impact on the economic growth of 57% of the countries studied. Despite the high importance of renewable energy in climate change mitigation, there is only a few of empirical works who documented the relationship between renewable energy consumption and economic growth (Yoo and Jung, 2005; Payne and Taylor, 2010, Apergis and Payne, 2010). In recent years there has been an intensive debate about the linkages between renewable energy and economic growth in general, and in particular the discussion was more heated in the case of developing countries. If renewable energy consumption are robustly found to improve environmental quality without negatively affecting economic growth. It will be of great interest especially for sub-Saharan African countries that are currently undergoing industrialization to use renewable energy to facilitate the implementation of national sustainable development strategies in order to reduce poverty while facing the mounting environment problems[6].

Club convergence

Recently the concept of club convergence has emerged as alternative to the traditional convergence testing procedure. Over the past few decades, the literature has widely applied methodological approaches, such as beta, sigma, and stochastic convergence to seek for income convergence across nations. However, the general observation from the application of these methodologies is that poor countries' income is not converging to the income levels of the rich countries. Later on Romer (1994) argued that endogenous factors within the economies were the main sources for the observed differences among countries. But when Baumol (1986) studied the relationship between average

[6] In 2014, more than 1.061 billion people worldwide - half of them located in Africa (excluding Northern Africa) - still lacked access to electricity (The World Bank. Global Tracking Framework 2017).

annual rates of growth and initial levels of income, he observed that industrial countries appear to belong to one convergence club, middle income countries moderately converging to a separate one, and that low income countries actually diverged over time. Following Baumol (1986) seminal work, an expanding body of the literature has started to investigate whether countries converge to equilibrium position, polarize or form a club at the long run (Bernard and Durlauf 1995; Quah 1996; Hobijn and Franses 2000; Phillips and Sul 2007). These studies showed that economies that have similar characteristics move from a disequilibrium position to their club-specific steady state positions. More recently, studies have applied the club convergence methodology to investigate the distribution of series, such as, inequality, income levels and energy consumption. Yet, Apergis and Payne (2017) is the single study of which we are aware has investigated the convergence at sectoral level using emissions data and found that per capita carbon dioxide emissions are club converging.

Structure of the thesis

This thesis consists of four chapters excluding the introductory one. The thesis contributes to the on-going research issue related to the factors influencing sustainable development in developed and developing countries. The first chapter investigates the factors behind individuals' willingness to pay to prevent environmental pollution. Using data from the World Values Survey (WVS), which contains socio-economic and socio-demographic information, and merged it with country level covariates. The chapter tries to examine whether wealthier people, individuals with higher education, those who possess post-materialist values as well as the wealth of the nation, the quality of institutions of the country in which they belong influence their ability to contribute financially to protect the environment. Furthermore, this chapter makes the distinction by controlling for the factors behind individuals' willingness to pay to prevent environmental pollution for developed and developing countries. The results highlight that in developed countries, about 90% of country variation in willingness to pay to prevent environmental pollution can be explained by individual characteristics. This portion reduces to 80% in the case of developing countries. We found that wealthier individuals, individuals with higher education, as well as those who possess post-materialist values are more likely to be concerned about environmental pollution than their peers who do not show these characteristics. Also, we observe that improvement in democracy and government stability reduce individuals' intention to donate to prevent environmental damage mainly in developed countries.

The second chapter seeks to empirically investigate the so-called "Environmental Kuznets Curve", the hypothesized U-shape relationship between environmental degradation (CO2 emissions) and economic growth (GDP growth). To test this relationship, we make use of a large sample of developed and developing countries and employ the Panel Smooth Transition Regression (PSTR) framework. The PSTR has been introduced in the literature by González et al. (2005), an approach that is a suitable to account for cross-country heterogeneity and time variability of the slope coefficients. Generally, it is found in the literature that energy consumption, industrialization, urbanization, trade openness, capital expenditure as well as quality of institutions variables play an important role in the relationship between environmental degradation and economic growth. To provide a more robust results, we accounted for these variables into the relationship and dealt with endogeneity biases in the estimation. Our findings reveal no sign of evidence supporting the Environment Kuznets Curve hypothesis, however, a non-linear relationship between environmental degradation and economic growth is found. In other words, we observe that emissions tend to rise rapidly in the early stages with economic growth, a then continue to increase but a lower rate in the later stages.

Having found an increasing relationship between environmental degradation and economic growth in the previous chapter 2, the next chapter tries to assess whether a long-run and causal relationship between clean energy consumption and economic growth can be establish. The issue is explored in the case eleven sub-Saharan African countries over the period 1971–2007. We apply the panel unit root test that accounts for the presence of multiple structural breaks (Carrion-i-Silvestre et al, 2005) and the newly-developed panel cointegration methodology which allows for cross-section dependence and multiple structural breaks (Westerlund and Edgerton, 2008) as well as a bootstrap-corrected Granger causality test to seek for evidence. The econometric estimations revealed that clean energy consumption and economic growth are cointegreted. Further, the results from the panel causality tests indicate that there is indeed a unidirectional Granger causal flowing from clean energy consumption to economic growth. These findings have major economic and long term environmental policy implications in countries where more than 70% of the population does not have access to electricity and a large proportion of them still burn fossil fuels for everyday energy need.

The last chapter of this thesis examines the idea of whether countries, regions that share same characteristics tend to converge towards one another and create a club convergence. To explore this, we use aggregate and sectoral levels data on per capita greenhouse gas emissions among Canadian provinces over the period 1990-2014. Then, we carried out the study by means of the novel regression-based technique that tests for convergence and club convergence proposed by Phillips and Sul (2007, 2009). This procedure for testing for convergences takes into account the heterogeneity of the provinces. Our findings support Baumol's idea of convergence clubs. More specifically, the results point out that Canadian provinces and territories are characterized by various convergence clubs at the aggregate as well as at sector levels. The existence of multiple steady state equilibria suggests that Canadian policy makers could tailor mitigation policies that equitably share the burden of greenhouse gas emissions reductions among provinces and territories, that help achieves national emissions' reduction targets.

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Chapter 1. A multilevel analysis of the determinants of willingness to pay to prevent environmental pollution across countries[7]

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1.1. Introduction

Over the past decades, particularly after the 1970s, the world has witnessed a burgeoning of ecological resistance and a rise in environmental concerns.[8] The surge in environmental consciousness has prompted increasing research to investigate in detail what shapes individuals' environmental awareness. Concerns about environmental problems were initially considered as a manifestation of affluence and belief to be linked to post-materialistic values (Inglehart, 1990, 1995). Recently, studies have shown that the rapidly increasing environmentalism has become a global phenomenon which spread through both developed and developing countries (Brechin and Kempton, 1994; Dunlap and Mertig, 1997; Brechin, 1999; Gelissen, 2007; Dunlap and York, 2008). It is worth mentioning that since the appearance of the modern environmental movement in the early 1970s, hundreds of thousands of people around the world have joined grassroots groups to protest exposure to environmental pollution (Tesh, 1993). The fast-growing and unprecedented expansion of environmental organisations in the years following the 1970s indicates that the movement is not only alive but that it may be stronger than ever (Dunlap & Mertig, 1991). Nowadays, environmental movements exist at the local, national, and international level. Greenpeace has millions of paying supporters around the globe. Earth Day Network has more than 50,000 partners in 196 countries reaching out to hundreds of millions of people. Furthermore, results from the fifth wave of the World Values Survey (WVS) indicate that about 65 per cent of the World population are willing to protect the environment through financial contribution. This uprise

[8] Dunlap and Jones (2002) define environmental concern as the degree to which people are aware of problems regarding the environment and support efforts to solve them and/or willingness to contribute personally to their solution.

in movements have ignited serious research and heated environmental policy debate during the past few decades.

A large body of literature has explored the reasons motivating individuals to engage in environmental protection. An influential strand of this literature postulates that on top of post-materialistic values, environmental concern is also driven by the increased incidence of climate-related disasters, coupled with almost conclusive scientific evidence as well as mass-media coverage of both disasters and scientific near-consensus (Doulton and Brown, 2009; Sampei and Aoyagi-Usui, 2009). Undeniably, these climate-related disasters have had a great incidence on individuals' environmental consciousness and have consolidated public views on the need to protect the environment. A number of previous studies have found socio-economic status as determinant of environmental concern (Sulemana, 2016; Sulemana, *et* al, 2016, Marquart-Pyatt, 2012). For instance, Sulemana (2016) studies the relationship between happiness and WTP to protect the environment in 18 countries. He concludes that happier individuals are more willing to make income sacrifices to protect the environment. In the same vein, Sulemana, *et* al. (2016a) explore whether people's perceptions about their socioeconomic status are correlated with their environmental concern. They find that relative to people who believe they are in the lower class, those in the working class, lower middle class, upper middle class, and upper class tend to show significantly more environmental concern in both African and developed countries. In a comparative study across 19 advanced industrial and former communist nations, Marquart-Pyatt (2012) reveals some factors (education and income) that are consistently related to pro-environmental attitudes and behaviors.

On the other hand, Franzen and Meyer (2010) argue that wealthier countries are more concerned about environmental issues than poorer countries. As pointed out by Inglehart (1995) regardless of being in a rich or a poor country, individuals who perceive their immediate environment deteriorating as a consequence of environmental pollution are more likely to take positive actions leading toward an environmental improvement. Sulemana et al (2016b) find evidence corroborating Inglehart's (1995) "objective problems and subjective values" in the case of African countries. However, given that environmental protection may be accompanied by real costs, individuals' actions alone would not suffice to combat environmental pollution. As such, a scaled up effort to preserve the environment may be seen as a viable avenue to adequately address environmental issues. Therefore, it is important to investigate the potential effects of contextual factors on individuals' willingness to combat environmental pollution. Although, research on environmental concern is an area of growing interest, the majority of studies exploring environmental concern have either ignored individual level or contextual level factors (Dunlap *et* al, 1993; Dunlap and Mertig, 1997; Inglehart, 1995, 1997; Kidd and Lee, 1997; Diekmann and Franzen, 1999; Franzen, 2003; Knight and Messer, 2012). Little has been done to test a model that integrates both individuals and contextual level variables. We are only aware of a few studies which have investigated the determinants of individuals and contextual factors (Gelissen, 2007; Franzen and Meyer, 2010; Fairbrother, 2012; Running, 2013 and Dorsch, 2014). They too have been limited in scope because they focus predominantly on the factors influencing environmental concern in highly industrialized countries.

The purpose of this chapter is to provide a more cohesive analysis, by applying multilevel modeling to unpack the factors behind individuals' WTP to prevent environmental pollution in developing and developed countries. We use socio-demographic, social structural, psychological, as well as contextual covariates to establish whether there are similarities or differences in WTP to prevent environmental pollution across countries. Results of multilevel logistic regressions indicate that a substantial proportion of country variation in WTP to prevent environmental pollution can be explained by individual characteristics. That is, education, income, post-materialist values, religion and membership of environmental organization are found to be consistent determinants in explaining WTP to prevent environmental pollution. Besides these strong and statistically significant individual level predicators, we find evidence that, mainly in developing countries, democracy and government stability are negatively correlated with individuals' intention to take action to mitigate environmental problems. Various reasons can be offered for the negative effects of democracy and government stability on individuals' financial contribution in developed countries. For instance, in developed countries, effective policies such as absolute limits on emissions, government funding of alternative-energy systems, and coordinated efforts to protect biodiversity are likely to lower individuals' participation to combat environmental problems. It can also be argued that in countries where democracy and government stability are prevalent, people pay their fair share of taxes and expect their government to do its part in addressing environmental challenges. Thus, this study represents not only the first research on efforts to elucide the role of the quality of institutions on individuals' participation to combat environmental problems, but is also one of the few empirical analyses to apply statistical tools to disentangle the effect of individuals and contextual level factors on WTP to prevent environmental pollution. Our findings echo that the longstanding developed - developing differential in the WTP to prevent environmental pollution can be explained by both individuals and contextual level covariates.

Chapter 1 proceeds as follows. The next section reviews relevant literature about individuals' and cross-national environmental concerns. We then present the multilevel logistic modeling approach. In Section 1.4., we describe the data. Section 1.5. discusses the empirical results. The last section concludes the chapter.

1.2. Related Literature

Different perspectives have been offered to explain what motivates individuals and nations to be concerned about environmental issues.[9] Yet, identifying the underlying factors behind individuals' and nations' environmental concerns is still a subject of debate in contemporary social science disciplines.

To date, there are three main theories which prevail, through which social scientists have attempted to explain individual and cross-national variation in environmental concerns. The theory of post-materialism values (Inglehart, 1990, 1995, 1997), the prosperity hypothesis (see; Diekmann and Franzen, 1999; Franzen, 2003; Franzen and Meyer, 2010 and Franzen and Vogl, 2013), and the global environmentalism theory (Dunlap and Mertig, 1997; Gelissen, 2007 and Dunlap and York, 2008).

1.2.1. The post-materialist values thesis

Inglehart's (1990) post-materialism values thesis postulates that environmental consciousness among individuals arises as a result of a certain cultural shift. The main claim is that, as societies become more prosperous, people depart from the core goals of materialistic values, such as physical sustenance and improvement of economic conditions, toward more so-called contemporary values such as political freedom, self-expression and environmental protection. Inglehart (1995) investigates environmental concern among nations by analysing data on the willingness to make financial sacrifices to protect the environment in 43 countries. He finds that among nations, there

[9] Among others, see (Dunlap *et* al., 1993; Scott and Willits, 1994; Inglehart, 1995; Brechin and Kempton, 1994; Dunlap and Mertig, 1997; Diekmann and Franzen, 1999; Gökşen *et* al., 2002; Kemmelmeier *et* al., 2002; Franzen, 2003; Gelissen, 2007; Dunlap and York, 2008; Franzen and Meyer, 2010; Meyer and Liebe, 2010; Givens and Jorgenson, 2011; Nawrotzki, 2012; Marquart-Pyatt, 2012; Knight and Messer, 2012; Franzen and Vogl, 2013; Jorgenson and Givens, 2013; Running, 2013, Lo and Chow, 2015).

are two very different states of fact behind environmental concerns. First, Inglehart posits that directly confronted with poor environmental conditions, such as air pollution and lack of clean drinking water, people in developing countries tend to provide support to overcome objective local environmental problems. This argument has to do with what he terms objective environmental issues.

The second argument is what has been labelled in the literature as subjective environmental values. Individuals in advanced industrial societies display pro-environmental attitudes because of a general shift from materialistic to post-materialistic values. Inglehart claims that as countries develop and accumulate certain levels of wealth, their citizens become more environmentally conscious and active than those living in developing countries. Furthermore, he argues that the growing number of individuals embracing post-materialistic values in industrialized countries in the decades following World War II has played an important role in building popular support for environmental protection in industrialized countries. Inglehart's subjective values hypothesis has become the cornerstone for the ongoing post-materialism theory debate.

1.2.2. The affluence hypothesis

As one might expect, a rise in income levels would stimulate the consumption of high quality goods. Since environmental quality is perceived as a normal good, economic theory predicts that, all other things being held constant, an increase in income levels will lead to rise in WTP to improve the quality of the environment. Numerous studies have attempted to explore the direct link between affluence and environmental concern. For example, Diekmann and Franzen (1999) use data on 21 countries - mostly industrialized nations that participated in the International Social Survey Programme (ISSP, 1993) to investigate whether environmental concern rises with national affluence. Their findings reveal that 9 out of the 11 items contained in the ISSP that measure environmental concern are correlated with GNP per capita. Franzen (2003) revisits the work by extending the sample size to 26 countries and uses a new release of the ISSP (ISSP, 2000). He finds evidence that corroborates their initial findings. In a similar vein, Kemmelmeier *et* al. (2002) examine the relationship between affluence and attitudes toward the environment at country and individual level. They notice that affluence has a positive impact on the ability to contribute to environmental protection. More recently, Lo and Chow (2015) employ a cross-national social survey to investigate how perception of climate change concern is related to a country's wealth. Their findings show that national wealth correlates positively with concern about climate change.

1.2.3. The global environmentalism theory

The view that awareness of environmental problems and support for environmental protection is limited to industrialized nations and elites within industrialized nations has been challenged in a series of papers (Dunlap *et* al., 1993; Brechin and Kempton, 1994; Dunlap and Mertig, 1997; Gelissen, 2007; Dunlap and York, 2008; Fairbrother, 2012). These authors argue that support for environmental protection is not confined to wealthy nations, as it is often thought. In contrast, it has spread to the general public and become a worldwide phenomenon instead of a particular result of post-materialism values or of a country's wealth. Using data on 24 countries that participated in the Health of the Planet Survey (HOP), Dunlap *et* al (1993) find that 9 out of the 14 items in the HOP that measure environmental concern are negatively correlated with GNP per capita. Similarly, Sandvik (2008) investigates public concern about the environment in 46 countries, and finds that public concern correlates negatively with national wealth. In a series of papers, Gelissen (2007) and Dunlap and York (2008) use data from different waves of the World Values Survey. Indeed, they discover that individuals in low income countries are more likely to be concerned about environmental issues than those in developed countries. These authors argue that objective environmental problems, which especially permeate developing countries, are a much more plausible explanation for global environmental concern than the shift towards post-materialist values.

This chapter proposes to contribute to the literature by using micro and macro-level data to investigate the sources of WTP to protect the environment. As alluded earlier, our goal is to apply a proper econometric technique and to use a richer set of independent variables to isolate the determinants of WTP for environmental protection in developed and developing countries.

1.3. Econometric framework

This section introduces the multilevel cross-sectional regression model. The multilevel regression is also referred to in the literature as a hierarchical logistic regression model, or as a mixed effects regression model - is an extension of the single-level regression model. The term mixed-effects refers to the fact that both the fixed and the random effects are simultaneously estimated within a single equation. An interesting feature of the multilevel approach is that, it provides an attractive and practical alternative to the conventional modeling approach, as the analysis accounts for the structure of the data, with Level-1 being nested in Level-2 (Gupta *et al*., 2007). As such, this study exploits the nested structure of the data by applying a multilevel cross-sectional logistic regression to individuals (Level-1) and country data (Level-2) to predict the WTP for environmental protection. The dependent variable used in this study is a binary variable taking the value of 1 if the individual agreed to pay for environmental protection and 0 otherwise. Let π_{ij} be probability of reporting the characteristic of interest for individual i in country j. The logistic regression model can be specified by the following equation:

$$\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_{0j} + \sum_{k=1}^{K} \beta_k\, x_{kij} + \epsilon_{ij} \quad (1)$$

In equation (1), the first term in the left hand side represents the log of the odds of WTP for environmental protection. The right hand side of equation (1) contains a set of individual-level covariates including age, gender, marital status, education, income, post-materialistic values, membership in environmental organizations and religious beliefs, with their corresponding coefficients denoted by β_k. Note that by putting subscript j, we allow for more than one country in the analysis. The residual errors $\epsilon_{ij} \sim N(0, \sigma_\epsilon^2)$ are assumed to have a mean of zero and a variance to be estimated. The intercept β_{0j} is assumed to have a multivariate normal distributions, it is allowed to vary across country and is considered to be a function of country characteristics (Level-2) and random components. The intercept β_{0j} can be defined by the following equation:

$$\beta_{0j} = \eta_{00} + \sum_{h=1}^{H} \eta_k\, z_{hj} + \mu_{0j} \quad (2)$$

Thus, the model that combines individual and country level covariates can be written as a multilevel regression equation by substituting equation (2) into equation (1), which yields:

$$\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \eta_{00} + \sum_{k=1}^{K} \beta_k\, x_{kij} + \sum_{h=1}^{H} \eta_k\, z_{hj} + \mu_{0j} + \epsilon_{ij} \quad (3)$$

From the resulting specification, the segment $\eta_{00} + \sum_{k=1}^{K} \beta_k \, x_{kij}$ contains the fixed (or deterministic) part of the model whereas $\sum_{h=1}^{H} \eta_k \, z_{hj} + \mu_{0j} + \varepsilon_{ij}$ represents the random (or stochastic) part of the model. The terms z_{hj} denote covariates at Level-2, η_{00} is an intercept that represents the grand mean of the Level-1 coefficients. The residual error terms $\mu_{0j} \sim N(0, \sigma_{\mu}^2)$ are assumed to have a mean of zero and to be independent from the errors ϵ_{ij}. By construction, the multilevel model assumes the explanatory variables at Level-2 and the random effects are uncorrelated. Nevertheless, it is well known that when unobserved heterogeneity at Level-2 is correlated with the explanatory variables, the standard errors are much too small, and this could yield bias estimated results. To circumvent this issue, we subtract group averages from the continuous individual-level covariates. By doing so, the regression is more likely to provide accurate estimates as well as the corresponding standard errors. In addition to the multilevel approach being a powerful analytical technique to disentangle composition and contextual effects, the multilevel model also assesses interclass correlation. It is natural to consider that individuals within the same country tend to behave more similarly compared to those located in different countries. Therefore, the interclass correlation calculates the variation between countries in terms of WTP for the protection of the environment, and tests for the significance of the random effects. Thus, the interclass correlation is specified as follow:

$$\rho = \frac{\sigma_{\mu}^2}{\sigma_{\mu}^2 + \sigma_{\epsilon}^2} \tag{4}$$

The interclass correlation coefficient ρ indicates simply the proportion of Level-2 variance compared to the total variance.

1.4. Data

1.4.1. The World Values Survey

The individual level data used in this study are from the WVS. The WVS is an investigation of basic values and beliefs of the general public in a large number of countries and regions. The fifth wave is more comprehensive than previous waves, it covers all regions and levels of development - high-income, upper middle income, lower middle income and low-income countries. The fifth wave took place in 59 countries and regions, and was carried out between 2005 and 2008. Table 1-6 (Appendix A) provides the year in which the survey was conducted for each country. A total of 83,975 individuals aged 15 years and above were interviewed. Personal information on socio-demographic characteristics, income, cultural and beliefs, and perception about environmental problems were gathered from individuals in the participating countries and regions. The fifth wave is based on representative and sufficiently large samples. Another advantage of the fifth wave, is that it includes many socio-economic and demographic variables. We use it as a rich source of supplementary independent variables to investigate in detail what shapes individuals to be concerned with environmental issues. Among the questions asked in the fifth wave, there are numerous items that measure environmental concern. However, for the purpose of this research, we analyse responses from two questions included in the survey. That being said, in some part of the survey questionnaire, the respondents were asked to state their WTP to prevent environmental pollution.

The exact wording is "I am now going to read out some statements about the environment. For each one I read out, can you tell me whether you strongly agree, agree, disagree, or strongly disagree.

> (1) I would be willing to give part of my income if I were sure that the money would be used to prevent environmental pollution.

(2) I would agree to an increase in taxes if the extra money is used to prevent environmental pollution.

We use the response from the two questions above to construct the dependent variable. The response codes are structured on a four-point scale (1=strongly agree, 2=agree, 3=disagree, 4=strongly disagree). We change the original coding format and create a binary variable that takes 1 if the respondent strongly agreed or agreed with the above two statements and 0 if the respondent disagreed or strongly disagreed with both statements[10]. Respondents who strongly agreed or agreed with an increase in taxes and disagreed or strongly disagreed to give part of their income to prevent environmental pollution are removed from the sample and vice versa. After deleting missing values from the sample and merging with the country level data, we end up with 44,258 observations (47 countries), representing 53% of the original sample.

1.4.2. Individual level covariates

We use information on individuals as well as on country level to understand the factors behind individuals' willingness to incur financial costs in order to prevent environment degradation. From WVS, we collect detailed information on socio-economic and demographic variables, such as age, gender, marital status, the presence of children in the household, level of education, self-classified income, religiosity, adhesion to environmental organizations, materialist and post-materialist values.[11]

[10] Our primary objective is to construct an indicator of willingness to make monetary sacrifice to protect the environment. Both statements offer an indication of WTP. See the recent studies by Dorsch (2014) and Running (2013) regarding the use of composite binary variable as measure of environmental concern.

[11] Torgler and Garcia-Valiñas (2007) provide an exhaustive literature review of relevant articles that included individual level covariates as predicators of environmental concerns.

Considering age, it is argued that recent birth cohorts express higher levels of pro-environmental behaviour and are more willing to contribute for its protection than older birth cohorts, since older cohorts will not live long to enjoy the benefits of preserving resources for later years (Dietz *et* al., 1998; Torgler and Garcia-Valiñas, 2007). Studies have also addressed the differences between male and female in environmental concern (Bord and O'Connor, 1997; Franzen and Meyer, 2010; McCright, 2010). These authors claim that in general women show more willingness to contribute in monetary terms to protect the environment than men. Zelezny and Yelverton (2000) have found that regardless of age, women are more willing to take positive actions aiming at the protection of the environment than men. Furthermore, Hunter *et* al (2004) provide valuable insights for the engagement of women in environmental protection. They argue that the traditional gender socialization of women, the motherhood mentality and the ethics of care explain women's engagement for the protection of the environment. In contrast, Swallow *et* al (1994) and Cameron and Englin (1997) have found lower participation from women.

Some studies explained the presence of children in the household as the reason why individuals are more willing to pay to protect the environment. For instance, Laroche *et* al (2001) observe that individuals who are keener to pay for eco-friendly products are women, married, and have at least one child. In short, it could be postulated that having children engenders social responsibility (altruism) and enhances concern for the environment and thereby leads to greater pro-environmental behaviour. Thus, we control for marital status and the presence of children in the household. Regardless of age and gender, richer people are more likely to be greener than poor people and are more willing to be concerned about the state of the environment

(Franzen and Meyer, 2010; Kemmelmeier *et* al., 2002; Franzen and Vogl, 2013). To test this assertion, we control for relative income.

Besides controlling for important individual level characteristics such as age, gender and relative income, studies also have shown that educated individuals are more concerned about the environment than non-educated ones, since they have better knowledge of environmental problems (Olli *et* al., 2001). Subsequently, we investigate the effect of education on the WTP to protect the environment. We also explore whether values and beliefs can affect environmental concern. We used the scale that was developed by Inglehart (1990) as the measure of post-materialistic values. Inglehart's scale involves a battery of questions to measure value orientations. Respondents were asked to determine what they believe to be the first and second most important issues out of four choices:

(1) Maintaining order in the nation;

(2) Give people more say;

(3) Fighting rising prices; or

(4) Protecting freedom of speech.

Individuals are said to hold materialistic values when they have a combination of answers (1) and (3), while individuals are said to hold post-materialistic values when they answer a combination (2) and (4). Individuals holding a mixture of materialistic and post-materialistic values have a combination of answers (1) and (2) or a combination of answers (3) and (4). It can also be argued that studies might be biased if the interviewed individuals seem to be environmental activists. To control for this type of bias, we account for adhesion to environmental movements.[12] And finally, we investigate the effect of religiosity (or religious beliefs) on environmental protection, since religion serves as an important source of morals to many individuals around the globe.

1.4.3. Country level covariates

We merged individuals' level data with data on country level. The country level data permits an investigation into the differences in WTP to protect the environment across countries. Prior studies have underlined the association between national wealth and environmental concern, and revealed that higher income countries have on average, higher demand for a clean environment (Gelissen, 2007; Franzen and Meyer, 2010; Knight and Messer, 2012). It has been argued that wealthier nations have better quality of public mechanisms, which contribute to individuals' wealth on top of their personal incomes and thereby increase their WTP for the protection of the environment (Franzen and Meyer, 2010). To test the effect of national wealth on the WTP for environmental protection, we consider the gross domestic income per capita. Therefore, higher standards regarding environmental legislations and solid institutions for the protection of the environment in developed countries may play a crucial role on individuals' involvement in the protection of the environment. Thus, we control for institutions quality (democracy and government stability). The local environmental quality condition is a significant aspect to consider. Awareness of local environmental pollution such as, nitrous oxide emissions, and of its negative impacts on humans' health and ecosystem may influence individual's action to contribute to improve local environmental problems. We also control for nitrous oxide emissions (thousand metric tons of $C0_2$ equivalent per capita). It is expected that as a country

[12] Adhesion to environmental organization is defined as being active or inactive member.

becomes more densely populated, environmental quality become of greater public concern. We control for population density. Public spending could be a crucial aspect in explaining individuals' attitudes to contribute for environmental protection. Therefore, we include government spending as a share of GDP to control for a country's ability to deliver public services to protect the environment. Except for the quality of institution which is from *International Country Risk Guide* (ICRG) database, all the other variables are from the *World Development Indicators* (World Bank). Table 1 provides a complete list of all variables along with descriptive statistics. Panel A of Table 1 shows individual level characteristics while Panel B provides statistics for the contextual covariates. Except for age and number of children, all the individual level variables are specified as categorical variables whereas the contextual covariates are continuous and averaged over 2005-2008. As can be seen, 65% of the World sample population participants were ready to take action toward environmental protection. This distribution is 70% for developing countries and 56% in the case of developed countries.[13] The average age of the whole sample was 41 with the target group being individuals of 15-98 years of age. In developing countries the average age is 38 years, and 47 years in developed countries. The average number of children in the household is comparable across groups of countries. Gender distribution of the population is 50% and 52% female in developing and developed countries, respectively. Regarding marital status, quite similar figures were observed among the group of individual classified as (Married/Living as married). Individuals who have Incomplete/complete primary and Incomplete/complete secondary education represent the largest group of educational attainment.

[13] One plausible explanation for the higher WTP to support environmental protection in developing countries compared to developed countries could be that, in developing countries, the livelihood of the masses depends on the exploitation of natural resources (coal, oil and gas, agricultural and forest resources), the exploitation and processing of which results in local environment degradation, such as soil erosion, desertification, poor air and water quality, thereby leading to more support for the environment.

With respect to relative income, a great portion of individuals falls in the second and third quintile categories. It is not surprising that there are more individuals possessing post-materialistic values in developed countries than developing countries. Surprisingly, there are more individuals claiming to be member of environmental organization in developing countries than developed countries. About 84% of individuals from developing world consider religion as important faith in their lives compare with only 50% in developed countries. The bottom end of Table 1-1 provides summary statistics for the country covariates used in the study. The higher the values for democracy and government stability, the better the quality of institutions[14].

[14] Detailed definition of individuals and contextual variables are not presented to conserve space, but are available upon request.

Table 1-1. Descriptive statistics

Variables	World		Developed		Developing	
Willingness to pay for environmental protection						
Yes	65.54%		55.99%		70.54%	
No	34.46%		44.01%		29.46%	
Panel A: Individual level covariates						
Age	41.35 (SD=16.25)		46.90 SD=16.56)		38.44 (SD=15.31)	
Children	1.86 (SD=0.65)		1.80 (SD=0.54)		1.89 SD=0.70)	
Gender						
Female	50.80%		52.37%		49.97%	
Male	49.20%		47.63%		50.03%	
Marital Status						
Married/Living as married	64.02%		65.02%		63.50%	
Divorced/Separated/Widowed	24.98%		18.90%		28.17%	
Single/Never married	10.99%		16.08%		8.33%	
Educational level						
No formal education	7.79%		0.74%		11.49%	
Incomplete/complete primary	22.72%		18.57%		24.89%	
Incomplete/complete secondary	32.55%		35.34%		31.09%	
Incomplete/ complete university	36.94%		45.35%		32.53%	
Income						
Lower quintile	18.88%		17.20%		19.76%	
Second quintile	27.00%		27.14%		26.93%	
Third quintile	31.70%		28.78%		33.24%	
Fourth quintile	16.95%		17.32%		16.76%	
Upper quintile	5.46%		9.55%		3.31%	
Value						
Mixed	55.42%		57.62%		54.27%	
Materialist	33.47%		26.96%		36.87%	
Post-materialist	11.11%		15.42%		8.86%	
Membership of environmental organisation						
Member	13.03%		8.53%		15.38%	
Not a member	86.97%		91.47%		84.62%	
Religion						
Important	72.51%		49.71%		84.45%	
Not important	27.49%		50.29%		15.55%	
Individuals	44258		15216		29042	
Panel B: Contextual level covariates	Mean	SD	Mean	SD	Mean	SD
Log(Gross domestic income)	8.15	1.46	9.32	1.25	7.53	1.16
Log(NOx)	9.09	2.38	8.25	3.15	9.53	1.69
Democracy	4.72	1.40	5.69	0.53	4.21	1.45
Government stability	9.36	2.03	10.95	1.62	8.53	1.69
Government spending	27.80	10.44	38.88	5.74	22.01	7.15
Density	106.97	95.68	99.41	87.02	110.92	99.69
Countries	47		20		27	

1.5. Results and discussion

1.5.1. Full sample of countries

Table 1-2 displays the estimated coefficients and the corresponding standard errors. Fixed effects are reported in the upper part, while random effects are in the lower part of the table. As a first step, the analysis begins by fitting an empty two-level model, that is, a model that contains only an intercept and a random effect which allow the WTP to protect the environment to vary across countries as specified in the model 0[15]. The empty specification reveals that most of the variability in WTP to protect the environment is originated in differences among individuals rather than between countries. More accurately, the value of the interclass correlation shows that the country dimension accounts for 19.5% of total variability. In other words, 80.5% of the variability in WTP to protect the environment can be attributable to individuals' level predictors. The findings indicate that individuals' level covariates play a more substantive role than contextual covariates in explaining differences among individuals in WTP to protect the environment. Nonetheless, countries' variability are not negligible and found to be also significant in explaining WTP to protect the environment. To corroborate these findings, we perform a test of variance equality between countries, the test rejects the null hypothesis that the between country variance is zero. Figure 1-1 (Appendix B) shows the estimated residuals for all the 47 countries. We see that for a substantial number of countries, the 95% confidence interval does not overlap the horizontal line at zero, indicating that the WTP for environmental protection is significantly above or below the zero line which implies quite a variation in terms of WTP across countries.

[15] Models are fitted via adaptive numerical integration with seven quadrature points.

The inclusion of demographic variables (age, gender, children, marital status, education attainment and income) brings changes to the model in terms of the estimate of the between-country variance. The random intercept variance increases from 0.746 in model 0 to 0.810 in model 1. Thus, it can be argued that the distribution of age, gender, children, marital status, education attainment and relative income is different across countries. With regard to the estimated coefficients, the study reveals that the effect of age on the log-odds of WTP to protect the environment is not statistically significant. However, the study found that educated individuals are generally more supportive of the environmental protection. This finding is in line with results reported in the literature regarding the effect of formal education on willingness to contribute for the environment (Veisten et al, 2004; Israel, D & Levinson, 2004). Wealthier individuals are found to be more willing to pay for the protection of the environment than poor people. More importantly, we observe that the effect of relative income on care for the environment increases linearly with income quintiles, suggesting that wealthier individuals are gradually more likely to participate in the protection of the environment than poorer individuals. Similar results were reported by Sulemana et al (2016b) who found that relative to people who believe they are in the lower class, those in the working class, lower middle class, upper middle class, and upper class tend to show significantly more environmental concern in both African and developed countries. The study also suggest that the group of Single/Never married and Divorced/Separated/Widowed are less caring for the environment than the group classified as Married/Living as married. This is evidenced by the negative and significant value of the estimated coefficients. As argued by Torgler and Garcia-Valiñas (2007) and Laroche et al (2001), married people are more concerned about environmental degradation than others, because of their social network and involvement in the community.

Furthermore, a bulk of the literature, however, has put forward values, religion and membership as sources for the emergence of environmentalism (Kidd and Lee, 1997; Schultzet al, 2000; Franzen, 2003; Torgler and Garcia-Valiñas, 2007; Yuchtman-Yaar and Alkalay, 2007). It can be seen that attitudes toward environmental protection differ substantially between post-materialistic and materialistic individuals, between religious and secular and between membership of environmental organization and non-member. Precisely, we found that post-materialistic individuals are more likely to contribute to protecting the environment than those possessing materialistic values. Being a member of environmental organization has a profound influence on the log-odds of WTP to protect the environment. The need to protect the environment was also found to be stronger in faithful individuals than those with secular behaviour.

It is highly possible that people with strong environmental preferences may choose to be members of environmental organizations. This could lead to endogeneity. To control for such a problem, values and membership have been removed in the last four estimations. The results remain robust after removing these two variables.

Then, we attempted to capture country attributes that are likely to influence individuals' decisions on WTP to protect the environment. We used national income to assess whether affluence can influence attitudes toward the environment. Nitrous oxide emissions was used as an indicator of the local ecological footprint. Also, scholars have stressed the relationship between the quality of institutions and environmental management (Paavola, 2007). Thus, we control for the level of democracy and government stability. Finally, we also investigate the effect of population density on the log-odds of the WTP to protect the environment.

Before including the aforementioned country level into the model, it is important to test the appropriateness of multilevel modeling. Basically, there is no standard procedure for testing the multilevel modeling structure of the data. However, in order to opt for the proper model, we perform a likelihood ratio test between the multilevel model without contextual effects (constrained model) and a model with contextual effects (unconstrained model). The likelihood ratio test clearly indicates that the unconstrained model is the preferred model ($\text{Prob} > \chi^2 = 0.0014$). Thus, we proceed by adding the contextual level variables into the model. It is interesting to see that the inclusion of the country level covariates decreases the random intercept variance. It is expected that the variance components would become smaller as relevant explanatory variables are included in the subsequent models (Hox *et* al, 2010). Furthermore, the inclusion of country level variables substantially reduces the interclass correlation by 4 to 6 percentage points.

With respect to the estimated coefficients, we observe that concerns for environmental protection is more pronounced in developing countries than developed countries. Local environmental condition and the density of population do not have influence on the log-odds of WTP to protect the environment. Country wealth has a limited effect on the WTP to protect the environment. The study found that the level of democracy as well as government stability is negatively associated with the WTP to protect the environment. However, the study finds that government spending has no statistically significant impact on individuals' preferences for environmental protection.

Table 1-2. Fixed and random part results for the multilevel logistic models - full sample.

	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Fixed part	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff
Individual level covariates										
Age		0.018	0.020	0.020	0.020	0.020	0.023	0.023	0.023	0.023
		(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Female		0.034	0.032	0.032	0.032	0.032	0.026	0.026	0.026	0.026
		(0.022)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
Children		0.057***	-0.049***	-0.049**	-0.049**	-0.049**	-0.047**	-0.047**	-0.047**	-0.047**
		(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Marital Status										
Single/Never married		-0.109***	-0.067*	-0.069	-0.069	-0.069	-0.051	-0.051	-0.051	-0.052
		(0.036)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)
Divorced/Separated/Widowed		-0.204***	-0.135***	-0.134***	0.134***	-0.134***	-0.135***	-0.135***	-0.135***	-0.135***
		(0.036)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)
Education										
Incomplete/complete primary		0.233***	0.212***	0.215***	0.216***	0.215***	0.200***	0.199***	0.200***	0.199***
		(0.050)	(0.051)	(0.051)	(0.051)	(0.051)	(0.050)	(0.050)	(0.050)	(0.050)
Incomplete/complete secondary		0.494***	0.380***	0.384***	0.385***	0.384***	0.426***	0.425***	0.426***	0.425***
		(0.051)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
Incomplete/ complete university		0.893***	0.671***	0.675***	0.677***	0.675***	0.746***	0.745***	0.747***	0.745***
		(0.052)	(0.053)	(0.053)	(0.053)	(0.053)	(0.053)	(0.053)	(0.053)	(0.053)
Personal Income										
Second quintile			0.131***	0.130***	0.130***	0.130***	0.109***	0.109***	0.109**	0.109***
			(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
Third quintile			0.360***	0.359***	0.358***	0.359***	0.349***	0.350***	0.349***	0.350***
			(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
Fourth quintile			0.469***	0.469***	0.468***	0.469***	0.466***	0.466***	0.466***	0.466***
			(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
Upper quintile			0.623***	0.624***	0.623***	0.624***	0.587***	0.588***	0.586***	0.587***
			(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)
Values										
Materialist			-0.257***	-0.258***	-0.258***	-0.258***				
			(0.025)	(0.025)	(0.025)	(0.025)				
Post-materialist			0.385***	0.386***	0.386***	0.386***				
			(0.039)	(0.039)	(0.039)	(0.039)				
Religion			0.226***	0.222***	0.223***	0.221***	0.221***	0.219***	0.220***	0.219***
			(0.031)	(0.031)	(0.031)	(0.031)	(0.030)	(0.030)	(0.030)	(0.030)
Membership of environmental organization			0.480***	0.479***	0.480***	0.479***				
			(0.039)	(0.039)	(0.039)	(0.039)				
Country level covariates										
Dummy (1 if developed country)				-0.791***	-0.746***	-0.914***	-0.842**	-1.005***	-0.369	-0.474
				(0.234)	(0.286)	(0.280)	(0.289)	(0.283)	(0.334)	(0.336)

Income					0.170	0.306	0.220*	0.338	0.333*	0.447*
					(0.131)	(0.181)	(0.133)	(0.188)	(0.133)	(0.177)
Noxide					0.107	0.097	-0.104	0.097	0.121	0.114
					(0.096)	(0.101)	(0.098)	(0.102)	(0.092)	(0.096)
Density					0.035	0.015	0.038	0.021	-0.001	-0.019
					(0.106)	(0.111)	(0.107)	(0.112)	(0.102)	(0.106)
Democracy					-0.351**		-0.335*		-0.287*	
					(0.148)		(0.149)		(0.142)	
Government stability						-0.303		-0.275		-0.242
						(0.172)		(0.175)		(0.164)
Government spending									-0.215	-0.243
									(0.170)	(0.142)
Constant	0.723***	0.209	-0.111	0.226	0.243	0.281	0.261	0.298	0.088	0.108
	(0.127)	(0.140)	(0.141)	(0.163)	(0.163)	(0.165)	(0.164)	(0.166)	(0.171)	(0.173)
Random part										
σ_{μ}^2	0.746***	0.810***	0.772***	0.621***	0.521***	0.546***	0.533***	0.559***	0.472***	0.489***
	(0.156)	(0.169)	(0.162)	(0.130)	(0.109)	(0.114)	(0.111)	(0.117)	(0.117)	(0.102)
ρ	0.195***	0.197***	0.190***	0.158***	0.136***	0.142***	0.139***	0.145***	0.125***	0.129***
	(0.031)	(0.033)	(0.032)	(0.028)	(0.024)	(0.025)	(0.025)	(0.026)	(0.023)	(0.023)
Log-likelihood	-25241	-24895	-24527	-24522	-24518	-24519	-24672	-24673	-24669	-24670
Observations	44379	44379	44379	44379	44379	44379	44200	44200	44200	44200

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

1.5.2. Developed countries

The evidence provided so far has been obtained for the full sample of countries. But, it can be argued that the effect of individuals and, particularly, that of countries are likely to vary between groups of countries. As such, we present subsequently the results obtained for developed and developing countries. Table 1-3 gives the results for developed countries. The findings reported in Model 0 indicate that the random intercept variance is 0.316 and the corresponding interclass correlation is 0.087, meaning that about 9% of total variability of the WTP to protect the environment can be attributable to countries level predictors in developed countries. As opposed to the results observed for the full sample of countries, the effect of age was found to be positive and statistically significant across all specification, signaling that older individuals are significantly more likely to agree to give part of their income for the protection of the environment. We found no evidence in gender difference with regard to WTP to protect the environment, which contradicts the results found by Torgler et al. (2008) indicating that women have both a stronger preference towards the environment and a stronger willingness to contribute. With respect to the effect of children on WTP to protect the environment, we found that individuals that have children are less likely to contribute to improve the quality of the environment in developed countries. The study also found correlation between individual's education and willingness to make income sacrifices to prevent environmental pollution. Individuals who have attained secondary and university education are more likely to agree to give part of their income for the protection of the environment in developed countries. It can be disputed that educated people are able to understand the harmful effects of pollution on the environment and are more willing to advocate for a clean environment. The effect of relative income on individuals' WTP was as expected, with higher relative income being associated with higher log odds of WTP to protect the environment. This association was statistically significant for all quintiles and consistent with previous findings by Sulemana et al (2016b). The findings also reveal religion and being a member of an environmental organization matter for the willingness to give part of one's income for environmental protection. Those who hold post-materialistic values are more likely to agree to give part of their income among individuals of developed countries.

Additionally, the results reported in Model 3 and 4 reveal that country's wealth has a significant influence on the log-odds of WTP to protect the environment. Individuals living in democratic and stable government are less likely to contribute for improvements to the quality of the environment. It could be argued that in developed countries, stability and predictability of the political and regulatory environment as well as good administrative conditions are favorable to implement environmental taxation. These tax compliance give rise to low incentives for individuals to contribute for preventing environmental damage. A possible explanation for the low WTP might be, people believe that government should address environmental issues and it is not necessary to pay additional taxes for environmental protection.

Population density has significant influence while local environment conditions do not have significant effect on individuals' WTP to protect the environment in developed countries.

Table 1-3. Fixed and random part results for the multilevel logistic models – developed countries

	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Fixed part	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff
Individual level covariates									
Age		0.041*	0.062**	0.062**	0.062***	0.071**	0.070**	0.072***	0.071**
		(0.021)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)
Female		-0.009	-0.002	-0.002	-0.002	0.019	0.021	0.019	0.020
		(0.035)	(0.036)	(0.036)	(0.036)	(0.036)	(0.037)	(0.036)	(0.036)
Children		-0.055**	-0.043	-0.044	-0.043	-0.038	-0.038	-0.038	-0.038
		(0.023)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Marital Status									
Single/Never married		-0.025	0.068	0.068	0.068	0.081	0.081	0.081	0.081
		(0.059)	(0.060)	(0.060)	(0.060)	(0.060)	(0.060)	(0.060)	(0.060)
Divorced/Separated/Widowed		-0.146**	-0.039	-0.038	-0.037	-0.040	-0.039	-0.040	-0.039
		(0.050)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
Education									
Incomplete/complete primary		0.275	0.253	0.252	0.252	0.228	0.228	0.227	0.226
		(0.210)	(0.214)	(0.214)	(0.214)	(0.211)	(0.211)	(0.211)	(0.211)
Incomplete/complete secondary		0.570**	0.435*	0.434*	0.432**	0.486*	0.485*	0.486*	0.484*
		(0.209)	(0.213)	(0.212)	(0.212)	(0.210)	(0.210)	(0.210)	(0.210)
Incomplete/ complete university		1.122***	0.843***	0.840***	0.837***	0.934***	0.932***	0.934***	0.931***
		(0.209)	(0.213)	(0.213)	(0.213)	(0.211)	(0.211)	(0.211)	(0.211)
Personal Income									
Second quintile			0.222***	0.223***	0.225***	0.258***	0.259***	0.258***	0.259***
			(0.055)	(0.055)	(0.055)	(0.054)	(0.054)	(0.054)	(0.054)
Third quintile			0.402***	0.404***	0.406***	0.445***	0.446***	0.445***	0.447***
			(0.057)	(0.057)	(0.057)	(0.056)	(0.056)	(0.056)	(0.056)
Fourth quintile			0.586***	0.585***	0.587***	0.677***	0.679***	0.677***	0.679***
			(0.065)	(0.065)	(0.065)	(0.064)	(0.064)	(0.064)	(0.064)
Upper quintile			0.659***	0.656***	0.658***	0.666***	0.668***	0.667***	0.669***
			(0.081)	(0.081)	(0.081)	(0.080)	(0.080)	(0.080)	(0.080)
Values									
Materialist			-0.246***	-0.244***	-0.245***				
			(0.042)	(0.043)	(0.042)				
Post-materialist			0.528***	0.527***	0.528***				
			(0.055)	(0.055)	(0.055)				
Religion			0.152***	0.156***	0.152***	0.156***	0.153***	0.156***	0.153***
			(0.040)	(0.040)	(0.040)	(0.039)	(0.039)	(0.039)	(0.039)
Membership of environmental organization			0.632***	0.631***	0.633***				
			(0.073)	(0.073)	(0.073)				
Country level covariates									
Income				0.261***	0.509***	0.315***	0.538***	0.295**	0.526***
				(0.092)	(0.122)	(0.095)	(0.130)	(0.100)	(0.125)

Noxide				0.030	0.041	0.006	-0.049	-0.015	-0.088
				(0.149)	(0.127)	(0.156)	(0.135)	(0.159)	(0.134)
Density				0.269***	0.313***	-0.170	-0.300**	-0.165	-0.307**
				(0.096)	(0.108)	(0.110)	(0.115)	(0.110)	(0.111)
Democracy				-0.657**		-0.520		-0.525	
				(0.282)		(0.292)		(0.289)	
Government stability					-0.434***		-0.377**		-0.411**
					(0.123)		(0.130)		(0.128)
Government spending								-0.110	-0.212
								(0.126)	(0.128)
Constant	0.306*	-0.433	-0.751***	-0.554	-0.910***	-0.764**	-1.047***	-0.861**	-1.240***
	(0.127)	(0.241)	(0.245)	(0.288)	(0.240)	(0.291)	(0.239)	(0.333)	(0.283)
Random part									
σ_μ^2	0.316***	0.282***	0.261***	0.169***	0.132***	0.182**	0.148**	0.179**	0.137**
	(0.101)	(0.091)	(0.084)	(0.055)	(0.043)	(0.059)	(0.048)	(0.058)	(0.045)
ρ	0.087***	0.079***	0.073***	0.049***	0.038***	0.052**	0.043**	0.051**	0.040**
	(0.025)	(0.023)	(0.022)	(0.015)	(0.012)	(0.016)	(0.013)	(0.016)	(0.012)
Log-likelihood	-9778	-9585	-9392	-9388	-9386	-9478	-9476	-9478	-9475
Observations	15225	15225	15225	15225	15225	15156	15156	15156	15156

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

1.5.3. Developing countries

Table 1-4 gives the results for developing countries. The intercept-only model was tried first (as reported in Model 0). The interclass correlation reported in Model 0 shows that country level covariates play a non-negligible role in determining the probability of contributing to improve the quality of the environment. After adjustment for individuals level variables (reported in Model 1), results show that most of the potential predictors considered were found to have a significant association with WTP to protect the environment. Overall, although previous studies have identified females with children as being more willing to pay for environmentally friendly products (Thompson, 1998, Laroche *et* al, 2001), we found that individuals that have children exhibit less pro-environmental intentions. Being female or male does not have impact on the log-odds of WTP to protect the environment. The regression result shows a negative and significant role for the group of Single/Never married and Separated/divorced/widowed, which suggest that Single/Never married and the segment of marital status Separated/divorced/widowed tend to contribute less for the protection of the environment compared with the group married/ and live as married couple. As expected, educated individuals are more likely to be concerned and willing to pay for the protection of the environment than their non-educated counterparts.

Environmental consciousness is related to individuals' perceptions about their beliefs and values. In line with the literature discussed in the previous section, individuals possessing post-materialistic values tend to engage more in the protection of the environment (see results in Model 2). In contrast, those possessing materialistic values are less worried about environmental issues. Result found that faithful individuals are more concerned about environmental issues. Unsurprisingly, members of environmental organization are more likely to show care for the environment than non-members.

The positive effect of members of environmental organization on environmental concern remains strong and highly significant across all model specifications.

Then, we introduced Income, Nitrous oxide, Density, Democracy and Government stability (As in Model 3 and of Table 1-4). As can be seen, a rise in government stability reduces the proportion of individuals willing to give part of their income to prevent environmental pollution. The remaining contextual variables do not have significant impact on the individuals' willingness to prevent environment pollution. It is important to note that the random intercept variance as well as the interclass correlation are relatively constant across the estimated models.

Table 1-4. Fixed and random part results for the multilevel logistic models – developing countries

	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Fixed part	coeff	coeff	coeff	coeff	coeff	coeff	coeff	coeff	coeff
Individual level covariates									
Age		0.009	0.001	0.001	0.002	0.002	0.002	0.002	0.002
		(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
Female		0.056	0.047	0.047	0.047	0.025	0.025	0.025	0.025
		(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)
Children		-0.058**	-0.050*	-0.050*	-0.050*	-0.052*	-0.052*	-0.053*	-0.053*
		(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Marital Status (Married=Ref.)									
Single/Never married		-0.148**	-0.137**	-0.137**	-0.137**	-0.110*	-0.110*	-0.111*	-0.111*
		(0.045)	(0.046)	(0.046)	(0.046)	(0.045)	(0.045)	(0.045)	(0.045)
Divorced/Separated/Widowed		-0.246***	-0.207***	-0.207***	-0.207***	-0.207***	-0.207***	-0.207***	-0.207***
		(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
Education (No education=Ref.)									
Incomplete/complete primary		0.261***	0.227***	0.228***	0.228***	0.222***	0.222***	0.222***	0.221***
		(0.053)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)
Incomplete/complete secondary		0.535***	0.422***	0.423***	0.424***	0.460***	0.460***	0.459***	0.459***
		(0.055)	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)
Incomplete/ complete university		0.797***	0.604***	0.606***	0.605***	0.661***	0.661***	0.661***	0.661***
		(0.057)	(0.059)	(0.059)	(0.059)	(0.058)	(0.058)	(0.058)	(0.058)
Personal Income (First quintile=Ref.)									
Second quintile			0.084*	0.084*	0.084*	0.029	0.030	0.029	0.029
			(0.041)	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)
Third quintile			0.350***	0.349***	0.350***	0.308***	0.309***	0.307***	0.308***
			(0.043)	(0.043)	(0.043)	(0.042)	(0.042)	(0.042)	(0.042)
Fourth quintile			0.409***	0.408***	0.409***	0.340**	0.340**	0.338***	0.339**
			(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
Upper quintile			0.626***	0.625***	0.626***	0.570***	0.571***	0.570***	0.570***
			(0.094)	(0.094)	(0.094)	(0.093)	(0.093)	(0.093)	(0.093)
Values (Mixed=Ref.)									
Materialist			-0.272***	-0.272***	-0.272***				
			(0.030)	(0.030)	(0.030)				
Post-materialist			0.211***	0.211***	0.211***				
			(0.056)	(0.056)	(0.056)				
Religion			0.338***	0.339***	0.337***	0.323***	0.320***	0.323***	0.320***
			(0.049)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)
Membership of environmental organization			0.412***	0.412***	0.410***				
			(0.046)	(0.046)	(0.046)				
Country level covariates									
Income				-0.066	-0.063	-0.115	-0.083	0.933	0.710
				(0.466)	(0.454)	(0.466)	(0.450)	(0.531)	(0.515)

Noxide				-0.110 (0.124)	-0.014 (0.140)	-0.103 (0.125)	0.001 (0.140)	-0.192 (0.112)	0.117 (0.134)
Density				0.134 (0.157)	0.173 (0.155)	0.140 (0.157)	0.179 (0.154)	0.032 (0.140)	0.077 (0.144)
Democracy				-0.290 (0.196)		-0.275 (0.195)		-0.294 (0.169)	
Government stability					-0.583 (0.348)		-0.615 (0.345)		0.415 (0.321)
Government spending								-0.352 (0.281)	-0.137 (0.296)
Constant	1.031*** (0.178)	0.590** (0.187)	0.208 (0.195)	0.132 (0.263)	-0.011 (0.263)	0.127 (0.263)	-0.016 (0.260)	0.114 (0.229)	-0.001 (0.236)
Random part									
σ_μ^2	0.844*** (0.232)	0.849*** (0.239)	0.883*** (0.243)	0.837*** (0.202)	0.720*** (0.198)	0.737*** (0.202)	0.706*** (0.195)	0.548*** (0.151)	0.572*** (0.158)
ρ	0.204*** (0.044)	0.208*** (0.045)	0.211*** (0.045)	0.193*** (0.041)	0.179*** (0.040)	0.183*** (0.041)	0.176*** (0.040)	0.142*** (0.033)	0.148*** (0.035)
Log-likelihood	-15456	-15278	-15084	-15082	-15081	-15151	-15151	-15147	-15148
Observations	29154	29154	29154	29154	29154	29044	29044	29044	29044

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

1.5.4. Robustness analysis of the results

In this subsection, we examine the robustness of our results by testing an alternative specification of the dependent variable. Recall that the analysis in this study proceeds by merging responses from the two aforementioned environment-related questions to construct a binary dependent variable and applying a multilevel logit model to investigate the WTP to prevent environmental pollution. To test robustness, we analysed each question separately by running a multilevel ordered logit model. The results from this exercise are presented in Table 1-5. The results are broadly in line with results obtained with the multilevel logit model. Similar to the multilevel logit model results, we found that the WTP to prevent environmental pollution is higher (from strongly disagree to strongly agree) with higher age, higher level of education, increase in income, post-materialistic values and religious beliefs. In other words, respondents in the lower category (e.g., strongly agree) are more likely to pay to prevent environmental pollution. The results are consistent across developed and developing countries. These observations demonstrate the robustness of the results.

Table 1-5. Parameter estimates of a multilevel ordered logit model of the WTP to protect the environment[1,2]

	All country		Developed countries		Developing countries	
	(1)	(2)	(1)	(2)	(1)	(2)
Individual level covariates						
Age	-0.031**	-0.029*	-0.058**	-0.054**	-0.026	-0.025
	(0.012)	(0.012)	(0.019)	(0.019)	(0.015)	(0.015)
Female	-0.019	-0.018	-0.018	-0.008	-0.014	-0.016
	(0.018)	(0.018)	(0.031)	(0.031)	(0.023)	(0.023)
Children	0.040**	0.040**	0.050*	0.061**	0.033	0.028
	(0.013)	(0.013)	(0.020)	(0.020)	(0.017)	(0.017)
Marital Status (Married=Ref.)						
Single/Never married	0.062*	0.064*	-0.050	-0.041	0.092**	0.089**
	(0.029)	(0.030)	(0.051)	(0.052)	(0.036)	(0.036)
Divorced/Separated/Widowed	0.136***	0.132***	0.026	0.002	0.194***	0.208***
	(0.031)	(0.031)	(0.045)	(0.045)	(0.043)	(0.043)
Education (No education=Ref.)						
Incomplete/complete primary	-0.088*	-0.086*	-0.211	-0.312	-0.119**	-0.115**
	(0.041)	(0.042)	(0.186)	(0.187)	(0.044)	(0.044)
Incomplete/complete secondary	-0.254***	-0.237***	-0.409*	-0.484***	-0.308***	-0.297***
	(0.042)	(0.043)	(0.185)	(0.186)	(0.045)	(0.046)
Incomplete/ complete university	-0.507***	-0.491***	-0.787***	-0.874***	-0.457***	-0.434***
	(0.044)	(0.044)	(0.186)	(0.187)	(0.047)	(0.048)
Personal Income (First quintile=Ref.)						
Second quintile	-0.087**	-0.103***	-0.198***	-0.193***	-0.035	-0.060
	(0.028)	(0.028)	(0.048)	(0.048)	(0.034)	(0.034)
Third quintile	-0.268***	-0.274***	-0.374***	-0.357***	-0.221***	-0.239***
	(0.028)	(0.028)	(0.050)	(0.050)	(0.034)	(0.035)
Fourth quintile	-0.320***	-0.333***	-0.529***	-0.548***	-0.215***	-0.223***
	(0.033)	(0.033)	(0.056)	(0.056)	(0.041)	(0.041)
Upper quintile	-0.491***	-0.489***	-0.582***	-0.565***	-0.433***	-0.433***
	(0.047)	(0.047)	(0.067)	(0.068)	(0.069)	(0.070)
Values (Mixed=Ref.)						
Materialist	0.221***	0.205***	0.243***	0.232***	0.218***	0.202***
	(0.020)	(0.020)	(0.037)	(0.037)	(0.024)	(0.024)
Post-materialist	-0.341***	-0.354***	-0.448***	-0.490***	-0.215***	-0.199***
	(0.030)	(0.031)	(0.045)	(0.046)	(0.041)	(0.042)
Religion	-0.172***	-0.173***	-0.140***	-0.158***	-0.222***	-0.208***
	(0.025)	(0.025)	(0.034)	(0.034)	(0.037)	(0.038)
Membership of environmental organization	-0.385***	-0.369***	-0.663***	-0.665***	-0.279***	-0.253***
	(0.029)	(0.029)	(0.057)	(0.057)	(0.034)	(0.034)
Country level covariates						
Income	-0.188	-0.215*	-0.226**	-0.251**	-0.607	-0.564
	(0.115)	(0.114)	(0.088)	(0.087)	(0.467)	(0.461)
Noxide	0.07	0.076	-0.025	-0.037	0.122	0.125
	(0.080)	(0.079)	(0.138)	(0.137)	(0.097)	(0.096)
Density	0.028	0.032	0.212*	0.251**	-0.033	-0.051
	(0.089)	(0.089)	(0.096)	(0.095)	(0.123)	(0.121)
Democracy	0.173	0.181	0.736**	0.735**	0.107	0.113
	(0.122)	(0.121)	(0.254)	(0.252)	(0.148)	(0.146)
Government spending	0.422**	0.437***	-0.003	0.004	0.604*	0.633**
	(0.121)	(0.121)	(0.163)	(0.161)	(0.247)	(0.245)
Constant cut1	-2.200***	-2.421***	-2.701***	-2.972***	-2.026***	-2.301***
	(0.102)	(0.102)	(0.294)	(0.293)	(0.201)	(0.200)
Constant cut2	0.145	0.149	-0.418	-0.519	0.355	0.332
	(0.101)	(0.101)	(0.293)	(0.292)	(0.201)	(0.199)
Constant cut3	1.724***	1.607***	1.171***	0.962***	1.936***	1.783***
	(0.102)	(0.101)	(0.293)	(0.292)	(0.202)	(0.200)
Var (Constant)	0.362***	0.357***	0.137***	0.135***	0.425***	0.415***

	(1)	(2)	(1)	(2)	(1)	(2)
	(0.076)	(0.075)	(0.045)	(0.044)	(0.117)	(0.114)
Log-likelihood	-51992	-51032	-18408	-18151	-33492	-32761
Observations	44379	44379	15225	15225	29154	29154

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001
(1). Would give part of my income for environment (1=strongly agree, 2=agree, 3=disagree, 4=strongly disagree).
(2). Increase in taxes if extra money used to prevent environment (1=strongly agree, 2=agree, 3=disagree, 4=strongly disagree).

1.6. Conclusions

This chapter investigates individual characteristics and contextual covariates guiding individuals toward environmental protection. It uses survey data from the fifth wave of WVS and country level data from the World Development Indicators database and applies a two level logistic regression to determine what shapes individual environmental concern. Overall, the study find that individual level covariates accounts for 80.5% of total variability in explaining environmental awareness across nations. The remaining 19.5% is attributable to country level characteristics. The commonly used individual level predicators such as education, relative income, post-materialistic values, religious beliefs and adhesion to environmental organization are found to be consistently associated with individuals' preference to incur financial cost in order to protect the environment. These results are in line with the findings reported in much of the literature dealing with determinants of environmental concern.

Although the results show that individual level characteristics play a significant role in explaining the WTP to protect the environment, contextual factors are also found to be non-negligible in explaining individuals' preferences towards environmental protection. The study reveals that country's wealth has a significant impact on individuals' willingness to give part of their income and agreeing to an increase in taxes to prevent environmental pollution. Furthermore, we observe that population density has an influence on individuals' environmental preferences mainly in developed countries. However, an aspect which has been overwhelmingly overlooked in the environmental literature is the effect of the quality of institutions on individuals' preference to pay money for the protection of the environment.

To assess the effect of the quality of institutions on individuals' preference, we use democracy and government stability as indicators. We observe that both democracy and government stability reduce individuals' intention to give part of their income and agreeing to an increase in taxes to prevent environmental pollution mainly in developed countries. This result remains robust after controlling for other contextual factors.

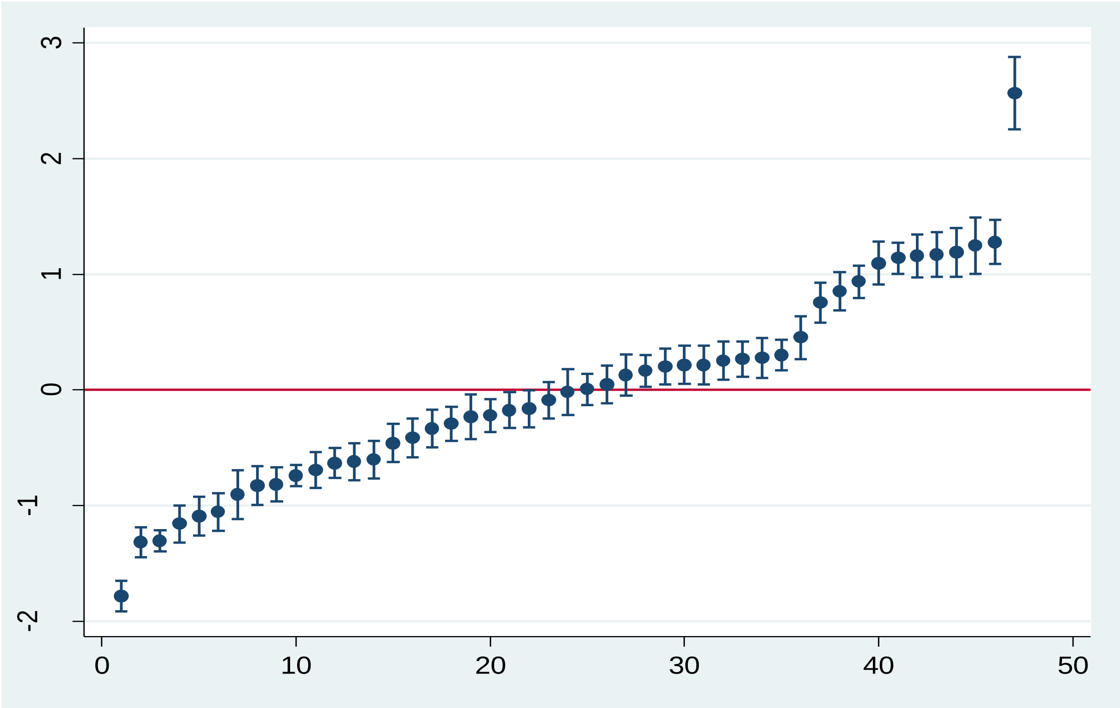
In sum, the findings from this study reveals that the disparities in the WTP to protect the environment between countries can be originated from both individual and country level covariates. Therefore, to better understand the factors behind individuals in relation to environmental prevention, it important to consider the economic condition and the quality of institutions of the country in which the individual is located. All these factors play an important role in defining the individual's engagement in environmental prevention.

Table 1-6. (Appendix A) List of countries included in the analysis

Country/Region	Survey year	Respondents	Developed/developing countries
Andorra	2005	769	1
Australia	2005	897	1
Brazil	2006	1,031	0
Bulgaria	2005	626	1
Burkina Faso	2007	867	0
Canada	2005	1,310	1
Chile	2006	668	0
China	2007	1,689	0
Cyprus	2006	815	0
Egypt	2008	2,244	0
Ethiopia	2007	1,137	0
Finland	2005	682	1
Georgia	2008	803	0
Germany	2006	1,332	1
Ghana	2007	1,116	0
Hungary	2008	665	1
India	2006	955	0
Indonesia	2006	1,102	0
Iran	2005	2,064	0
Italy	2005	483	1
Japan	2005	499	1
Jordan	2007	782	0
Malaysia	2006	840	0
Mali	2007	683	0
Mexico	2005	1,029	0
Moldova	2006	758	1
Morocco	2007	715	0
New Zealand	2005	390	1
Norway	2007	766	1
Peru	2006	946	0
Poland	2005	657	1
Romania	2005	1,141	1
Rwanda	2007	1,111	0
Serbia and Montenegro	2005	685	1
Slovenia	2005	646	1
South Africa	2006	2,082	0
South Korea	2005	780	0
Spain	2007	815	1
Sweden	2006	706	1
Switzerland	2007	762	1
Thailand	2007	1,141	0
Trinidad and Tobago	2006	733	0
Turkey	2007	1,072	0
Ukraine	2006	627	1
Uruguay	2006	630	0
Viet Nam	2006	1,264	0
Zambia	2007	743	0

Countries are classified according to macro geographical regions and sub-regions, and selected economic and other groupings (the United Nations Statistics Division), China includes Taiwan, developed countries =1.

Figure 1-1. (Appendix B) 95% confidence interval of the estimated level 2 residuals



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Chapter 2. On the relationship between CO2 emissions and economic growth: Evidence from panel smooth transition regression[16]

[16] Revised and resubmitted in Environment, Development and Sustainability, currently under review.

2.1. Introduction

Ever since the seminal work of Grossman and Krueger (1991) that led to finding an inverted U-shape relation between environmental degradation and economic growth, a large and still-growing body of literature has continued to identify aspects of the relationship between various measures of environmental quality and economic growth. The presumptive assumption held by these studies is that, environmental quality deteriorates in the early stages of economic growth and then improves in the later stages once economic growth has reached a certain threshold. This phenomenon has been termed "Environmental Kuznets Curve" (EKC) because of its resemblance to the relationship between inequality and income levels observed by Kuznets (1955). The EKC has gained tremendous enthusiasm both from the theoretical framework and environmental policies[17]. From policy-making perspectives, the EKC constitutes the cornerstone for establishing a strategic plan to achieve sustainable economic growth.

From a theoretical standpoint, a number of papers have posited explanations for the observed pattern between emissions and economic growth. At the core of this body of theoretical literature is the study by Arrow et al. (1995) which postulates that environmental quality generally worsens during the initial phases of economic growth but when societies have achieved relatively more advanced stages of economic growth, they tend to give greater attention to environmental quality through either market mechanisms or regulatory policies. A second type of explanation is contained in studies that decompose the change of pollution emissions into scale, composition and technique effects (Grossman and Krueger, 1995; Antweiler et al, 2001 and Brock and Taylor, 2005). These authors offer the explanation that a scale effect arises from an expansion of economic activity, but

[17] Stern (2004) and Dinda (2004) provide a comprehensive review of earlier studies on the EKC framework. A more recent studies on the EKC literature is found in Kijima et al. (2010).

when economic activity shifts from energy-intensive industries to cleaner ones, emissions fall through the composition effect, and that because of this investments in environmentally-friendly technology become more effective thus leading to sustainable development. A related explanation offered by Dinda (2004) describes the EKC as a natural progression of economic growth, from a clean agrarian economy to a polluting industrial to a cleaner service economy.

Thus, the main goal of this chapter is to investigate the nature of the relationship between CO2 emissions and economic growth of 96 countries over the period 1984-2013. In doing so, the study contributes to the existing literature by, first, applying the Panel Smooth Transition Regression (PSTR) model of González et al. (2005); and, second, by incorporating energy consumption, industrialization, urbanization, trade openness, capital expenditures and quality of institutions in the model besides CO2 emissions and economic growth to solve the omitted variable bias issue suffered by most previous studies. To the best of our knowledge, this is the first study that account for the quality of institutions into the relationship between CO2 emissions and economic growth. Finally, we also dealt with potential endogeneity of regressors through Instrumental Variable estimation.

The study unveils the existence of a non-linear relation between CO2 emissions and economic growth rather than an inverted U-shaped relation. Interestingly, we also find evidence suggesting that quality of institutions matters to the relationship between CO2 emissions and economic growth; better quality of institutions enhances environmental quality.

The remainder of the chapter is organized as follows. The next section briefly reviews the literature on CO2 emissions and economic growth relation. Section 2.3. introduces the PSTR model and testing procedure. Section 2.4. describes data sources and variable definitions. Section 2.5. presents the empirical results and discusses their implications. Finally, the last section will conclude.

2.2. Brief literature review

Despite the numerous attempts that contributed to the discussion and to deepen our understanding of the nature of the relationship between different types of emissions and economic growth, there still is no consensus among scholars as to why and how exactly the EKC relationship emerges for certain environmental indicators but not for others[18]. Studies have found different results for the same pollutant by using different time frame and estimation techniques (Ekins, 1997). For instance, Schmalensee et al. (1998) use a piecewise linear function to investigate the relationship between CO2 emissions and economic growth. By adopting the piecewise linear function, the authors find evidence of an EKC for CO2 emissions. To add to the list, Galeotti et al. (2006) employ a more flexible functional form, the Weibull function to validate the EKC hypothesis. They find evidence of an inverted U-pattern for the group of OECD countries but not so for non-OECD countries. Luo et al. (2017) investigate whether the EKC holds in a group of G20 countries. By accounting for trade openness, the ratio industry value-added to GDP and population density as additional control variables, they find evidence pointing toward the EKC hypothesis for the G20 members. Martino and Van (2016) employ an instrumental semiparametric panel model and apply it to data consisting of 106 countries over the 1970-2010 period. They find no evidence supporting the EKC, even for the OECD countries. Azomahou et al. (2006) depart from the parametric functions and adopt a non-parametric approach to investigate the relationship between CO2 emissions and economic growth

[18] Empirical literature has documented that EKC hold for local pollutants such as sulfur oxides (SOx), nitrogen oxides (NOx), carbon monoxide (CO) and suspended particulate matter (SPM) (Selden and Song, 1994; Stern and Common, 2001; Harbaugh et al, 2002; Brock and Taylor, 2010; Miah et al, 2010; Liddle and Messinis, 2015; Georgiev and Mihaylov, 2015; Wang et al, 2016; Fujii, and Managi, 2016). In the case of global emissions, however, the empirical findings are still far from convergent and it is not difficult to find conflicting results. For instance, Ahmed and Long, (2012); Kaika and Zervas, (2013); Apergis and Ozturk, (2015) and Balaguer and Cantavella, (2016) have found evidence pointing towards the inverted U-shape while Du et al, (2012); Al-Mulali et al, (2015); Yang et al. (2015) and Baek, (2015) have reported environmental quality declines with increasing income.

of a panel of 100 countries over the period 1960-1996. Their finding indicates that the relationship between the two variables is upward sloping. Using the Common Correlated Effects (CCE) estimation procedure by Pesaran (2006), Apergis et al. (2017) assess the validity of the EKC hypothesis across 48 US states. The findings suggest that the EKC hypothesis holds in only 10 states. Narayan and Narayan (2010) examine the EKC for 43 developing countries using the panel cointegration and the panel long-run estimation techniques. Their findings support the inverted U-shaped curve only for the group of Middle East and South Asian countries.

More recently, works such as Stern et al. (1996) and Stern (2015), have raised concerns over the functional forms and estimation methods used to investigate the relationship between different indicators of environmental quality and economic growth. They claim that previous studies have arbitrarily modeled and estimated a quadratic polynomial framework to capture the non-linearity between emissions and economic growth. One of the drawbacks mentioned of using the quadratic polynomial is that it ignores the presence of heterogeneity across countries. To remedy econometric issues in estimation due to the aribitrary choice of functional forms and to deal with heterogeneity issue, González et al. (2005) propose the Panel Smooth Transition Regression (PSTR) as estimation technique to alleviate these issues. The PSTR addresses the problems of heterogeneity and time instability in a non-linear setting. Furthermore, the PSTR presents significant advantages over the traditional quadratic polynomial model[19]. Firstly, the PSTR permits a continuum in the country-specific correlation with respect to the threshold variable. Secondly, it allows the emissions-economic growth relation coefficient to vary between countries and over time. Lately, some studies have applied the PSTR to investigate the non-linearities between macroeconomic variables. See for

[19]Aslanidis and Xepapadeas (2006) show the quadratic or cubic polynomial model used in the literature is a specific case of the more general PSTR.

instance, Bessec and Fouquau (2008) on the relationship between electricity demand and temperature; Chiu (2012) on deforestation and per capita income; Duarte et al. (2013) on per capita water use and per capita income; Seleteng et al, (2013) and Thanh (2015) on inflation and economic growth.

In the present chapter, we have adopted the PSTR by González et al. (2005) to study the complex links between CO2 emissions and economic growth.

2.3. Econometric methodology

2.3.1. PSTR model specification

To investigate the potential non-linear relationship between per capita CO2 emissions and economic growth, we apply the more flexible econometric technique, the PSTR developed by González et al. (2005). The PSTR is a suitable approach to account for cross-country heterogeneity and time variability of the slope coefficients. Furthermore, it accommodates for the presence of exogenous variables with constant coefficients. The PSTR can be viewed as a generalization of the Panel Threshold Regression (PTR) model proposed by Hansen (1999). Contrary to the PTR model that imposes a sharp shift when transitioning from one regime to another, the PSTR model allows the regression coefficients to switch gradually from one regime to the next.

Therefore, the equation used to estimate the non-linear relationship between per capita CO2 emissions and economic growth is a two extreme regimes PSTR model with single transition function and some control variables as stated below:

$$lnCO2_{it} = \mu_i + \beta_0 lnGDP_{it} + \beta_1 lnGDP_{it} g(lnGDP_{it-1}; \gamma, c) + \alpha_0' Z_{it} + \epsilon_{it} \qquad (1)$$

where $i = 1,2, \dots, N$ and $t = 1,2, \dots, T$ denote the cross-section and time dimensions, respectively. The dependent variable $lnCO2_{it}$ is the log value of per capita CO2 emissions, μ_i represents the country-specific effects and $lnGDP_{it}$ refers to the log value of real gross domestic product GDP per capita; Z_{it} is a k-dimensional vector of a set of time-invariant exogenous variables which includes: energy consumption per capita; industrialization level, which is proxied with the ratio of industry value added in GDP; urbanization level, measured by the fraction of the population living in urban areas; the ratio of gross fixed capital formation to GDP; and import and export of merchandise as percentages of GDP. Institutional quality variables were also controlled for to gauge to what extent the quality of institutions matter for environmental pollution. The transition function $g(lnGDP_{it-1}, \gamma, c)$ is a continuous function normalized and bounded between 0 and 1 of the observable variable $lnGDP_{it-1}$. As noted by van Dijk et al. (2002), the threshold variable can be an exogenous variable or a combination of the lagged endogenous one. To estimate the effect of GDP per capita on per capita CO2 emissions, we consider in this study the lagged level of the log of the real GDP per capita as a threshold variable. The slope parameter γ denotes the smoothness of the transition function from one regime to another, c is the threshold or location parameter, and ϵ_{it} is the error term. It is worth mentioning that γ and c are endogenously determined.

Following the methodology proposed by Granger and Teräsvirta (1993), Teräsvirta (1994), Jansen and Teräsvirta (1996), and the extension to panel data by González et al. (2005), the logistic transition function is formulated as follows:

$$g(lnGDP_{it-1}; \gamma, c) = \left(1 + exp\left(-\gamma \prod_{j=1}^{m}\left(lnGDP_{it-1} - c_j\right)\right)\right)^{-1}, \ \gamma > 0, \ c_1 \leq c_2 \leq \cdots \leq c_m \qquad (2)$$

where $c = (c_1, \dots, c_m)'$ denotes an m-dimensional vector of location parameters. Restrictions on $\gamma > 0$ and $c_1 \leq c_2 \leq \cdots \leq c_m$ are imposed for identification. González et al. (2005) indicate that in empirical exercise, it is sufficient to consider m = 1 or m = 2 to capture the non-linearities due to regime switching. The case m=1 refers to a logistic PSTR model while the case m=2 corresponds to a logistic quadratic PSTR specification (Bereau et al. 2010). When $\gamma \rightarrow \infty$, the transition function $g(lnGDP_{it-1};\gamma,c)$ becomes an indicator function and the PSTR turns into a PTR model (Hansen, 1999). However, when $\gamma \rightarrow 0$, the transition function $g(lnGDP_{it-1};\gamma,c)$ becomes constant and the model collapses into a standard linear panel regression model with fixed effects.

Hence, the PSTR model has many advantages over the widely applied quadratic polynomial model. First and foremost, the PSTR allows the parameters to vary across countries and over time. Second, parameters are allowed to change smoothly with the threshold variable $lnGDP_{it-1}$. Another advantage of the PSTR is that the value of the elasticities for a given country and at a given date can be different from the estimated parameters for the extreme regimes. Thus, the impact of the real GDP per capita on per capita CO2 emissions is given by:

$$\frac{\partial lnCO_{2it}}{\partial lnGDP_{it}} = \beta_0 + \beta_1 g(lnGDP_{it-1},\gamma,c) \tag{3}$$

Given the properties of the transition function, the parameter β_0 corresponds to the elasticity only if the transition function $g(lnGDP_{it-1},\gamma,c)$ tends to 0. The sum of the parameters β_0 and β_1 corresponds to the elasticity only if the transition function $g(lnGDP_{it-1},\gamma,c)$ tends to 1. At any point between these two extremes, the elasticity is defined as a weighted average of the parameters β_0 and β_1. As a consequence, it is possible only to interpret the signs of the parameters rather than their magnitudes.

2.3.2. Model specification and testing procedure

González et al. (2005) also propose a test for linearity against the PSTR model as well as a test of no remaining linearity. As outlined in their paper, the procedure for testing the null hypothesis of linearity consists of testing the null hypothesis: $H_0 : \gamma = 0$ or $H_0 : \beta_0 = \beta_1$. In both cases, the test is non-standard since, under the null hypothesis, the PSTR model contains unidentified nuisance parameters. That is, classical test is not valid. A viable solution to this issue consists of replacing the transition function $g(lnGDP_{it-1}, \gamma, c)$ by its first-order Taylor expansion around the null hypothesis: $H_0 : \gamma = 0$ and by testing an equivalent hypothesis in an auxiliary regression model that takes the following form:

$$lnCO_{2_{it}} = \mu_i + \beta_0^* LnGDP_{it} + \beta_1^* lnGDP_{it} lnGDP_{it-1} + \cdots + \beta_m^* lnGDP_{it} lnGDP_{it-1}^m + \epsilon_{it}^* \qquad (4)$$

the parameters $\beta_0^*, \ldots, \beta_m^*$ are multiples of γ and $\epsilon_{it}^* = \epsilon_{it} + R_m \beta_1^* lnGDP_{it}$, where R_m is the remainder of the Taylor expansion.Therefore, testing $H_0 : \gamma = 0$ in Eq. (1) is equivalent to testing the null hypothesis: $H_0 : \beta_1^* = \cdots = \beta_m^* = 0$ in Eq. (4). Following Colletaz and Hurlin (2006), three type of tests have been performed to assess the linearity. The Wald test:

$$LM_w = NT(SSR_0 - SSR_1)/SSR_0 \qquad (5)$$

where SSR_0 is the panel sum of the squared residuals under the null hypothesis (linear model with individual effects) and SSR_1 is the panel sum of the squared residuals under the alternative hypothesis (PSTR model with two regimes). Likewise, the Fisher test is defined as follows:

$$LM_f = [NT(SSR_0 - SSR_1)/mK]/[SSR_0 /(TN - N - m(K+1))] \quad (6)$$

where K is the number of explanatory variables and m the number of regimes. And finally, the *pseudo*-likelihood ratio test is given by:

$$LR = -2[log(SSR_1) - log(SSR_0)] \quad (7)$$

Under the null hypothesis, the Wald and likelihood ratio statistics have an asymptotic $\chi^2(mk)$ distribution while the Fisher statistic is approximated to have the distribution of $F(mK, TN - N - mK)$.

If the linearity hypothesis is rejected, then the next step consists of testing for no remaining linearity. In other words, we test whether there is one transition function or if, on the other hand, there are at least two transition functions. This is done by testing the following hypothesis: $H_0: r = r^*$ against $H_1: r = r^* + 1$. If H_0 is not rejected, the procedure stops. Otherwise, the null hypothesis: $H_0: r = r^* + 1$ is tested against $H_1: r = r^* + 2$. Then the testing sequence continues until the first acceptance of the null hypothesis of no remaining linearity. It is important to bear in mind that the estimation of the PSTR model is conducted by first eliminating the individual effects μ_i.Then a grid search is performed to obtain initial values for the slopes and the location parameters by applying Non-Linear Least Squares (NLS) to the transformed data. This estimation technique is equivalent to the maximum likelihood estimation since the error term ϵ_{it} follows a normal distribution.

2.3.3. PSTR estimates and endogeneity

The literature has suggested that first difference transformations and non-linear modeling strategies mitigate endogeneity issues (Omay and Kan, 2010; Lopez Villavicencio and Mignon (2011).

However, for comparative purposes and robustness check, we follow Fouquau et al. (2008) to correct for potential endogeneity problems. As in Fouquau et al. (2008), we take the lagged value of explanatory variables as instrumental variables. Let $Z_{it} = lnGDP_{it-1}$; $\widetilde{lnCO}2_{it} = lnCO2_{it} - \overline{lnCO2}_{it}$ and $\tilde{Z}_{it}(\gamma, c) = \left(Z_{it} - \bar{Z}, g(lnGDP_{it-1}; \gamma, c) - \bar{\zeta}(\gamma, c)\right)$, where $\bar{Z} = T^{-1}\sum_{t=1}^{T} Z_{it}$ *and* $\bar{\zeta}(\gamma, c) = T^{-1}\sum_{t=1}^{T} Z_{it}\, g(lnGDP_{it-1}; \gamma, c)$. Given the couple (γ, c), the estimate will be obtained by instrumental variables as follows:

$$\hat{\beta}_{IV}(\gamma, c) = \left[\sum_{i=1}^{N}\sum_{t=1}^{T} \widetilde{lnGDP}'_{it}(\gamma, c)\tilde{Z}_{it}(\gamma, c)\left(\tilde{Z}'_{it}(\gamma, c)\tilde{Z}_{it}(\gamma, c)\right)^{-1}\tilde{Z}'_{it}(\gamma, c)\widetilde{lnGDP}_{it}(\gamma, c)\right]^{-1} \times \left[\sum_{i=1}^{N}\sum_{t=1}^{T} \widetilde{lnGDP}'_{it}(\gamma, c)\tilde{Z}_{it}(\gamma, c)\left(\tilde{Z}'_{it}(\gamma, c)\tilde{Z}_{it}(\gamma, c)\right)^{-1}\tilde{Z}'_{it}(\gamma, c)\widetilde{lnCO}2_{it}(\gamma, c)\right]$$

Then, during the second stage, the parameters of the transition function γ and c are estimated by NLS conditionally to $\widehat{\beta}_{IV}(\gamma, c)$.

2.4. Data sources and variable definitions

The data set used in this study is comprised of a balanced panel for 96 countries, over the period 1984-2013. The data are mainly drawn from the World Bank (2017) *World Development Indicators* (WDI) database; the institutional quality data are taken from the *International Country Risk Guide* (ICRG) database. The choice of countries and the sample period were dictated by the availability of the ICRG data. The sample includes countries in the lower, middle and higher income groups.

The dependent variable is the per capita CO2 emissions. Our main variable of interest is real GDP per capita ($2010 U.S. dollars) but we also consider a set of exogenous macroeconomic variables to be better able to scrutinize the evolution of per capita CO2 emissions. We use energy consumption per capita (use of primary energy before transformation to other end-use fuels in kilograms of oil equivalent per capita), the fraction of the population living in urban areas as measure of urbanization, industrial value added to GDP as indicator of the industrialization process, the ratio of import and export of merchandise to GDP as measure of trade openness, and the ratio of capital expenditures to GDP. To study the relationship between CO2 emissions and GDP, we also control for quality of institutions. The institutional quality indicators considered are democratic accountability of the government, bureaucracy quality and government stability[20]. These indicators are widely employed in empirical studies to capture the effect of quality of institutions on macroeconomic variables. The government stability ranges from 0 to 12 points while both democratic accountability and bureaucracy quality indexes range between 0 and 6 points. A score of 0 translates into a poor institutional quality while higher scores indicate better institutional quality. Table 2-1 provides descriptive statistics of the macroeconomic variables. The average per capita carbon dioxide emissions are 5.540 metric tons per capita[21]. The average energy consumption is 2,393 kg of oil equivalent per capita. On average, 33% of GDP is produced by the industrial sector. It is worth noting that in our sample about 60% of the population lives in urbanized areas. Table 2-1 also shows the correlation between the variables; as can be seen, there is a positive linkage between CO2 emissions, energy consumption and economic growth. The next section presents the estimation results.

[20] Bhattarai and Hammig (2001) showed that improvements in political institutions and governance significantly reduce deforestation.

[21] Per capita emission ranges from a low of 0.057 metric tons in Congo Dem. Rep to a high of 49.651 metric tons in Qatar. Similarly, GDP per capita ranges from a low of $234 for Ethiopia to a high of $80,702 for Luxembourg with a cross country average of $2,881.

Table 2-1. Descriptive statistics

Variable	Per capita CO2 emissions	Per capita GDP	Per capita energy consumption	Industrial GDP/GDP, %	Urban population/total population, %	Capital stock/GDP, %	Trade openness
Mean	5.540	14,821	2,393	32.732	60.027	22.782	79.346
Standard deviation	7.324	18,873	2,930	12.264	22.536	7.494	56.541
Minimum	0.017	130	104	3.329	8.534	0.000	11.087
Maximum	70.985	110,001	22,762	96.615	100.000	63.853	455.415
Correlations							
Per capita CO2 emissions	1.000						
Per capita GDP	0.651	1.000					
Per capita energy consumption	0.908	0.725	1.000				
Industrial GDP/GDP	0.391	0.035	0.327	1.000			
Urban population/total population	0.472	0.601	0.504	0.111	1.000		
Capital stock/GDP	0.161	0.089	0.107	0.242	0.168	1.000	
Trade openness	0.213	0.237	0.205	0.004	0.319	0.183	1.000

2.5. Empirical results

2.5.1. Linearity and no remaining non-linearity test results

The linearity and no remaining non-linearity tests results are presented in Table 2-2. First, we test whether regime switching is supported by the data or not. To do so, we test for linearity versus PSTR and PSTR IV models[22]. The non-linearity test results indicate that the null hypothesis of linearity $H_0: r = 0$ is strongly rejected at the 1% significance level by all the tests for both the PSTR as well as the PSTR IV specification. The results suggest that the relationship between CO2 emissions and economic growth is indeed non-linear. Next we test for no remaining linearity assuming a two-regime model. The results clearly indicate that the null hypothesis $H_0: r = 1$ cannot be rejected at the 5% significance level, which implies that the model has one threshold or two regimes. As a

[22]Estimation results are likely to be spurious and seriously biased if the data properties are not investigated and addressed in the empirical analysis. Therefore, prior to estimation, we carried out Cross-section Dependence (CD) tests following Pesaran (2004) and implemented panel unit root tests following Pesaran (2007). Results provide evidence that the raw data are subject to considerable cross-section dependence and the levels variable series are integrated of order 1. Results are not presented in this paper but can be made available upon request.

result, one threshold was sufficient to capture the non-linearity in the relationships between CO2 emissions and economic growth. Consequently, we choose to estimate models with one transition function and one location parameter.

Table 2-2. Linearity and no remaining non-linearity tests of the PSTR and PSTR IV models

Model	PSTR		PSTR IV	
H0: r=0 vs H1: r=1	Statistic	p-value	Statistic	p-value
Lagrange multiplier — Wald	469.191***	0.000	464.735***	0.000
Lagrange multiplier — Fischer	270.716***	0.000	267.650***	0.000
Likelihood ratio	512.145***	0.000	506.826***	0.000
H0: r=1 vs H1: r=2				
Lagrange multiplier — Wald	254.155	0.063	197.268	0.082
Lagrange multiplier — Fischer	169.365	0.057	204.641	0.076
Likelihood ratio	266.075	0.062	204.349**	0.023

Notes: Under *H0*, the Wald and Likelihood ratio statistics have asymptotic *χ2(mK)* distribution, whereas the Fisher has an asymptotic *F(mK, TN−N−m(K+1))* distribution. Moreover, *r* is the number of transition function. *r*=0, (1 regime no transition function), *r*=1, (2 regimes 1 transition function), *r*=2, (3 regimes 2 transitions). (***), (**) denote significance at 1% and 5%, respectively.

2.5.2. PSTR estimation results

The parameter estimates of the PSTR models are reported in column [1] through column [12] of Table 2-3. The table also presents the standard errors corrected for heteroskedasticity. The results of the model 1 consider only GDP per capita and one transition variable as regressors, while model 2 onwards control for some additional variables that might have an impact on CO2 emissions. It is worth mentioning that only the signs of the estimated parameters on GDP per capita and GDP as transition variable can be interpreted; however, both the sign and the magnitude of the control variables have meaningful interpretations.

From model 1, we observe that the GDP per capita coefficient (β_0) is positive (0.929) and statistically significant, whereas the parameter of the transition variable (β_1) is negatively significant (-0.236) and lower than (β_0) in absolute value. Furthermore, the sum of β_0 and β_1 is smaller than (β_0), which implies that per capita CO2 emissions increase rapidly in the early stage with economic growth and then continue to increase but at a lower rate in the later stages. The results show that there is a non-linear relationship between per capita CO2 emissions and economic growth rather than evidence for the presence of EKC for CO2 emissions. These findings are in line with the results obtained by Aslanidis and Iranzo (2009) and Chiu (2017).

To correct for possible omitted variable bias, we estimated the PSTR model controlling for variables that might influence the relationship between CO2 emissions and economic growth. As can be seen from the result of model 2, when we control for energy consumption, the estimates of GDP per capita (β_0) as well as the one associated with the transition variable (β_1) are close to the estimates reported in model 1 in terms of sign and magnitude. Moreover, the coefficient of energy consumption is positive (0.816), which indicates that a 1% increase in energy consumption per capita leads to a 0.816% rise in per capita CO2 emissions. Model 4 through model 12 extend the specification of model 2 by considering the impact of industrialization, urbanization, capital investment, trade openness as well as quality of institutions. The results show that industrialization level has a positive and significant impact on per capita CO2 emissions, which is in line with results found in earlier studies (Shahbaza and Lean, 2012, Shahbaz et al., 2014). With respect to the effect of urbanization level on per capita CO2 emissions, it has been argued that urbanization helps to achieve economies of scale for public infrastructure (e.g., public transportation, schools, hospitals, water supply, and waste management) and that these economies of scale lead to lower environmental damage (Burton, 2000; Capello and Camagni, 2000). Outcomes show that the estimated coefficients on urbanization are negative and statistically significant in the first two specifications but negative and statistically insignificant in the specification of model 6 through model 12. The estimated coefficients of capital are significantly positive and range in value between 0.153 and 1.170. Capital expenditures increases CO_2 emissions mainly through industrialization process. A high capital investment means a rapid industrialisation process and thereby impact on the environment. The result also shows that per capita CO_2 emissions decline 0.052% to 0.059% as trade openness increases by 1%. Similar findings are reported by Grossman and Krueger (1991) and Xu and Lin (2015).

As alluded to earlier, one of the specific objective of this analysis is to investigate the effect of the quality of institutions on per capita CO_2 emissions. Our results show that both democratic accountability and government stability have a negative and statistically significant impact on per capita CO_2 emissions. This suggests that improvements in democratic accountability and government stability will reduce environmental pollution; in other words, better quality of institutions can reduce CO_2 emissions. These findings are consistent with the results of Duarte et al (2013) who found that an improvement in democracy entails a betterment of environmental performance.

Table 2-3. Estimates for the PSTR models (dependent variable: log of CO2 emission per capita).

Interaction variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Regime 1												
GDP	0.929***	0.736***	0.727***	0.751***	0.703***	0.729***	0.729***	0.724***	0.727***	0.718***	0.728***	0.720***
	(0.018)	(0.023)	(0.023)	(0.026)	(0.026)	(0.027)	(0.027)	(0.025)	(0.027)	(0.024)	(0.027)	(0.024)
Regime 2												
GDP$g(LnGDP_{it-1};\gamma,c)$	-0.236***	-0.363***	-0.347***	-0.346***	-0.323***	-0.329***	-0.330***	-0.331***	-0.328***	-0.329***	-0.329***	-0.330***
LGDP	(0.010)	(0.013)	(0.013)	(0.013)	(0.013)	(0.014)	(0.014)	(0.013)	(0.014)	(0.013)	(0.014)	(0.013)
Control variables												
Energy consumption		0.816***	0.795***	0.808***	0.803***	0.796***	0.801***	0.797***	0.796***	0.788***	0.798***	0.792***
		(0.021)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.021)	(0.022)	(0.021)	(0.022)	(0.021)
Industrialization			0.065***	0.065***	0.047**	0.057**	0.059**	0.059***	0.058**	0.059***	0.055**	0.056***
			(0.020)	(0.020)	(0.020)	(0.021)	(0.021)	(0.020)	(0.021)	(0.020)	(0.021)	(0.020)
Urbanization				-0.111**	-0.103**	-0.058	-0.038		-0.055		-0.050	
				(0.041)	(0.041)	(0.043)	(0.043)		(0.043)		(0.043)	
Capital expenditures					0.153***	0.167***	0.168***	0.169***	0.166***	0.168***	0.168***	0.170***
					(0.028)	(0.028)	(0.028)	(0.027)	(0.028)	(0.027)	(0.028)	(0.027)
Trade openness						-0.053***	-0.052***	-0.056***	-0.053***	-0.059***	-0.053***	-0.058***
						(0.015)	(0.015)	(0.014)	(0.016)	(0.014)	(0.015)	(0.014)
Democratic accountability							-0.004***	-0.004***				
							(0.001)	(0.001)				
Democratic quality									0.001	0.001		
									(0.001)	(0.001)		
Government stability											-0.002**	-0.002**
											(0.001)	(0.001)
Location parameters	4.721	4.401	4.413	4.404	4.412	4.408	4.411	4.413	4.407	4.410	4.406	4.409
Slope parameters	3.777	2.143	2.149	2.214	2.264	2.175	2.168	2.140	2.177	2.139	2.168	2.132
RSS	20.251	13.809	13.76	13.726	13.58	13.527	13.452	13.455	13.525	13.532	13.517	13.522
AIC	-4.954	-5.337	-5.34	-5.341	-5.351	-5.355	-5.360	-5.359	-5.354	-5.354	-5.355	-5.354
BIC	-4.946	-5.326	-5.327	-5.327	-5.335	-5.336	-5.339	-5.341	-5.333	-5.335	-5.334	-5.336
Observations	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880

Notes: Dependent variable is per capita CO2 emissions in natural logarithm. Values in parenthesis are standard errors. Standard errors are corrected for heteroskedasticity. **, *** stand for 5% and 1% significant levels.

To check for the robustness of the results reported earlier, we also correct for possible endogeneity issues. Table 2-4 reports the estimation results of PSTR IV. In sum, our estimates reach the same general conclusion as those reported in Table 3. That is, the estimated coefficients of GDP per capita in the first regime are greater than the coefficients of GDP per capita as transition variable in absolute terms after correcting for endogeneity. The results provide evidence of a non-linear relationship between per capita CO2 emissions and GDP per capita. We observe that the slope coefficients for energy consumption variables are somewhat close to the estimated coefficients obtained by PSTR. In most specifications, the parameters of the control variables are comparable to the parameters reported in Table 2-3. With respect to the quality of institution variables, we find that democratic accountability has a negative and statistically significant impact on per capita CO2 emissions. However, the only variable that ceases to be statistically significant after controlling for endogeneity is government stability.

Table 2-4. Estimates for the PSTR- IV models (dependent variable: log of CO2 emission per capita).

Interaction variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Regime 1												
GDP	0.904***	0.654***	0.647***	0.668***	0.622***	0.642***	0.643***	0.640***	0.641***	0.635***	0.640***	0.635***
	(0.018)	(0.022)	(0.021)	(0.024)	(0.025)	(0.025)	(0.025)	(0.023)	(0.025)	(0.023)	(0.025)	(0.023)
Regime 2												
GDP $g(LnGDP_{it-1};\gamma,c)$	-0.198***	-0.295***	-0.280***	-0.281***	-0.259***	-0.261***	-0.261***	-0.261***	-0.260***	-0.259***	-0.261***	-0.260***
LGDP	(0.009)	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)	(0.012)	(0.011)	(0.012)	(0.011)	(0.011)	(0.011)
Control variables												
Energy consumption		0.801***	0.779***	0.789***	0.783***	0.776***	0.782***	0.779***	0.775***	0.771***	0.778***	0.774***
		(0.021)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.021)	(0.022)	(0.021)	(0.022)	(0.022)
Industrialization			0.070***	0.070***	0.055***	0.064***	0.066***	0.066***	0.061***	0.066***	0.063***	0.064***
			(0.020)	(0.020)	(0.021)	(0.021)	(0.021)	(0.020)	(0.021)	(0.021)	(0.021)	(0.021)
Urbanization				-0.088**	-0.080*	-0.036	-0.016		-0.032		-0.028	
				(0.041)	(0.041)	(0.043)	(0.043)		(0.043)		(0.043)	
Capital expenditures					0.147***	0.161***	0.161***	0.162***	0.159***	0.161***	0.162***	0.163***
					(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Trade openness						-0.052***	-0.052***	-0.053***	-0.053***	-0.056***	-0.052***	-0.055***
						(0.016)	(0.015)	(0.014)	(0.016)	(0.014)	(0.015)	(0.014)
Democratic accountability							-0.005***	-0.004***				
							(0.001)	(0.001)				
Democratic quality									0.001	0.001		
									(0.001)	(0.001)		
Government stability											-0.001	-0.001
											(0.001)	(0.001)
Location parameters	4.682	4.401	4.415	4.407	4.419	4.417	4.420	4.422	4.416	4.419	4.417	4.420
Slope parameters	4.391	2.438	2.451	2.501	2.579	2.498	2.495	2.485	2.500	2.478	2.491	2.472
RSS	20.325	14.090	14.033	14.011	13.879	13.827	13.746	13.746	13.825	13.827	13.819	13.820
AIC	-4.951	-5.316	-5.319	-5.321	-5.329	-5.332	-5.337	-5.338	-5.332	-5.332	-5.332	-5.333
BIC	-4.942	-5.306	-5.307	-5.306	-5.313	-5.314	-5.317	-5.319	-5.311	-5.313	-5.311	-5.314
Observations	2784	2784	2784	2784	2784	2784	2784	2784	2784	2784	2784	2784

Notes: Dependent variable is per capita CO2 emissions in natural logarithm. Values in parenthesis are standard errors. Standard errors are corrected for heteroskedasticity. **, *** stand for 5% and 1% significant levels.

Figure 2-1 Figure 2-1 depicts the scatter plot of the PSTR transition function against per capita GDP. The graph suggests that the change from one regime to another is relatively gradual. The estimated threshold value of 4.721 points to the half-way of the transition function.

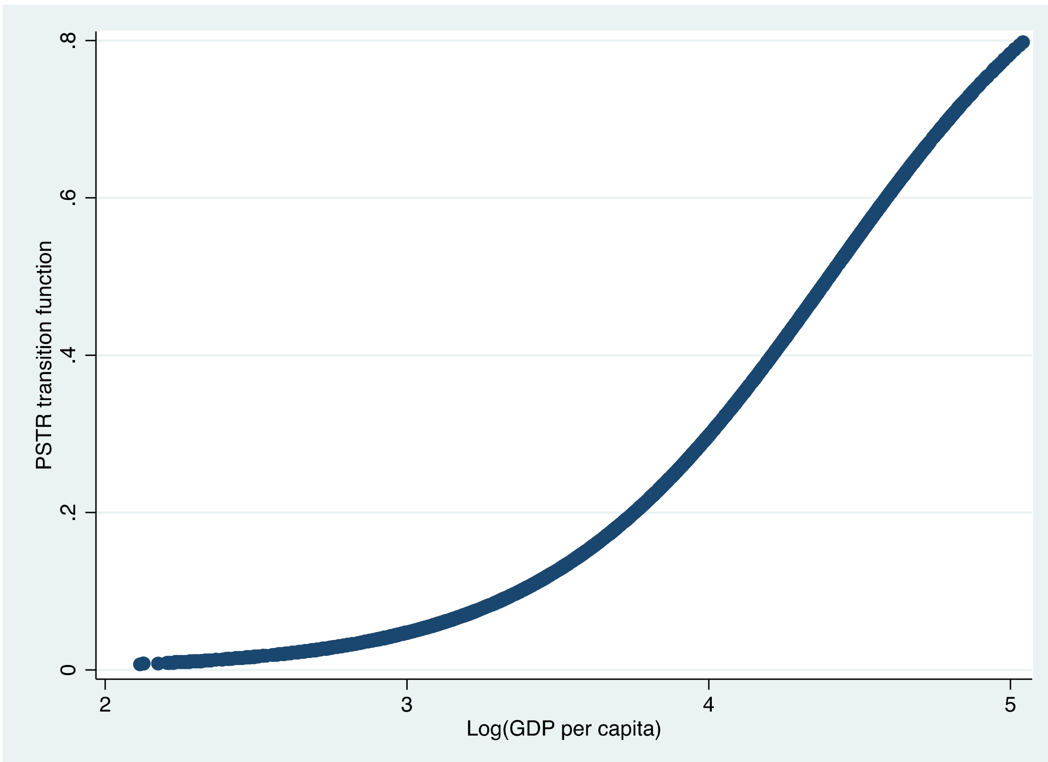

Figure 2-1. Estimated PSTR transition function

Figure 2-2 shows the PSTR IV transition function plotted against the per capita GDP. It is obvious that the change from the first regime to the second regime is relatively smooth. The estimated transition parameter is now 4.682, slightly lower than the one obtained by estimating the PSTR. It is worth noting that correcting for endogeneity reduces the transition parameter. The estimated threshold value of 4.682 points to the half way point of the transition.

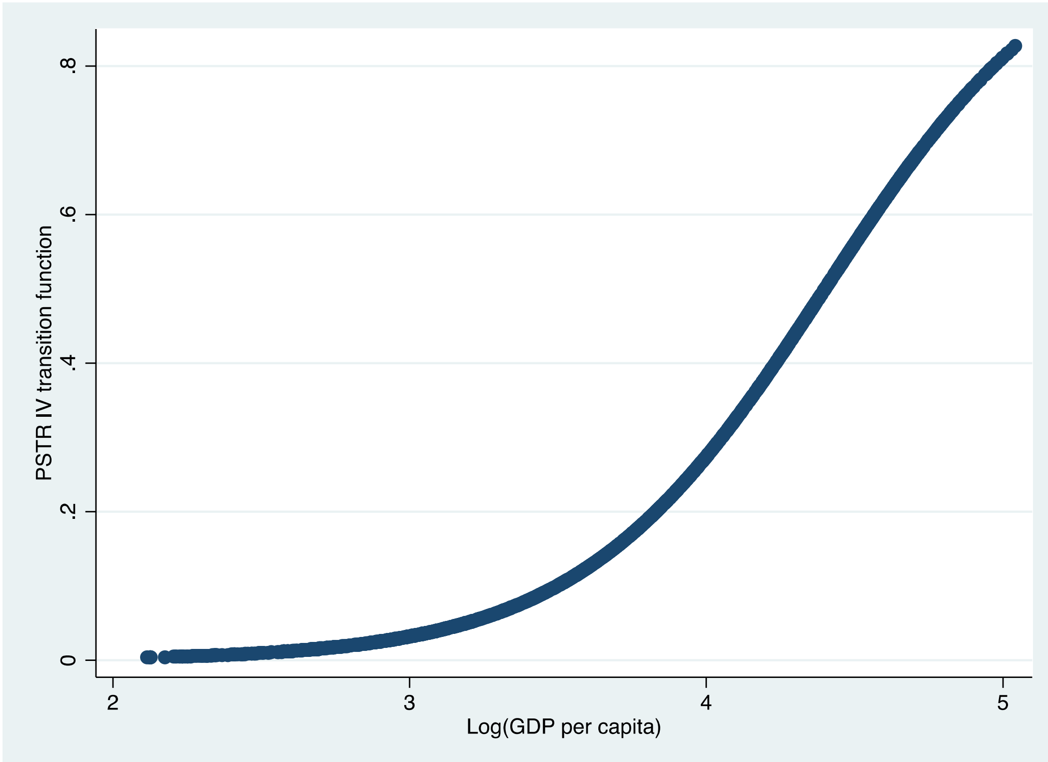

Figure 2-2. Estimated PSTR IV transition function

Table 2-5 reports the average elasticities as well as the average standard deviations of per capita GDP derived from the PSTR and the PSTR IV models controlling for additional variables. The average elasticities corrected for endogeneity are roughly similar to those obtained by performing the PSTR. Further, we also observe that the estimated average standard deviations resulting from the two estimations are relatively close. The bottom line is that these results are in line with the argument provided by Fouquau et al (2008) which states that the use of a non-linear framework (PSTR) addresses the problems of endogeneity.

Table 2-5. Individual average elasticities of CO2 emissions with respect to real GDP.

	PSTR		PSTR IV			PSTR		PSTR IV	
Country	Mean	Std.dev	Mean	Std.dev	Country	Mean	Std.dev	Mean	Std.dev
Albania	0.696	0.010	0.624	0.006	Kenya	0.715	0.001	0.636	0.000
Algeria	0.682	0.004	0.614	0.003	Korea,Rep	0.615	0.031	0.562	0.027
Angola	0.693	0.007	0.622	0.005	Lebanon	0.658	0.009	0.596	0.007
Argentina	0.646	0.010	0.586	0.007	Luxembourg	0.487	0.018	0.447	0.017
Australia	0.528	0.013	0.482	0.012	Malaysia	0.660	0.016	0.597	0.012
Austria	0.533	0.013	0.486	0.012	Malta	0.603	0.021	0.550	0.019
Bahrain	0.581	0.008	0.529	0.007	Mexico	0.646	0.006	0.586	0.004
Bangladesh	0.720	0.002	0.639	0.001	Mongolia	0.703	0.006	0.628	0.003
Belgium	0.536	0.012	0.489	0.011	Morocco	0.701	0.006	0.627	0.004
Bolivia	0.706	0.003	0.630	0.002	Mozambique	0.724	0.002	0.640	0.001
Botswana	0.675	0.012	0.609	0.009	Netherlands	0.528	0.014	0.482	0.013
Brazil	0.640	0.008	0.581	0.006	New Zealand	0.555	0.010	0.506	0.009
Brunei Dar	0.534	0.005	0.486	0.005	Nicaragua	0.709	0.002	0.632	0.001
Bulgaria	0.673	0.011	0.608	0.008	Nigeria	0.707	0.005	0.631	0.003
Cameroon	0.711	0.003	0.633	0.002	Norway	0.489	0.011	0.447	0.010
Canada	0.529	0.010	0.482	0.009	Oman	0.595	0.008	0.542	0.008
Chile	0.641	0.020	0.583	0.017	Pakistan	0.716	0.002	0.636	0.001
China	0.703	0.016	0.629	0.010	Panama	0.666	0.012	0.602	0.008
Colombia	0.672	0.008	0.606	0.005	Paraguay	0.693	0.003	0.622	0.002
Congo, Dem Rep	0.722	0.003	0.639	0.002	Peru	0.684	0.008	0.616	0.005
Congo, Rep	0.693	0.003	0.621	0.002	Philippines	0.705	0.003	0.630	0.002
Costa Rica	0.661	0.011	0.599	0.008	Poland	0.646	0.018	0.587	0.014
Cote d'ivoire	0.709	0.002	0.632	0.001	Portugal	0.589	0.015	0.537	0.014
Cyprus	0.568	0.018	0.519	0.017	Qatar	0.496	0.003	0.452	0.003
Denmark	0.512	0.010	0.468	0.009	Romania	0.663	0.012	0.600	0.009
Dominican Republic	0.684	0.010	0.615	0.007	Saudi Arabia	0.600	0.008	0.546	0.006
Ecuador	0.680	0.004	0.612	0.003	Senegal	0.715	0.001	0.636	0.000
Egypt,	0.702	0.005	0.628	0.003	Singapore	0.554	0.026	0.506	0.023
El Salvador	0.692	0.006	0.621	0.004	South Africa	0.657	0.004	0.595	0.003
Ethiopia	0.725	0.001	0.641	0.000	Spain	0.564	0.015	0.515	0.014
Finland	0.536	0.015	0.489	0.013	Sri Lanka	0.704	0.007	0.629	0.004
France	0.539	0.010	0.491	0.009	Sudan	0.714	0.004	0.635	0.002
Gabon	0.629	0.007	0.571	0.006	Sweden	0.526	0.012	0.480	0.011
Ghana	0.714	0.003	0.635	0.001	Switzerland	0.496	0.006	0.452	0.005
Greece	0.574	0.013	0.523	0.012	Tanzania	0.720	0.001	0.638	0.001
Guatemala	0.696	0.003	0.624	0.002	Thailand	0.686	0.012	0.617	0.008
Honduras	0.704	0.003	0.629	0.002	Togo	0.721	0.001	0.638	0.000
Hong Kong	0.575	0.021	0.526	0.020	Trinidad and Tabago	0.633	0.024	0.576	0.020
Hungary	0.630	0.012	0.573	0.010	Tunisia	0.691	0.008	0.620	0.005
Iceland	0.541	0.013	0.494	0.012	Turkey	0.649	0.012	0.589	0.010
India	0.717	0.004	0.637	0.002	United Kingdom	0.546	0.014	0.498	0.013
Indonesia	0.700	0.007	0.626	0.005	United States	0.528	0.012	0.482	0.011
Iran,	0.675	0.008	0.608	0.006	Uruguay	0.643	0.013	0.584	0.010
Ireland	0.545	0.030	0.498	0.028	Venezuela,	0.618	0.006	0.562	0.005
Italy	0.544	0.009	0.496	0.009	Vietnam	0.717	0.005	0.637	0.002
Jamaica	0.674	0.005	0.608	0.004	Yemen,	0.713	0.001	0.634	0.001
Japan	0.534	0.010	0.487	0.010	Zambia	0.713	0.002	0.634	0.001
Jordan	0.687	0.005	0.618	0.004	Zimbabwe	0.713	0.003	0.634	0.002

2.6. Concluding remarks

The purpose of this chapter was to investigate the nature of the relationship between CO2 emissions and economic growth and to derive policy implications from the results. To this end, the Panel Smooth Transition Regression (PSTR) model of González et al. (2005) was applied to a sample of 96 countries over the period 1984-2013 to empirically examine the relationships among CO2 emissions, economic growth.

The main focus of this study has been to verify the validity of the so-called "Environmental Kuznets Curve" by using a more appropriate econometric technique and by incorporating energy consumption, industrialization, urbanization, trade openness, capital expenditures as well as quality of institutions in the model besides CO2 emissions and economic growth. In doing so, we have expanded upon previous critiques by applying a more appropriate method and by controlling for most of the relevant factors identified in the literature to have influence on CO2 emissions. We discovered that the relationship between CO2 emissions and economic growth is not a U-shaped relation. Indeed, our data demonstrate that the link between CO2 emissions and economic growth is a non-linear relationship. More specifically, we observe that CO2 emissions tend to rise rapidly in the early stages of economic growth, then continue to increase but at a lower rate. This finding is in common with Aslanidis and Iranzo (2009) who also show that emissions accelerate with economic growth in a low-income regime and then decelerate in a high-income regime.

This finding has clear policy implications, suggesting that to curb CO2 emissions in the long-run, countries need to adopt advance abatement technology to enhance energy efficiency. Further observation to be drawn from this result is that quality of institutions do matter for emissions-economic growth relation. Therefore, it may be fruitful in future empirical researches that aiming to investigate CO2 emissions-economic growth nexus to consider the potential determinants of CO2 emissions such as energy consumption, industrialization, urbanization, trade openness and capital expenditures into the relation. In addition to this, it will also be important to take into account the quality of institutions prevailing in each country in order to shed more light on the true impact of economic growth on CO_2 emissions, and thereby to provide new insight that help policy makers to design effective environmental policies.

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Chapter 3. Clean energy-growth nexus in sub-Saharan Africa: Evidence from cross-sectionally dependent heterogeneous panel with structural breaks[23]

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3.1. Introduction

Determining the link between energy consumption and economic growth has become a topic studied in depth in the field of energy economics, given the scarcity of energy resources and the fact that energy serves as a major input in production processes. Previous studies have found a strong correlation between energy usage and the level of economic development and growth in both developed and developing economies (Ferguson et al. 2000). However, the presence of a strong correlation does not necessarily imply a causal relationship. Identifying the existence and directions of the causalities is important in the design and effectiveness of energy policies. For instance, if there is a unidirectional causality running from energy consumption to economic growth, reducing energy consumption could lead to a fall in economic growth. In contrast, if there is a unidirectional causality running from economic growth to energy consumption, it could imply that policies designed at reducing energy consumption may be implemented with little or no adverse impact on economic growth.

There is a plethora of empirical work that examines the causality between energy consumption and economic growth. Some studies are those of Narayan and Smyth (2008), Jinke et al. (2008), Bowden and Payne (2009), Wolde-Rufael (2010a), Chandran et al. (2010), Lean and Smyth (2010), Apergis and Payne (2010a), Payne and Taylor (2010), Wolde-Rufael (2010b), Menegaki (2011) , Dedeoglu et al. (2014), Al-Mulali (2014), Jin and Kim (2015), Husaini and Lean (2015), Shahbaz et al. (2015) to name only a few. Yet, there seems to be no consensus regarding the causal relationship between energy consumption and economic growth. In general, the empirical findings have yielded rather mixed results. The lack of consensus among the empirical works may be attributed to such factors as differences in variable selection, model specification, sample size, the reference period and the econometric approaches undertaken, among others (Zachariadis, 2007; Costantini and Martini, 2010; Apergis and Payne 2011).

For instance, Narayan and Smyth (2008) investigate the relationship between gross capital formation, total energy consumption and real GDP in a panel of G7 countries over the period 1972–2002. The authors find evidence of a unidirectional causality running from energy consumption to real GDP. In a similar study, Bowden and Payne (2009) examine the causality between total energy consumption and real GDP at the aggregate and sectoral level in the U.S. over the period 1949–2006. They fail to reach a consensus as to the direction of causation. Dedeoglu et al. (2014) examine the relationship between energy consumption and real gross domestic product (GDP) per capita for the 15 former Soviet Union countries over the period 1992–2009. Their results evidence the presence of a unidirectional causal relationship running from energy consumption to the real GDP per capita in the long run but not in the short-run. However, they discover a bidirectional relationship for oil importer and natural gas importer within the 15 former Soviet Union countries.

On the coal consumption-growth nexus, Jinke et al. (2008) investigate the relationship between coal consumption and economic growth in a group of coal consuming countries (OECD and non-OECD) over the period 1980–2005. They find a unidirectional causality running from economic growth to coal consumption in Japan and China and no causality relationship between coal consumption and economic growth in India, South Korea and South Africa. For the case of the United States, the series are not even cointegrated. Similarly, Wolde-Rufael (2010a) applies a modified version of the Granger causality test to the same sample of countries, by expanding the time span, 1965–2005. He finds a unidirectional causality running from coal consumption to economic growth in India and Japan while the opposite causality running from economic growth to coal consumption was found in China and South Korea. A bi-directional causality running between economic growth and coal consumption was found in the case of South Africa and the United States. In a study of this sort, Jin and Kim (2015) examine the causal relationship between coal consumption and economic growth for 58 countries (OECD and non-OECD countries) over the period 1971–2010. They find that coal consumption and economic growth have a long-run equilibrium in OECD countries. In contrast, no long-run relationship between coal consumption and economic growth is found for non-OECD countries.

Using time series data for the period 1971–2003 and applying a bivariate and multivariate framework, Chandran and colleagues (2010) study the relationship between electricity consumption and real GDP in Malaysia. The authors discover a unidirectional causality flowing from electricity consumption to economic growth. Lean and Smyth (2010) investigate the same issue, by examining electricity consumption, aggregate output, exports, labor and capital in a multivariate framework. They find a unidirectional causality running in the opposite direction, i.e., Granger causality running from aggregate output to electricity consumption. More recently, Husaini and Lean (2015) investigate the relationship between electricity consumption, output, and price in the manufacturing sector in Malaysia over the period 1978 to 2011. They find that there is a unidirectional causality from manufacturing output to electricity consumption in the long run.

Apergis and Payne (2010a) explore the causality between renewable energy consumption and economic growth for 13 countries within Eurasia over the period 1992–2007. They find a bidirectional causation between renewable energy consumption and economic growth. Menegaki (2011) investigates the causal relationship between renewable energy and economic growth for 27 European countries in a multivariate framework over the period 1997–2007. She adds variables such as greenhouse gas emissions and employment and reports no causality between renewable energy consumption and economic growth. Shahbaz et al. (2015) examine the relationship between renewable energy consumption and economic growth by using quarterly data over the period of 1972Q1–2011Q4 and by incorporating capital and labour as potential determinants of production function in case of Pakistan. They find evidence of a bidirectional causality between economic growth and renewable energy consumption.

Research on the causal relationship between nuclear energy consumption and economic growth was performed by Yoo and Jung (2005) for the case of Korea over the period 1977–2002. Their findings show that nuclear energy consumption causes economic growth but economic growth does not cause nuclear energy consumption. Payne and Taylor (2010) employ the Toda and Yamamoto (1995) test to examine the causal relationship between nuclear energy consumption and GDP growth in the United States over the 1957–2006 period. Their results indicate that there is no causality associated with nuclear energy consumption and economic growth. Al-Mulali (2014) investigates the causality between nuclear energy consumption, GDP growth and CO_2 emission in 30 major nuclear energy consuming countries over the period 1990–2010. He find that nuclear energy consumption has a positive short run causal relationship with GDP growth and a negative short run causal relationship with CO_2 emission.

While most of the existing published literature has focused on the relationship between electricity consumption and economic growth, the relationship between coal consumption and economic growth, the relationship between renewable energy consumption and economic growth or the relationship between nuclear energy consumption and economic growth, virtually no published research exists that looks into the relationship between clean energy consumption and economic growth in either developed or developing economies[24]. In this chapter, we extend the findings of the existing literature by applying rigorous econometric techniques to a sample of sub-Saharan African countries to study the causality between clean energy consumption and economic growth. One of the major limitation of earlier studies is the use of the traditional panel unit root test and panel cointegration test (first generation of panel unit root and cointegration tests). Recent developments in panel data analysis have raised concerns about the validity of the first generation of panel unit root and cointegration tests which may lead to biased inferences and hence misleading results due to lower power of the unit root and cointegration test (Andrews, 2005; Pesaran, 2006; Bai and Ng, 2010). To overcome some of the shortcomings, we employ a second generation of panel unit root and cointegration tests, namely, the Carrion-i-Silvestre et al. (2005) panel unit root test, that accommodates structural breaks and combines with the panel cointegration test proposed by Westerlund and Edgerton (2008) which accounts for both cross-sectional dependence and structural breaks to exploit the extra power[25]. Furthermore, the chapter contributes to the literature by applying a bootstrap-corrected Granger causality test to assess the short-run and the long-run dynamics between clean energy consumption and economic growth.

We find evidence of a unidirectional causal relationship running from clean energy consumption to economic growth. This implies that economic growth derives in part from greater clean energy consumption, and that a decrease in clean energy consumption would be a drag on economic growth. Therefore, the use of clean energy technologies in sub-Saharan Africa can be an economically

[24] Clean energy is noncarbohydrate energy that does not produce carbon dioxide when generated. It includes hydropower and nuclear, geothermal, and solar power, among others (http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2014).

[25] As noted by Westerlund and Edgerton (2008), when studying macroeconomic data, cross-sectional dependencies are likely to be the rule rather than the exception, due to strong inter-economy linkages.

beneficial and environmentally friendly alternative to fossil energy sources[26]. Given this crucial advantage accruing from the use of clean energy, and while faced with increasing demand for energy and vulnerability to climate change, it would seem sensible for economies in sub-Saharan Africa to set aside any pre-conceived inhibitions and to diversify their energy supply and to strengthen their energy security by fostering the adoption of clean energy alternatives to fossil fuels[27].

The roadmap for the remainder of this chapter is as follows. Section 3.2. provides the model adopted and explains the data employed. Section 3.3. discusses and presents the results of panel unit root and cointegration tests along with the results of a panel error correction model. Section 3.4. provides the concluding remarks.

3.2. Model Specification and Data

Following Apergis and Payne (2009), the long-run relationship between clean energy consumption and economic growth is given as follows:

$$\ln Y_{it} = \beta_{0i} + \beta_{1i} \ln C_{it} + \epsilon_{it} \tag{1}$$

where i=1,2,...,N for each country in the panel and t=1,2,...,T refers to the time period. Y_{it} is real GDP per capita; C_{it} denotes clean energy consumption per capita, and ϵ_{it} is the error term. In order to investigate whether there is a relationship between clean energy consumption and economic growth, data covering the period 1971–2007 are used. The choice of the starting and ending dates was constrained by the availability of data. We employ annual data on clean energy consumption

[26] Africa is a stable and a safe clean energy supply, solar across all of Africa, hydro in many African countries, wind mainly in coastal areas and geothermal in the East African Rift Valley.

[27] According to the International Energy Outlook 2010, in 2008, more than 70% of the sub-Saharan African populations do not have access to electricity and a large proportion of the current energy usage stems from the burning of fossil fuels (http://large.stanford.edu/courses/2010/ph240/riley2/docs/EIA-0484-2010.pdf).

per capita (aggregate consumption of hydropower and nuclear, geothermal, wind and solar consumption, among others, in kg of oil equivalent, divided by the number of population). The real GDP per capita series is in constant 2000 U.S. dollars and used as a proxy for economic growth. The data on the two variables were obtained from the World Development Indicators. The countries considered are: Cameroon, Congo (RDC), Côte d'Ivoire, Ghana, Kenya, Nigeria, South Africa, Sudan, Togo and Zambia. Table 3-1 provides descriptive statistics for real GDP per capita and clean energy consumption per capita for each country. As can be seen, the mean real GDP per capita ranges from 3213.553 U.S. dollars in South Africa to 192.978 U.S. dollars in Congo (RDC). As for clean energy consumption per capita, it ranges from as high as 90.207 kg of oil equivalent per capita in Zambia to as low as 2.294 kg in Togo.

Table 3-1. Descriptive statistics

	Real GDP (2000 US dollars per capita)			Clean energy consumption ((kg of oil equivalent per capita)		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Cameroon	683.779	669.460	126.708	16.771	17.894	2.451
Congo Democratic Republic.	192.978	223.623	89.165	11.998	12.523	1.712
Congo Republic.	1059.693	1092.685	170.347	8.532	9.179	4.250
Côte d'Ivoire	740.622	689.644	175.605	7.787	7.962	3.523
Ghana	244.589	239.418	32.918	28.770	30.385	7.465
Kenya	415.356	413.737	21.977	15.674	18.346	9.481
Nigeria	388.387	373.763	44.451	3.848	3.959	0.873
South Africa	3213.553	3212.637	196.584	46.811	63.719	33.896
Sudan	309.413	284.445	64.787	2.721	2.724	0.392
Togo	276.028	273.804	30.907	2.294	1.952	1.311
Zambia	412.329	396.136	89.991	90.207	78.603	32.176

Figure 3-1 depicts the relationship between clean energy consumption and the economic growth from 1971 to 2007. There is a strong positive relationship between clean energy consumption and the economic growth in Togo, Congo Republic, Ghana and Congo Democratic Republic, with correlation coefficients to be (0.8480), (0.7726), (0.5949), and (0.5468) respectively. However, in the case of Cameroon, Côte d'Ivoire and Zambia the relationship between clean energy consumption growth and economic growth tends to decrease as income increases.

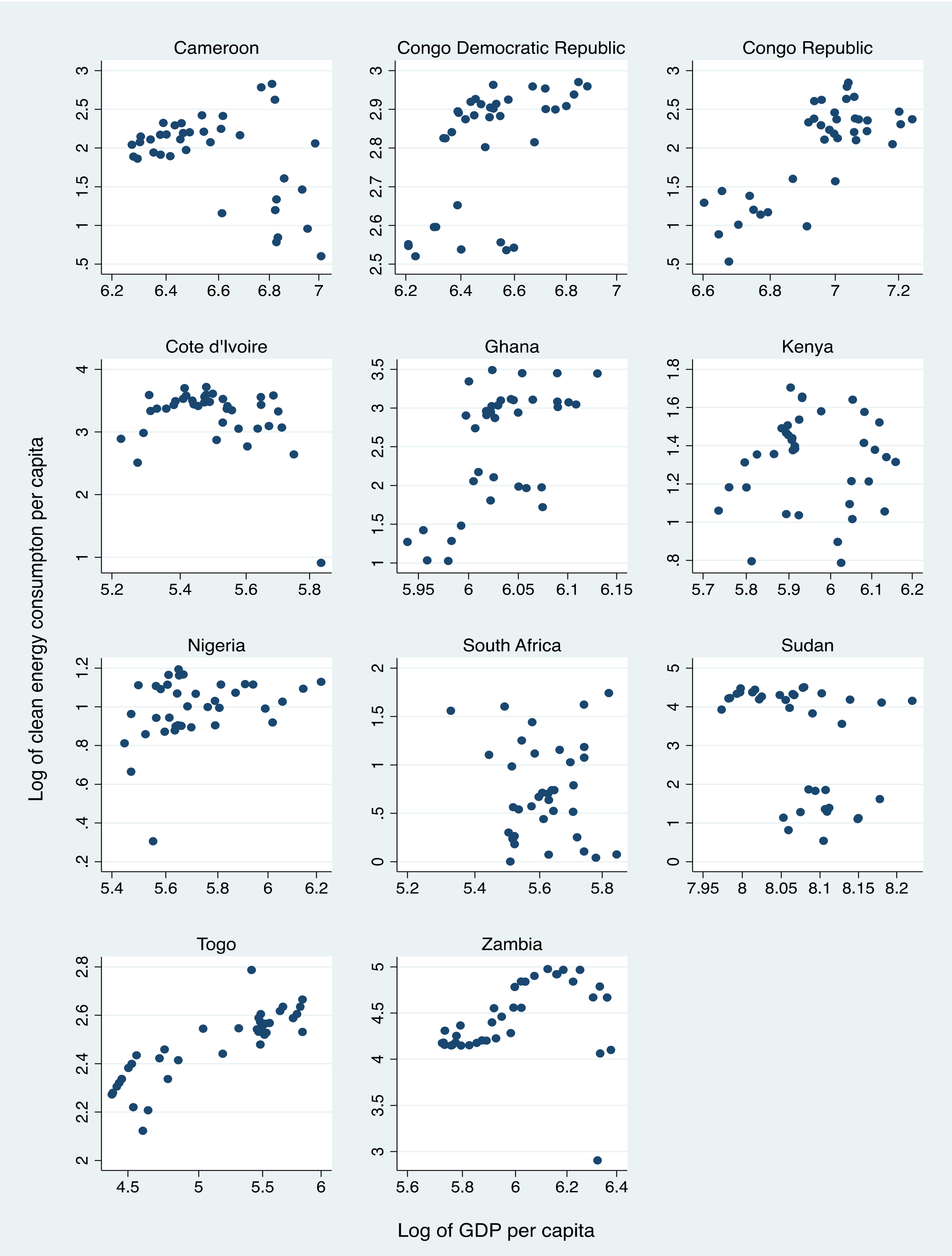

Figure 3-1. Log of clean energy consumption per capita vs. log of GDP per capita

3.3. Econometric methodology and results

Our econometric approach to investigate the causal relationship between clean energy consumption and economic growth consists of the following four steps. First, we investigate the stationarity properties of the series. Second, if the series are found to be integrated of same order, we proceed by testing for the long-run relationships among the set of integrated series. Next, we estimate the long-run equilibrium relationship, and finally, once the long-run equilibrium relationship is established, we employ dynamic panel causality tests to investigate the short-run and log-run direction of causalities.

3.3.1. Cross-section dependence test

Before proceeding with investigating the order of integration of the series, a phase that is of major concern is to test for cross-sectional dependence of the series. When cross-sectional dependence is found, the traditional panel unit root and cointegration tests (first generation) may yield large size distortions and thereby fail to assess clearly the integration and long-run relations among the variables. Therefore, we start by checking for cross-sectional dependency of the data. In doing so, we apply the cross-section dependence (CD) test developed by Pesaran (2004). Pesaran proposes a simple diagnostic test that does not require an *a priori* specification of a connection or spatial matrix and is applicable to a wide range of panel data models. The proposed test is based on a simple average of all pair-wise correlation coefficients of the Ordinary Least Squares (OLS) residuals from the standard panel regressions:

$$y_{it} = \alpha_i + \beta_i' x_{it} + u_{it} \quad (2)$$

where i=1,2,...,N indexes the cross section dimension and t=1,2,...,T the time series dimension, x_{it} is a $kx1$ vector of observed time-varying regressors. The individual intercepts, α_i and the slope coefficients, β_i are defined on a compact set and are allowed to vary across i. For each i, $u_{it} \sim iid(0, \sigma_{iu}^2)$ and for all t, although they could be cross-sectionally correlated. The dependence of u_{it} across i could arise in a number of different ways. It could be due to spatial dependence, omitted unobserved common components, or idiosyncratic pair-wise dependence of u_{it} and u_{jt} for $i \neq j$. The regressors could contain lagged values of y_{it}, be either stationary or have unit roots. The CD test is

$$CD = \sqrt{\frac{2T}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}} \quad (3)$$

where $\hat{\rho}_{ij}$ is the sample estimate of the pair-wise correlation of the residuals

$$\hat{\rho}_{ij} = \hat{\rho}_{ji} = \frac{\sum_{t=1}^{T} e_{it} e_{jt}}{(\sum_{t=1}^{T} e_{it}^2)^{\frac{1}{2}} (\sum_{t=1}^{T} e_{jt}^2)^{\frac{1}{2}}} \quad (4)$$

and e_{it} is the OLS estimate of u_{it} in Eq. (1), defined by

$$e_{it} = y_{it} - \hat{\alpha}_i - \hat{\beta}_{it}' x_{it} \quad (5)$$

Pesaran shows that the CD statistic has a mean of zero for fixed values of T and N; under a variety of panel data models, including heterogeneous dynamic models subject to single or multiple structural breaks in the slope coefficients and/or error variances. Table 3-2 displays the CD test results. As shown in Table 3-2, the null hypothesis of cross-sectional independence is rejected at a 1% significance level for the GDP, which indicates that the GDP series are cross-sectionally correlated. For the clean energy consumption variable, the test rejects the null hypothesis of cross-sectional c independence at a 10% significance level. The overall result favors the presence of cross sectional dependence in panels[28]. Given the presence of cross-sectional dependence, we apply panel unit root and panel cointegration tests which provide more powerful tests and estimates, and which have many advantages in the presence of cross section dependence over the traditional panel unit root and cointegration tests. This is done in the next sections.

Table 3-2. CD test results, cross-section correlations of the residuals in AR(p)

Specification	$ln(Y)$		$ln(C)$	
	Statistics	Prob	Statistics	Prob
AR(1)	4.501***	0.000	1.727*	0.084
AR(2)	2.929***	0.003	1.627	0.104
AR(3)	2.897***	0.004	1.652*	0.098

(*) and (***) denote statistical significance at the 10% and 1% levels.

3.3.2. Second generation panel unit root test

In light of the cross-sectional dependence test results, the panel unit root is checked using a second generation of panel unit root test. We employ the Carrion-i-Silvestre *et al*. (2005) test to assess the stationarity properties of the series. The benefit derived from this test is that it is general enough to allow for heterogeneity and the possibility of multiple endogenous structural breaks and can be adapted to accommodate cross-sectional dependence in the panel data. The model under consideration is:

$$y_{it} = \alpha_i + \sum_{k=1}^{m_i} \theta_{ik} DU_{ikt} + \beta_{it} + \sum_{k=1}^{m_i} \gamma_{ik} DT^*_{ikt} + \varepsilon_{it} \quad (6)$$

[28] To corroborate our findings, we apply the modified Wald statistic for groupwise heteroskedasticity in the residuals and the Lagrange multiplier (LM) tests, both tests confirm the presence of groupwise heteroskedasticity and correlation of errors across cross-sectional units. Results are not presented in the paper but can be made available upon request.

where i=1,2,...,N indexes the cross section dimension and t=1,2,...,T the time series dimension. The dummy variables DU_{ikt} and DT^*_{ikt} are defined as

$$DU_{ikt} = \begin{cases} 1 \; if \; t \; > T^i_{bk} \\ 0 \; otherwise \end{cases}; \qquad DT^*_{ikt} = \begin{cases} t - T^i_{bk} \; if \; t \; > T^i_{bk} \\ 0 \; otherwise \end{cases}$$

with T^i_{bk} denoting the $k-th$ date of the break for the $i-th$ individual, k=1,2,...,m_i ;$m_i \geq 1$, and α_i and β_i are the parameters of the constant and time trend, respectively. And ε_{it} denotes the disturbance term. The model includes individual effects, individual structural break effects and temporal structural break effects. The test statistic is constructed by averaging the univariate stationarity test in Kwiatkowski *et al*. (1992). The general form of the test is defined as:

$$LM(\lambda) = N^{-1} \sum_{i=1}^{N} \widehat{\omega}_i^{-2} T^{-2} \sum_{i=1}^{N} \hat{S}^2_{it} \tag{7}$$

where $\hat{S}_{it} = \sum_{j=1}^{t} \hat{\varepsilon}_{ij}$ denotes the partial sum process that is obtained from the estimated OLS residuals of Eq. (6), and $\widehat{\omega}_i^2$ being a consistent estimate of the long-run variance of ε_{it}[29]. By construction, Carrion-i-Silvestre *et* al. (2005) test does not account for the presence of cross-section dependence. To overcome the bias in the panel unit root testing due to cross-section dependence, we follow the approach suggested by Maddala and Wu (1999) which recommend applying a bootstrapped method. The application of bootstrap methods to handle cross-section dependence has been applied in a number of studies (Narayan and Smyth, 2008; Basher and Westerlund, 2009; Apergis and Payne, 2010b). Table 3-*3* displays the panel stationarity test results, where breaks are allowed in the level and the first difference of the series. The results show that the series are non-stationary in their levels—both the asymptotic and the bootstrapped p-values reject the null

[29] $\omega_i^2 = \lim_{T \to \infty} T^{-1} E(S^2_{it})$

hypothesis of stationarity at the conventional significance level. In contrast, the stationarity test applied to the differenced variables suggests that the null hypothesis of stationarity cannot be rejected. Since the series are found to be integrated of the same order, the next step is to test for cointegration in order to establish the long-run equilibrium relationship among the variables.

Table 3-3. Panel unit root tests

	$ln(Y)$			$ln(C)$		
Specification	Statistics	Prob[a]	Prob[b]	Statistics	Prob[a]	Prob[b]
Levels						
Constant	8.343***	0.000	0.000	9.231***	0.000	0.000
Constant and trend	7.868***	0.000	0.001	6.387***	0.000	0.001
Break in constant	8.244***	0.000	0.006	1.792*	0.037	0.094
First differences						
Constant	1.825	0.034	0.181	0.362	0.359	0.208
Constant and trend	3.436*	0.000	0.012	1.106	0.134	0.346
Break in constant	0.528	0.299	0.336	-0.653	0.743	0.601

Notes: (a) and (b) denote probability values for a one-sided test based on the normal distribution and bootstrapped distribution, respectively.
We use 5000 replications in the bootstrapping procedure.
We use a maximum of three breaks and the Bartlett kernel with the bandwidth of 4(T/100)2/9.
(***), (**) and (*) denote statistical significance at the 1%, 5% and 10% levels, respectively.

3.3.3. Second generation panel cointegration test

To examine whether the variables are cointegrated, we use the panel cointegration test newly-developed by Westerlund and Edgerton (2008). The novelty of Westerlund and Edgerton (2008) test is that it is flexible enough to allow for heteroskedastic and serially correlated errors, unit-specific time trends, cross-sectional dependence and unknown structural breaks in both the intercept and slope of the cointegrated series. It allows the structural breaks to be located at different dates for different units. Furthermore, the distribution of the test is found to be normal and free of nuisance parameters under the null hypothesis. As such, the Westerlund and Edgerton (2008) test has several advantages over the first generation of panel cointegration tests. The cornerstone of Westerlund and Edgerton (2008) test is based on the Lagrange multiplier (LM) unit root tests approach (Schmidt and Phillips, 1992; Ahn, 1993; Amsler and Lee, 1995). The model can be set up as follows:

$$y_{it} = \alpha_i + \eta_i t + \delta_i D_{it} + x_{it}'\beta_i + (D_{it}x_{it})'\gamma_i + z_{it} \tag{8}$$

$$x_{it} = x_{it-1} + w_{it} \tag{9}$$

$$z_{it} = \lambda_i' F_t + v_{it} \tag{10}$$

$$F_{jt} = \rho_j F_{jt-1} + u_{jt} \tag{11}$$

$$\Delta v_{it} = \phi_i v_{it-1} + \sum_{j=1}^{p} \phi_{ji}\, \Delta v_{it-j} + e_{it} \tag{12}$$

where i=1,2,...,N indexes the cross section dimension, t=1,2,...,T the time series dimension, j=1,2,...,K the common factors dimension, x_{it} is a k-dimensional vector containing the regressors and D_{it} is a scalar break dummy such that $D_{it} = 1$ if $t > T_i$ and zero otherwise. The parameters α_i and β_i represent the intercept and slope, respectively, before the break, while δ_i and γ_i represent, respectively, the change at the time of the shift. The errors e_i , v_{it} and u_{it} are mean zero stationary processes which are identically and independently distributed cross-sectionally. The e_{it} and w_{it} are mutually independent for all i and t. Moreover, it is assumed that $\rho_j < 1$ for all j and $T_i^b = \lambda_i^b T$ where $\lambda_i^b \in [n, n-1]$ and $n \in (0,1)$.

The hypothesis to be tested is $H_0: \phi_i = 0$ for all vs. $H_1: \phi_i < 0$ for at least some i. To derive the test, Westerlund and Edgerton (2008) use the Schmidt and Phillips (1992) score principle[30]. They show that the score vector evaluated at the restricted maximum likelihood estimates is proportional to the numerator of the least squares estimate of ϕ_i in the regression

$$\Delta\hat{S}_{it} = a_{it} + \phi_i \hat{S}_{it-1} + \sum_{j=1}^{p} \phi_{ji} \, \Delta\hat{S}_{it-j} + \xi_{it} \quad (13)$$

where the residuals $\hat{S}_{it} = y_{it} - \hat{\alpha}_i - \hat{\delta}_i D_{it} - \hat{\eta}_i t - x'_{it}\hat{\beta}_i - (D_{it}x_{it})\hat{\gamma}_i - \hat{\lambda}_i \hat{F}_t$ for t=2,3,...,T with $\hat{S}_{i1} = 0$. This implies that the restricted maximum likelihood estimate of α_i is: $\hat{\alpha}_i = y_{i1} - \hat{\eta}_i - \hat{\delta}_i D_{i1} - x'_{i1}\hat{\beta}_i - (D_{i1}x_{i1})\hat{\gamma}_i$ and the remaining parameter estimates can be obtained by an OLS regression of the equation

$$\Delta y_{it} = \hat{\eta}_i + \hat{\delta}_i \Delta D_{it} + \Delta x_{it}\hat{\beta}_i + \Delta(D_{it}x_{it})'\hat{\gamma}_i + \Delta z_{it} \quad (14)$$

and $\hat{\lambda}_i$, $\hat{F}_i$ are principal components estimates of λ_i and F_t. Westerlund and Edgerton (2008) propose the following LM-based statistics to test the null hypothesis

$$LM_\phi = \frac{1}{N}\sum_{i=1}^{N} T\hat{\phi}_i \frac{\hat{\omega}_i}{\hat{\sigma}_i},$$

$$LM_\tau = \frac{1}{N}\sum_{i=1}^{N} \frac{\hat{\phi}_i}{s.e(\hat{\phi}_i)}$$

where $\hat{\phi}_i$ is the least squares estimate of ϕ_i in Eq. (12), $\hat{\sigma}^2{}_i = \frac{1}{T}\sum_{i=1}^{T}(\Delta\hat{S}_{it})^2$ and $\hat{\omega}_i^2 = \frac{1}{T-1}\sum_{j=-M}^{M}(1 - \frac{j}{M+1})\sum_{t=j+1}^{T} \Delta\hat{S}_{it}\,\Delta\hat{S}_{it-j}$ where M is a kernel bandwidth parameter that determines

[30] The derivation of the *LM* test is provided in Appendix of Westerlund and Edgerton (2007).

how many lagged covariances of $\Delta\hat{S}_{it}$ to be estimate in the kernel. To ensure that the results provided in this section are robust, we first test for cointegration by employing the Westerlund and Edgerton (2008) test without allowing for structural breaks and then, we allow for level and regime shift. Table 3-4 provides the results. The findings do not provide any evidence of cointegration if we ignore the possibility of structural break. In contrast, if we allow for level breaks in the panel cointegration test, both statistics support the null hypothesis of cointegration at the conventional significance level. However, if a regime shift is allowed, only one of the statistics favors the null hypothesis of cointegration. Since both statistics reveal consistent results supporting the null hypothesis of cointegration in the case of a level shift, we conclude that the series are cointegrated around a broken intercept. Having found the presence of a long-run cointegrating relationship, the next step is to estimate the long-run equilibrium relationship among the variables.

Table 3-4. Panel cointegration tests

	$LM\tau$		$LM\phi$	
Specification	Statistics	Prob	Statistics	Prob
No break	-0.087	0.465	-1.039	0.149
Level break	-1.627*	0.052	-4.376***	0.000
Regime shift	0.187	0.574	-4.606***	0.000

(***) and (*) denote statistical significance at the 1% and 10% levels, respectively.

3.3.4. Long-run elasticity estimate

Given the presence of of a long-run cointegrating relationship, four estimation techniques are implemented to investigate the long-run effect of clean energy consumption per capita on real GDP per capita. The Ordinary Least Squares (OLS), the Dynamic Ordinary Least Squares (DOLS) estimator proposed by Mark and Sul (2003), the Fully Modified OLS (FMOLS) technique for heterogeneous cointegrated (Pedroni, 2000, 2004) and the Dynamic Seemingly Unrelated Regression (DSUR) estimator for multiple cointegrating regressions proposed by Mark et al. (2005). In the case of balanced panels when the cross sectional dimension N is substantially smaller than the temporal dimension T (as is the case in this analysis), the DSUR technique produces very well behaved estimators with all of the usual desirable properties (Mark et al., 2005). The results from the estimation of Eq. (1) are shown in Table 3-5. Column 2 displays the point estimate and column 3 contains the standard error. The coefficient on clean energy consumption have the expected sign and statistically significant at the 1% significance level. Since the variables are in natural logarithms, coefficient on clean energy consumption can be interpreted as elasticity. All four estimation techniques, OLS, DOLS, FMOLS and DSUR produce relatively similar results in terms of sign, magnitude and statistical significance. The DSUR result indicates that a 10% increase in clean energy consumption per capita increases real GDP per capita by about 0.91%. With respect to DOLS and the FMOLS, both approaches provide a point estimate for clean energy consumption elasticity of 0.093. This result is in line with Banerjee (1999) who showed that the DOLS and the FMOLS are asymptotically equivalent for more than 60 observations. The estimate produce by OLS technique show that the elasticity is 0.119 which is slightly greater than the value obtained by applying the other econometrics techniques. Thus, it appears legitimate to apply the panel-based vector error correction model to investigate the existence and directions of causalities among the variables.

Table 3-5. Panel long-run estimates

Methods	β	Standard Error
OLS	0.119***	0.032
DOLS	0.093**	0.046
FMOLS	0.093***	0.013
DSUR	0.091***	0.020

(***) and (**) denote statistical significance at the 1% and 5% levels, respectively.

3.3.5. Panel causality test

To identify the existence and directions of causalities among the variables, we adopt the two-step procedure of Engle and Granger (1987). In the first step, we estimate the long-run model specified in Eq. (1) to obtain the estimated residuals and then use these residuals lagged one period as the error correction term. A dynamic error correction is estimated

$$\Delta \ln Y_{it} = \pi_{1j} + \sum_{k=1}^{q} \mu_{11ik} \Delta \ln Y_{it-k} + \sum_{k=1}^{q} \mu_{12ik} \Delta \ln C_{it-k} + \psi_{1i} ect_{it-1} + \upsilon_{1it} \quad (14.a)$$

$$\Delta \ln C_{it} = \pi_{2j} + \sum_{k=1}^{q} \mu_{21ik} \Delta \ln C_{it-k} + \sum_{k=1}^{q} \mu_{22ik} \Delta \ln Y_{it-k} + \psi_{2i} ect_{it-1} + \upsilon_{2it} \quad (14.b)$$

where ECT is the fitted value from Eq. (1) denoted by

$$ect_{it} = \ln Y_{it} - \hat{\beta}_{0i} - \hat{\beta}_{1i} \ln C_{it} \quad (15)$$

Δ is the first difference operator, k is the number of lags lengths, set at two as determined by the Schwarz information criteria and υ is the serially uncorrelated error term. Also, to ensure that the result is free of cross section dependence, we adopt a bootstrapped method. In terms of short-run causality, short-run causality flows from $\Delta \ln c$ to $\Delta \ln y$ if the null hypothesis, $\mu_{12ik} = 0\forall_{ik}$ is rejected. Similarly, short-run causality runs from $\Delta \ln y$ to $\Delta \ln c$ if the null hypothesis, $\mu_{22ik} = 0\forall_{ik}$ is rejected. With respect to the long-run causality, we tested the significance of the estimated coefficient on the error correction term. Table 3-6 reports the results of the short- run and long-run Granger-causality tests. The short-run dynamics suggests a unidirectional causality from clean energy consumption to economic growth. With respect to the long-run dynamics, there appears to be also a unidirectional causality from clean energy consumption to economic growth without any feedback effect[31].

Table 3-6. Panel Granger causality

Dependent variable	Independent variables		
	Short-run		Long-run
	$\Delta\ln(Y)$	$\Delta\ln(C)$	ECT
$\Delta\ln(Y)$		33.091*** (0.000)	23.690*** (0.000)
$\Delta\ln(C)$	0.750 (0.686)		1.032 (0.310)

In parentheses are the bootstrapped probability values for Wald tests with a χ^2 distribution. We use 1000 replications in the bootstrapped methods. (***) denotes statistical significance at the 1%.

3.4. Concluding remarks

The study investigates the causal relationship between clean energy consumption and economic growth using panel data for 11 sub-Saharan African countries over the period 1971-2007. We employed the panel unit root and cointegration tests that account for the presence of cross-sectional dependence and multiple structural breaks as well as a bootstrap-corrected Granger causality test. The application of the panel unit root and cointegration tests reveals that there is a long-run relationship between clean energy consumption and economic growth for a panel of sub-Saharan Africa. The elasticity of the clean energy consumption ranges from 0.091 to 0.119, which means a 10% increase in per capita clean energy consumption increases per capita economic growth by

[31] The estimated coefficient on the error correction term is found to be -0.349 (not reported) which suggests that when disequilibrium does occur, it will take about 2.86 years to adjust back to equilibrium.

approximately 0.91% to 1.19%. The results from the panel error correction models indicate the presence of both short-run and long-run unidirectional causality running from clean energy consumption to economic growth.

The existence of a unidirectional causal relationship from clean energy consumption to economic growth has major policy implications for sub-Saharan Africa. The findings offer valuable insights for policymakers in crafting appropriate energy policy that aims to diversify the sources of energy and to find a stable and a safe energy supply for sub-Saharan African countries. Further, the use clean energy use not only stimulates economic growth but also helps in addressing the international commitments to reduce CO2 emissions. As such, the use of clean energy should be taken into consideration and promoted accordingly in the region in order to ensure sustainable economic development.

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Chapter 4: Regional and sectoral convergence of greenhouse gas emissions in Canada[32]

[32] Under review in Journal of Environmental Economics and Policy.

4.1. Introduction

There is a broader consensus in Canada and elsewhere that action is required to address mounting challenges of climate change. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), global anthropogenic greenhouse gas (GHG) emissions grew on average by 0.4 gigatonne carbon dioxide equivalent (GtCO2 eq) per year from 1970 to 2000, whereas during the period of 2000 to 2010, emissions have risen by 1.0 GtCO2 eq on annual basis[33]. The report also states that the unprecedented increase in GHG emissions observed over the last few decades is unequivocally responsible for the discernible adverse impact on the climate and are very likely to have contributed to the increase of global warming. A wide range of recent scientific assessments also highlighted that most of the global warming has been caused by human activities, mainly human-induced GHG emissions. GHG emissions are known to have severe adverse effects on global average temperature, average sea level, more extreme heat waves, floods and droughts as well as environmental refugees, among others (Lashof and Ahuja, 1990; Manne et al, 1995; Dasgupta et al, 2007; Cayan et al, 2008).

As awareness of the stakes involved has increased, so has the will to combat, limit or prevent GHG emissions reinforced. Admittedly, governments around the globe have made significant efforts to effectively mitigate emissions and to address other climate change issues. International climate negotiations among parties, such as the United Nations Framework Convention on Climate Change (UNFCCC) was one of the most tangible proof of efforts towards this direction.

As a signatory to the UNFCCC, Canada has committed to reduce its GHG emissions to 17% below the 2005 level by the year 2020. Although, Canada emissions represent only 1.6% of the global

[33] GHG emissions are considered as the main cause of global warming and climate change.

GHG emissions in 2012, it is one of the highest per capita emitters. Canada's emissions gradually increased since 1990.[34] In 2014, Canada's total GHG emissions were estimated to be 732 of megatonnes of carbon dioxide equivalent (Mt CO2 eq), about 20% higher of what it was in 1990[35]. As a result, in May 2015, the Canadian government has reiterated its intent to take ambitious action to reduce GHG emissions by 30% below 2005 levels by 2030. However, to attain this objective, the Canadian government understands that the need for all provinces and territories in Canada to play their part in stabilizing atmospheric greenhouse gases is crucial in fulfilling its international emissions-reductions commitments. As such, a comprehensive plan to curb emissions across all sectors of Canada's economy was launched in 2016 (*The Pan-Canadian Framework on Clean Growth and Climate Change)*. The goal of the Pan-Canadian Framework is to build in a collaborative approach between provincial, territorial, and federal governments in order to reduce GHG emissions while enabling sustainable economic growth.

Mitigating GHG emissions in Canada requires a good understanding of the status of per capita GHG emissions of each province as well as the behaviour, evolution and relative lags between sectors and across provinces. To our knowledge, no previous empirical study has examined the distribution of GHG emissions among Canadian provinces still less at disaggregated level. We argue that a good understanding of the Canadian carbon footprint is important in helping implement effective environmental policies. As it has been claimed by Apergis et al (2017), any environmental policy design should consider regional differences in order to deliver a mitigation policy that does not adversely affect the underlying economic structure of each region.

[34] 1990 is the base year required by the UNFCCC Reporting Guidelines.
[35] Emissions exclude Land Use, Land Use Change and Forestry estimates.

Thus, the aim of this chapter is to investigate the convergence of per capita GHG emissions across Canadian provinces for the period from 1990 to 2014. We use aggregate and sectoral (residential and transportation) level data and apply the log (*t*) convergence test and clustering algorithm developed by the Phillips and Sul (2007, 2009). Specifically, we would like to test whether there is convergence, or if not, is there convergence clubs among Canadian provinces? Basically, our question is: are Canadian provinces per capita GHG emissions converging to a unique steady state or are they clustering around different steady states? The application of the convergence test indicates that per capita GHG emissions do not converge to a single steady state at aggregate and at sectoral levels. The lack of overall convergence forces us to investigate for the possibility of convergence clubs. By controlling for the structural characteristics of provinces, we observe that Canadian provinces' per capita GHG emissions form distinct groups that converge to different steady states. Moreover, the study reveals that, club members are not necessarily geographically neighboring. Therefore, we do believe that the analysis presented in this chapter provide clearer pictures of the emissions patterns either at aggregated or sectoral levels. These findings might serve as a base for environmental policies debate and could certainly provide valuable insights for policy makers to implement efficient local environmental policies that help achieve national emission reduction targets.

The remainder of the chapter is organised as follows; the next section provides a brief survey of the literature. Section 4.3. presents the methodology proposed by Phillips and Sul (2007, 2009) to test for convergence and convergence clubs. Section 4.4. describes the data. Section 4.5. presents and discusses the results. The last section concludes.

4.2. Literature review

The widening gap in per capita GHG emissions among countries has attracted a lot of attention from both policy makers and academics in the field of environmental economics. As argued by Timilsina (2016), the huge differences in per capita CO2 emissions between countries was one of the contentious issues of the ongoing climate negotiations.

Over the past few decades, numerous studies have borrowed heavily from the income growth literature to explore the convergence of emissions across countries/regions[36]. Common methodological approaches, such as beta, sigma, stochastic and club convergence have been applied in the environmental economics literature to investigate convergence of per capita emissions[37].

In one of the earliest investigations in the field, List (1999) applied *beta*-convergence to take a closer look at convergence of dioxide and nitrogen oxides across states in the U.S. for the period between 1929 to 1994. The finding showed that per capita emissions are converging among U.S states. In the same vein, Romero-Ávila (2008) examined the convergence of CO2 emissions in 23 countries of the Organisation for Economic Co-operation and Development (OECD) over the period 1960–2002. His results supported the convergence of CO2 emissions after applying both stochastic and deterministic convergence tests. Drawing from the economic growth literature on *sigma*-

[36] Convergence entails that per capita emissions across countries become more equal or to some extent start narrowing over time.
[37] Sigma-convergence is measured as standard deviation of the natural logarithm of per capita emissions. If this measure declines over time, then per capita emissions are converging in a sigma-sense (Barro and Sala-i-Martin, 1992). On the other hand, the stochastic-convergence tests whether time series of relative emissions per capita were characterized by a unit root. If per capita emissions are converging in a stochastic sense, then shocks to emissions are temporary and the data are stationary over time.

convergence, Aldy (2006) investigated whether per capita CO2 emissions have been converging among 23 OECD countries over 1960–2000 period. The result showed that per capita emissions are converging in a sigma sense. By considering annual data for over more than a century, spanning from 1870–2004, Barassi et al (2011) studied the convergence of CO2 emissions within the OECD using a stochastic convergence testing approach; they discovered that 13 out of 18 OECD countries are indeed converging. Although most research results have provided support of convergence in per capita emissions among industrialized countries, there is still ongoing debate when it comes to global convergence in per capita emissions. For instance, Van (2005) applied a nonparametric distribution approach to investigate the convergence in per capita emissions among 100 countries during 1966–1996. The results offered strong evidence of convergence among industrial countries, but no evidence of convergence was found for the entire sample. Similarly, Criado and Grether (2011) employed a nonparametric stochastic approach to investigate the convergence of per capita emissions among 166 countries for the period 1960–2002. They found no evidence for convergence. On the other hand, Panopoulou and Pantelidis (2009) used a sample of 128 countries for the period the 1960–2003 to explore convergence of per capita emissions. They employed the convergence club test to look for evidence of convergence. Their results showed that countries tend to converge in the early years of the sample, but two convergence clubs were formed in the later years. Many studies thereafter have followed in the footsteps of Panopoulou and Pantelidis (2009) by applying the Phillips and Sul (2007, 2009) methodology to detect for existence of convergence clubs among countries and regions. For instance, Camarero et al. (2013) applied the Phillips and Sul (2007, 2009) methodology to investigate convergence in CO2 emission intensity (emission over gross domestic product) among OECD countries over the period 1960-2008. They identified distinctive groups of countries that converge to different equilibria in the emission intensity for the majority of OECD countries. Herrerias (2013) also used the convergence clubs technique to assess environmental convergence hypothesis in carbon dioxide emissions for a large group of developed and developing countries from 1980 to 2009. Although some countries displayed divergence, he found convergence clubs for a large group of countries.

More recently, Apergis and Payne (2017) applied the convergence clubs approach to per capita carbon dioxide emissions at the aggregate and sectoral level. They found evidence for presence of multiple equilibria with respect to per capita carbon dioxide emissions at aggregate and sectoral level. Compared with traditional convergence methodologies, the Phillips and Sul (2007, 2009) procedure is viewed as a conditional sigma convergence that controls for the common factors. Furthermore, the method accommodates for convergence clusters without exogenously assuming any convergence pattern in advance; previous applied methods can only examine the panel convergence behaviour. As such, we do believe that the Phillips and Sul (2007, 2009) convergence test is the most appropriate approach to apply for identification of convergence clusters with respect to per capita carbon dioxide emissions in Canada.

4.3. Methodology

4.3.1. The log (t) test

To identify convergence patterns of per capita greenhouse gas emissions across Canadian provinces and territories at the aggregate and sectoral levels, we run the regression based technique introduced by Phillips and Sul (2007, 2009). The novel aspect of this methodology is that, it is a nonlinear model with a growth component and a time varying factor that allows for transitional dynamics and capture heterogeneity across individuals and over time. Furthermore, it permits to classify convergence clusters endogenously. Phillips and Sul's methodology is robust to the stationarity properties of the series. That is, it does not suffer from the small sample properties of traditional unit root and cointegration tests. Their methodology assumes the time-varying common-factor representation for the observable series X_{it}, of province i at time t as follows:

$$X_{it} = \varphi_i \mu_t + \epsilon_{it} \tag{1}$$

here X_{it} is the log value of per capita greenhouse gas emissions; φ_i represents the unit characteristic component; μ_t is a common component which may follow either a non-stationary stochastic trend with drift or a trend-stationary process and ϵ_{it} the error term. In the specification above, the per capita greenhouse gas emissions can be further decomposed into a common trend component μ_t and an individual element δ_{it} such as:

$$X_{it} = \left(\varphi_i + \frac{\epsilon_{it}}{\mu_t}\right)\mu_t = \delta_{it}\mu_t \tag{2}$$

Since it quite impossible to estimate δ_{it} from equation (2) due to over parameterization, Phillips and Sul (2007, 2009) construct the convergence and long run equilibrium of the series based on a relative measure of the loading coefficient as:

$$h_{it} = \frac{X_{it}}{N^{-1}\sum_{i=1}^{N} X_{it}} = \frac{\delta_{it}}{N^{-1}\sum_{i=1}^{N} \delta_{it}} \tag{3}$$

note that the common component μ_t is removed[38]. Hence, h_{it} measures the transition path of province i to the panel average at time t. If the factor loadings δ_{it} converge to δ_i, the relative transition paths governed by h_{it} converges to 1 for all i as $t \to \infty$. Therefore, the cross-sectional variance of h_{it} given by $H_t = N^{-1} \sum_i^N (h_{it} - 1)^2$ converges to zero as $t \to \infty$. To test the null hypothesis of convergence, Phillips and Sul (2007, 2009) propose a semiparametric form for the loading coefficient δ_{it} as follows:

$$\delta_{it} = \delta_i + \sigma_i \xi_{it} L(t)^{-1} t^{-\alpha} \tag{4}$$

where δ_i is fixed, σ_i is an idiosyncratic scale parameter, $\xi_{it} \sim idd(0,1)$, $L(t)$ is a slow varying function of time and α is a decay rate. This representation ensures that δ_{it} converges to δ_i for all values of $\alpha \geq 0$. The null hypothesis of convergence can be written as:

$$H_0: \delta_i = \delta \text{ and } \alpha \geq 0 \text{ vs. } H_A: \delta_i \neq \delta \text{ for all } i \text{ or } \alpha < 0 \tag{5}$$

To test for relative convergence, Phillips and Sul (2007, 2009) suggest estimating the following regression by ordinary least squares.

[38] Note that the common component μ_t is eliminated through rescaling by the panel average.

$$\log\left(\frac{H_1}{H_t}\right) - 2\log L(t) = \hat{a} + \hat{b}\log t + \widehat{u_t} \quad (6)$$

where $L(t) = \log(t+1)$ and $\hat{b} = 2\hat{\alpha}$ where $\widehat{\alpha}$ is the ordinary least squares estimate of α. The null hypothesis of convergence can be tested by applying a conventional one-sided t-test for the slope coefficient $\widehat{b}$ constructed using heteroskedasticity and autocorrelation consistent standard errors. At the 5 % significance level, the null hypothesis of convergence is rejected if $t_{\hat{b}} < -1.65$. Note that the regression starts at some point $t = [rT]$, where $[rT]$ is the integer part of rT. Phillips and Sul (2007, 2009) recommend $r = 1/3$ as a satisfactory choice in terms of both size and power. However, the rejection of full convergence does not imply the absence of convergence in subgroups of the panel. Phillips and Sul (2007, 2009) propose the following algorithm for detecting convergence clubs.

4.3.2. The clustering algorithm

Schnurbus et al. (2017) propose some minor adjustments to the original clustering algorithm of Phillips and Sul (2007, 2009). The Schnurbus et al. (2016) adjusted algorithm is briefly outlined below. Schnurbus et al. (2017) apply the following stepwise procedures to identify initial convergence clubs, to merge clubs and to establish final convergence clubs.

Step 1: Sorting

The first step consists of sorting the Hodrick and Prescott (1997)-smoothed per capita greenhouse gas emissions series according to the last observation.

Step 2: Core group formation

Step 2.1: Start with the highest per capita greenhouse gas emissions, find the first two consecutive provinces for which the log *(t)* regression test statistics $t_{\hat{b}} > -1.65$. If $t_{\hat{b}} < -1.65$ for all sequential pairs of provinces, exit the algorithm and conclude that there are no convergence subgroups in the panel[39].

Step 2.2: Start with the $k = 2$ provinces identified in Step 2.1, increase k proceeding with the subsequent province and perform the log *(t)* regression test. Stop increasing k if the convergence hypothesis fails to hold. The core group consists of the k^* provinces that yield the highest value of the log *(t)* regression test statistic.

Step 3: Extention of the initial core group

Step 3.1: Form a complementary core group of all remaining provinces not included in the core group.

Step 3.2: Add one province at a time from the complementary to core group, (Step 3.1) to form the core group. Run the log *(t)* test, if the resulting test statistic is greater than the critical value, form a club candidate group of all provinces passing this test.

Step 3.3: An initial convergence club is obtained if the convergence hypothesis jointly holds for both the core group and the club candidate group. Otherwise, repeat Step 3.2 until convergence criterion is met.

Step 4: Recursion and stopping rule

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[39] The term log *(t)* stands for a parameter, which is twice the speed of convergence of this club towards the average. The convergence test is distributed as a simple one-sided *t*-test with a critical value of -1.65.

Form a subgroup of the remaining provinces that are not sieved by Step 3. Perform the log *(t)* test for this subgroup. If the test statistic is greater than -1.65, the subgroup forms the next convergence club. Otherwise, repeat Steps 2-3 on this subgroup.

Step 5: Club merging

Perform the log *(t)* regression for all pairs of subsequent clubs and across formed clubs. Merge those clubs fulfilling the convergence hypothesis jointly. Continue the procedure until no clubs can be merged.

4.4. Data source

The data used in the study are from two sources. The first source is Environment and Climate Change Canada (formerly known as the Environment Canada). This data set includes information on greenhouse gas emissions, which comprise of carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF6), and nitrogen trifluoride (NF3)). The greenhouse gas emissions are expressed as Mt CO2eq. The second source of data is Statistics Canada from which, we collect data on population count. We gather aggregate and sectoral levels data of all 10 Canadian provinces and territories observed between the periods 1990-2014[40]. The sample contains the following provinces and territories: Newfoundland and Labrador (NL), Prince Edward Island (PE), Nova Scotia (NS), New Brunswick (NB), Quebec (QC), Ontario (ON), Manitoba (MB), Saskatchewan (SK), Alberta (AB), British

[40] Note that for the years preceding 1999, data for Nunavut and Northwest Territories are combined in a single region. After the creation of Nunavut in 1999, Nunavut data are presented separately, but we decided to combine the data for Nunavut and Northwest Territories to make a single series.

Columbia (BC), Yukon (YK), Northwest Territories and Nunavut (NN). The sectors considered in this study are residential and transportation sectors.

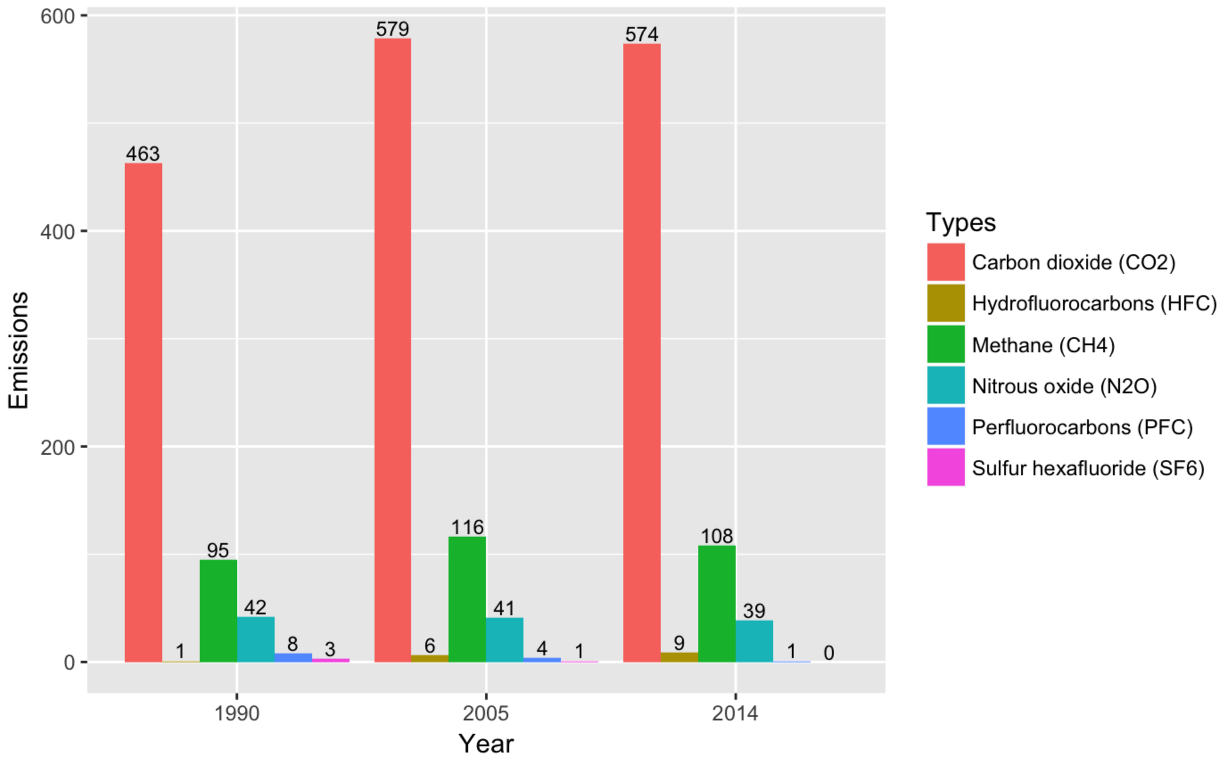

Figure 4-1. Emissions by type of gas (Mt C02eq)

Figure 4-1 shows trends of Canadian's emissions by type of gas. As shown in Figure 4-1 below, more than 75% of Canada's emission is derived from carbon dioxide emission. Methane accounted for about 15% of total emissions. Looking at the emission trend, we observe in 2014, Canada's emission was down 2% from the 2005 level. This decline was mainly the result of a drop from carbon dioxide, methane and nitrous oxide emissions. Table 4-1 provides summary statistics of greenhouse gas emissions at aggregate and sectoral levels. As can be seen, Canada's greenhouse gas emissions totalled 732 Mt CO2eq in 2014. Quebec and Yukon were the only provinces to report declines in average greenhouse gas emissions during the first decade following the 1990s.

Conversely, during the 2003-2014 period, all provinces and territories, except the Prairie Provinces registered decreases in the greenhouse gas emissions. It is worth noting that greenhouse gas emissions in most provinces were increasing during the 1990 to 2002 period, whereas, during the 2003-2014 period a large proportion of Canadian provinces and territories are showing decline in their emissions. Is this trend suggesting emissions are converging across Canadian provinces? The next section provides the results of this investigation.

Table 4-1. Trends in greenhouse gas emissions in Canada

	Canada					Residential					Transportation				
	GHG emissions (Mt of C02eq)			Average annual growth rate		GHG emissions (Mt of C02eq)			Average annual growth rate		GHG emissions (Mt of C02eq)			Average annual growth rate	
	1990	2002	2014	1990-2002	2003-2014	1990	2002	2014	1990-2002	2003-2014	1990	2002	2014	1990-2002	2003-2014
Newfound and Labrador	9.58	11.79	10.56	2.27	-0.76	0.82	0.67	0.44	-1.47	-2.05	3.05	3.32	3.78	0.76	1.37
Prince Edward Island	1.96	2.05	1.80	0.42	-0.96	0.39	0.32	0.29	-1.40	-0.09	0.69	0.80	0.78	1.28	-0.13
Nova Scotia	19.97	20.72	16.58	0.36	-1.62	2.22	1.99	1.46	-0.67	-1.80	4.88	5.46	4.48	1.00	-1.40
New Brunswick	16.40	21.60	14.90	2.53	-2.93	1.15	0.77	0.59	-3.02	-1.15	4.07	5.27	3.98	2.19	-1.80
Quebec	89.14	88.59	82.68	-0.03	-0.53	8.20	6.93	4.40	-1.26	-3.50	27.96	31.78	33.74	1.11	0.53
Ontario	181.76	207.06	170.16	1.14	-1.53	18.12	19.56	21.78	0.94	1.18	48.29	60.20	60.23	1.88	0.05
Manitoba	18.68	20.38	21.48	0.77	0.49	1.68	1.32	1.25	-1.78	-0.11	7.19	7.01	8.43	-0.15	1.72
Saskatchewan	45.08	67.26	75.52	3.47	0.98	2.13	2.01	1.87	-0.27	-0.39	9.32	10.53	16.38	1.13	3.87
Alberta	175.23	229.58	273.75	2.29	1.52	6.85	8.24	9.15	1.90	1.07	22.61	31.49	45.30	2.92	3.20
British Columbia	52.88	64.59	62.94	1.73	-0.19	4.57	4.51	4.20	0.07	-0.23	18.80	23.88	24.75	2.03	0.40
Yukon	0.54	0.50	0.27	-0.07	-4.61	0.03	0.03	0.01	4.62	-2.98	0.31	0.27	0.18	-0.94	-2.69
Northwest Territories and Nunavut	1.64	2.17	1.80	3.32	-0.60	0.15	0.12	0.11	2.65	0.25	0.62	1.04	0.97	6.13	1.63
Canada	612.87	736.27	732.43	1.55	-0.02	46.31	46.47	45.56	0.20	-0.02	147.79	181.05	203.00	1.73	0.98

4.5. Empirical results

Table 4-2 reports the convergence results for aggregate per capita greenhouse gas emissions across the Canadian provinces and territories. The top half of Table 4-2 displays the results for the full sample convergence and the club clustering, while the bottom half presents the result for clubs merging. As can be seen from the first column of Table 4-2, the estimated value for *beta* for the full convergence is −1.114 and the corresponding *t*-statistic: −77.541. Based on results from the *t*-statistic, the null hypothesis of full convergence can be rejected at the 5% level since the *t*-statistic value is below −1.65. The absence of full convergence does not exclude the presence of convergence clubs. Thus, we implement the club-clustering algorithm to identify provinces that satisfy the convergence clubs criterion. The club clustering algorithm classifies four distinctive convergence clubs, with Saskatchewan and Alberta in the first club; Newfoundland and Labrador, Nova Scotia, New Brunswick and Northwest Territories and Nunavut in the second club; Prince Edward Island, Ontario and British Columbia in the third club and Quebec and Yukon in the fourth. Furthermore, we perform tests to assess whether any of formed clubs can be merged to constitute a larger convergence club. The bottom half of Table 4-2 reports the testing results. The findings provide no evidence that any subsequent clubs can be merged together to form a larger convergence club.

Table 4-2. Club convergence of per capita greenhouse gas emissions, total.

Tests of club convergence				
Full sample	1st Club	2nd Club	3rd Club	4th Club
Newfoundland and Labrador, Prince Edward Island, Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, Yukon, Northwest Territories and Nunavut (***beta*** = −1.114, ***t-statistic*** = −77.541)	Saskatchewan, Alberta (***beta*** = 4.445, ***t-statistic*** = 3.424)	Newfoundland and Labrador, Nova Scotia, New Brunswick, Northwest Territories and Nunavut (***beta*** = 1.465, ***t-statistic*** = 8.157)	Prince Edward Island, Ontario, British Columbia (***beta*** = 1.965, ***t-statistic*** = 4.750)	Quebec, Yukon (***beta*** = 3.401, ***t-statistic*** = 3.238)
Tests of club merging				
	1st Club	2nd Club	3rd Club	4th Club
1st Club		−0.815 (−34.872)	−0.968 (−81.188)	−1.133 (−71.113)
2nd Club			−0.908 (−39.112)	−1.339 (−152.174)
3rd Club				−1.330 (−10.914)
4th Club				

Notes: The clubs reported above have been obtained by applying the algorithm proposed by Phillips and Sul (2007, 2009). The test makes use of the critical value $t_{0.05}$; rT−2−1=228=−1.65156 across all cases. The null hypothesis of convergence is rejected if $t_{\hat{b}} < -1.65$.

Figure 4-2 plots the relative transition paths of per capita greenhouse gas emissions. The relative transition curves are meant to visually assess whether individual provinces converge relative to the cross-sectional average over time. Full convergence occurs if the paths of all provinces asymptotically approach one. Any point above one indicates that the province's per capita greenhouse gas emissions is above the cross-sectional average and vice versa.

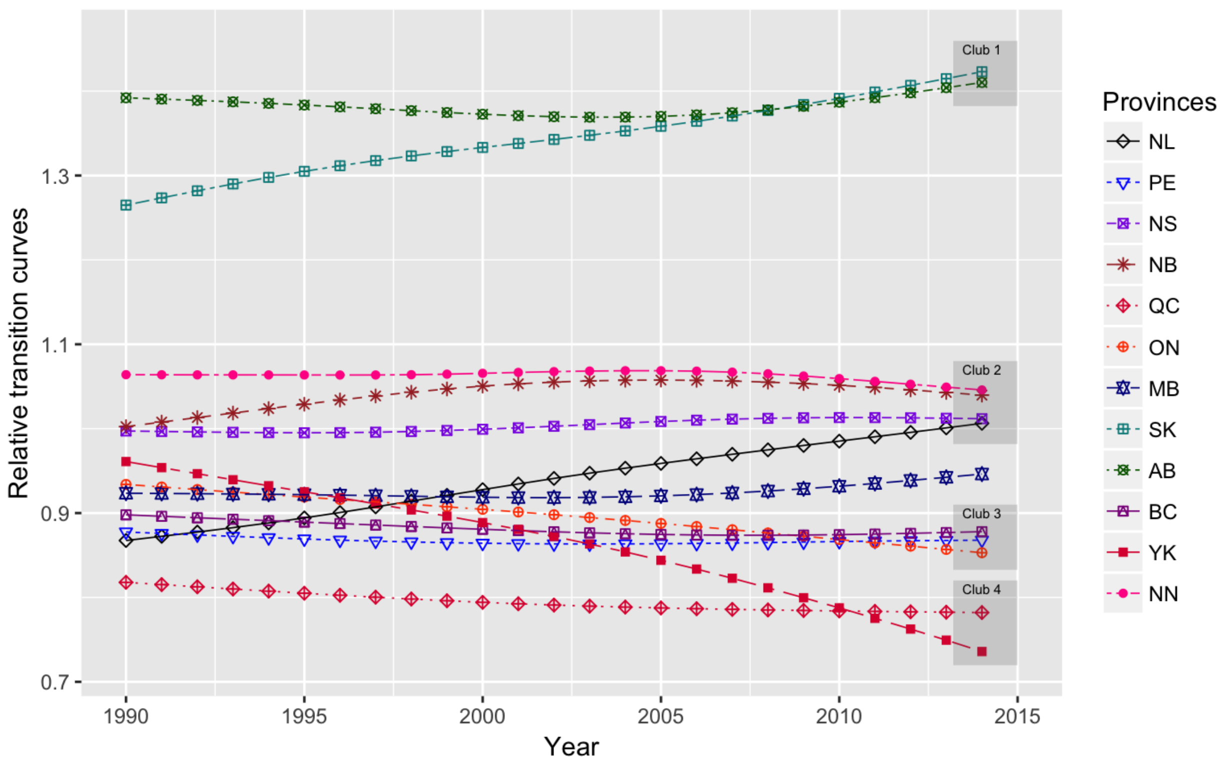

Figure 4-2. Economy-wide relative transition paths of per capita greenhouse gas emissions

As shown in Figure 4-2, the curves eloquently capture the growth course for each province relative to the sample average. Saskatchewan and Alberta converge to a steady state that is above the cross-sectional average. One possible explanation that can be put forward for the high levels of per capita emissions in these two provinces would be their reliance on coal-fired electricity generation as well as oil sands and heavy oil production. Quebec and Yukon have their steady state way below the national average. The member of the provinces in the second club reach their steady state about the panel average. Prince Edward Island, Ontario and British Columbia, which belong to the third convergent club, have their steady state ending to a point below the sample average.

Table 4-3. Club convergence of per capita greenhouse gas emissions, residential.

Tests of club convergence			
Full sample	1st Club	2nd Club	Divergent Club
Newfoundland and Labrador, Prince Edward Island, Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, Yukon, Northwest Territories and Nunavut (***beta*** = −3.465, ***t-statistic*** = −16.924)	Prince Edward Island and Alberta (***beta*** = −0.281, ***t-statistic*** = −0.091)	Newfoundland and Labrador, Quebec, Manitoba (***beta*** = 0.148, ***t-statistic*** = 0.113)	Nova Scotia, New Brunswick, Ontario, Saskatchewan, British Columbia, Yukon, Northwest Territories and Nunavut (***beta*** = −3.324, ***t-statistic*** = -11.187)
Tests of club merging			
	1st Club	2nd Club	
1st Club		−3.506 (−23.147)	
2nd Club			

Notes: The clubs reported above have been obtained by applying the algorithm proposed by Phillips and Sul (2007, 2009). The test makes use of the critical value $t_{0.05}$; rT−2−1=228=−1.65156 across all cases. The null hypothesis of convergence is rejected if $t_{\hat{b}} < -1.65$.

Table 4-3 reports the results for the residential sector's per capita greenhouse gas emissions across the Canadian provinces and territories. Clearly, the null hypothesis of full convergence is rejected at the 5% level. The divergence of per capita greenhouse gas emissions for the whole sample does not, however, rule out the possibility of convergence clubs. The convergence clubs tests results indicate the presence of two convergent clubs and one divergent set of provinces. The first club consists of Prince Edward Island and Alberta. The second club includes Newfoundland and Labrador, Quebec and Manitoba. The divergent set of province is made up of Nova Scotia, New Brunswick, Ontario, Saskatchewan, British Columbia, Yukon, Northwest Territories and Nunavut.

When tested for clubs mergers, the *t*-statistic value for club merging, −23.147, is significantly smaller than −1.65, strongly rejecting the null hypothesis of clubs merging.

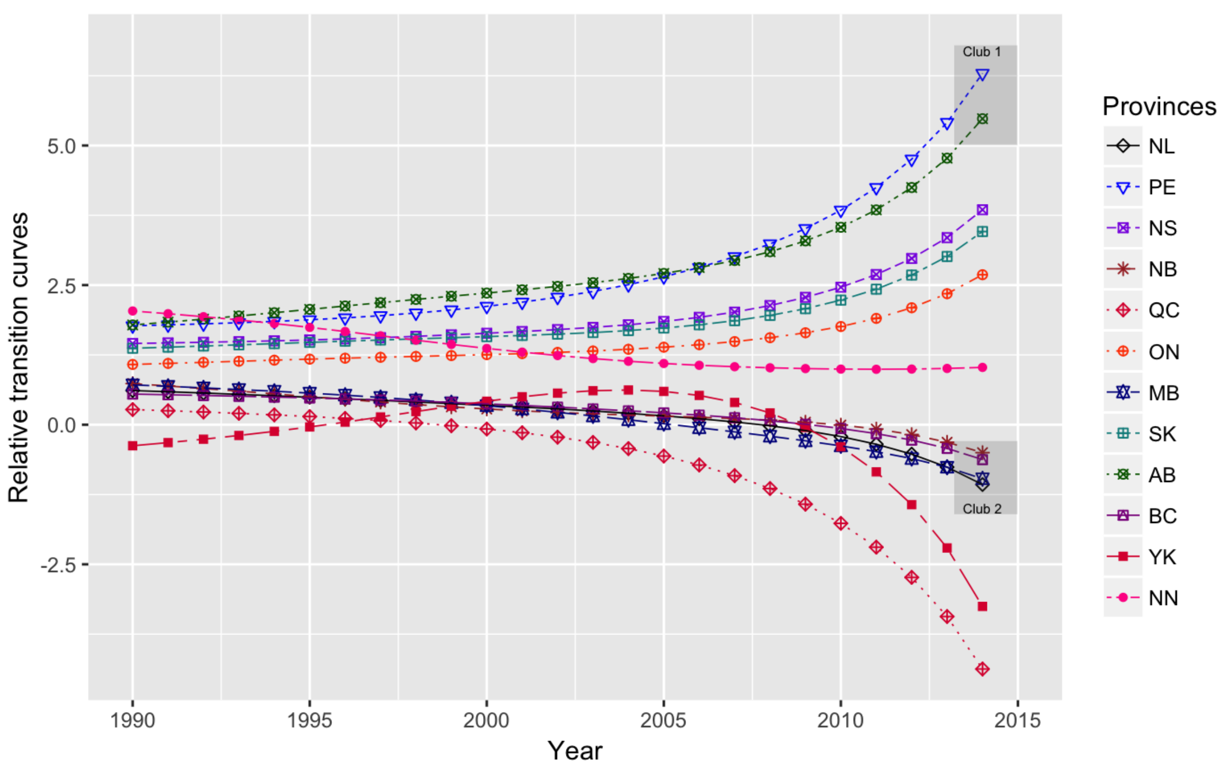

Figure 4-3. Residential relative transition paths of per capita greenhouse gas emissions

Figure 4-3 displays the paths of the relative convergence across Canadian residential sector emissions. The emissions trajectories for the member of first club (Prince Edward Island and Alberta) appear to be increasing with respect to the sample average. The increasing level of greenhouse gas emissions for residential sector in Alberta can be explained by the size of homes in Alberta. In Alberta, homes built between 2000 and 2010 are approximately 37 per cent larger than those built from 1960 to 1980. Larger homes require more energy for heating, thus more emissions to be released. However, for the case of Prince Edward, Island, it can be explained by Island homes burn fossil fuels like light fuel oil, heavy fuel oil, diesel, and propane to produce heat or electricity. These fuels are known to generate more greenhouse gas emissions. Several additional observations are worth mentioning. In most provinces, greenhouse gas emissions remain steadily constant up to 2004 and then start to increase or decline in certain cases.

Table 4-4. Club convergence of per capita greenhouse gas emissions, transportation.

Tests of club convergence					
Full sample	1st Club	2nd Club	3rd Club	4th Club	Divergent Club
Newfoundland and Labrador, Prince Edward Island, Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, Yukon, Northwest Territories and Nunavut (***beta*** = −1.173, ***t-statistic***= −101.910)	Saskatchewan, Northwest Territories and Nunavut (***beta*** = 0.083, ***t-statistic*** = 2.869)	Newfoundland and Labrador, Alberta (***beta*** =1.465, ***t-statistic*** = 8.157)	New Brunswick, Manitoba, Yukon (***beta*** = 0.759, ***t-statistic*** = 1.907)	Quebec, Ontario, British Columbia (***beta*** = 0.267, ***t-statistic*** = 4.461)	Prince Edward Island, Nova Scotia (***beta*** = −7.662, ***t-statistic*** = −3.526)
Tests of club merging					
	1st Club	2nd Club	3rd Club	4th Club	
1st Club		-0.302 (-5.377)	-1.358 (-133.745)	-1.179 (-127.063)	
2nd Club			-1.246 (-12.334)	-0.962 (-21.981)	
3rd Club				0.147 (4.212)	
4th Club					

Notes: The clubs reported above have been obtained by applying the algorithm proposed by Phillips and Sul (2007, 2009). The test makes use of the critical value $t_{0.05}$; rT−2−1=228=−1.65156 across all cases. The null hypothesis of convergence is rejected if $t_{\hat{b}} < -1.65$.

Table 4-4 shows the results of the log (*t*) convergence test and clustering procedure for the transportation sector. The first column reports the result for testing the hypothesis that all provinces converge to a single steady state while that of the remaining columns report the results obtained when we apply the clustering algorithm. First, the null hypothesis of overall greenhouse gas emissions convergence is rejected at the 5% level. With respect to convergence clubs, the algorithm classifies provinces into four convergence clubs and only one set of diverging club is found. The first club comprises of Saskatchewan, Northwest Territories and Nunavut, the second club contains Newfoundland and Labrador and Alberta, the third club is formed by New Brunswick, Manitoba and Yukon and the last club identified consist of Quebec, Ontario and British Columbia. The divergence group contains Prince Edward Island and Nova Scotia. Then, we conducted a test to determine whether any of the original clubs can be merged to form larger convergence clubs. The test result suggests that the third and fourth convergence clubs can be merged to form a larger convergence club as the *t*-statistic is 4.212 which is significantly greater than the 5% level of −1.65. Therefore, the third and fourth clubs are the only club that pass the merging test to form separate convergence club.

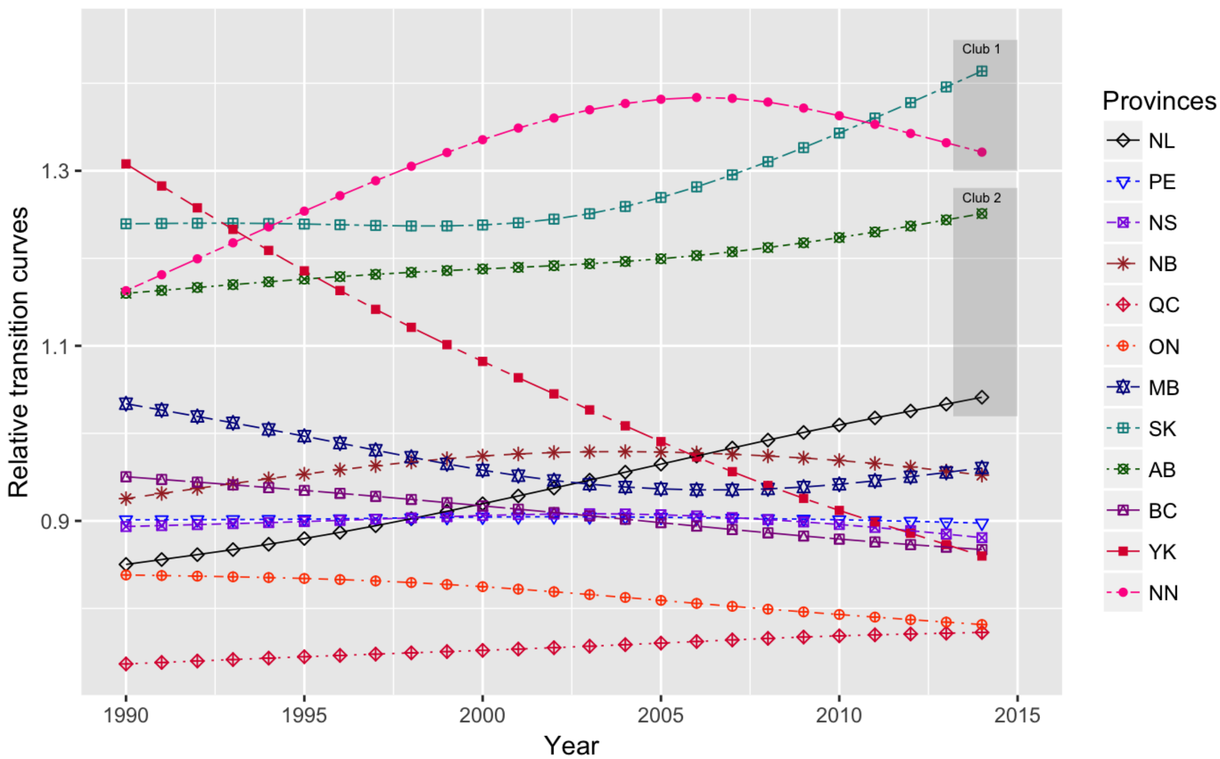

Figure 4-4. Transportation relative transition paths of per capita greenhouse gas emissions

We also present a graph showing the relative emissions convergence of the transportation sector. As can be seen below, the relevant relative transition curves, displayed in Figure 4, corroborates the converging behaviour of the identified convergence clubs. The member of the club belonging to the first club, Saskatchewan, Northwest Territories and Nunavut are trended upward and have their steady state converging toward a point well above the national average. The second club has its steady state converging to a point exceeding the cross-sectional average. The merged club (3rd three and 4th club) exhibits constant trends in its relative per capita greenhouse gas emissions.

The relative transition curves show us graphically the formation of the convergence clusters. Nevertheless, to have a sense not only at the formation of the convergence clusters, but also at the spatial agglomeration of each clubs, we show the geographical connection between the members of the convergence clubs.

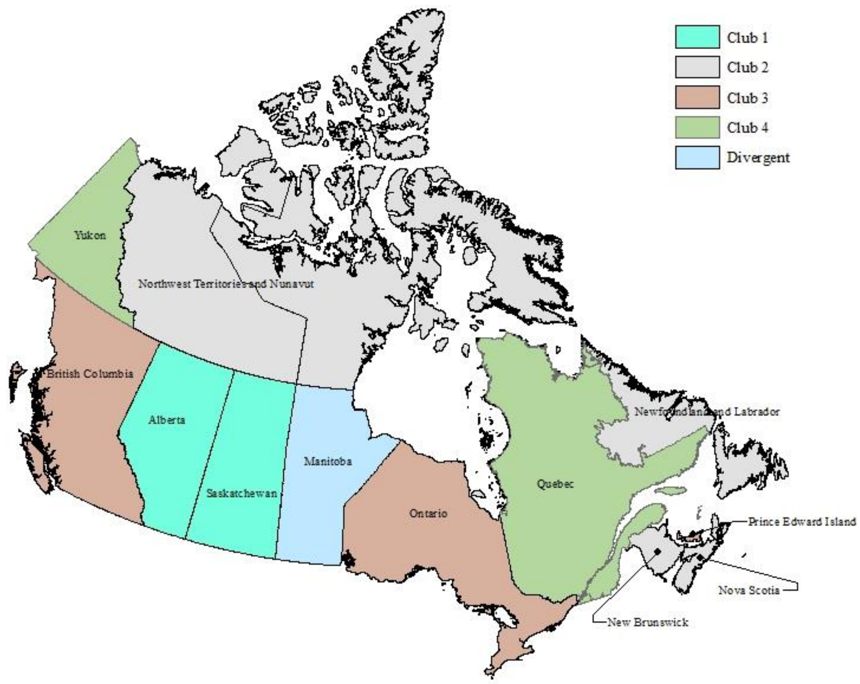

Figure 4-5. (Map: Aggregate (a)).

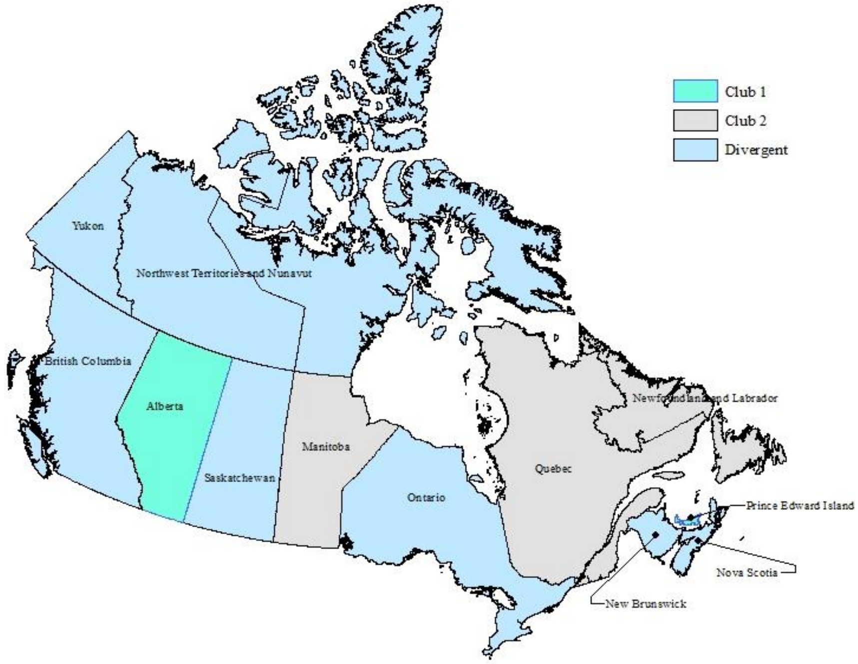

Figure 4-6. (Map: Residential (b)).

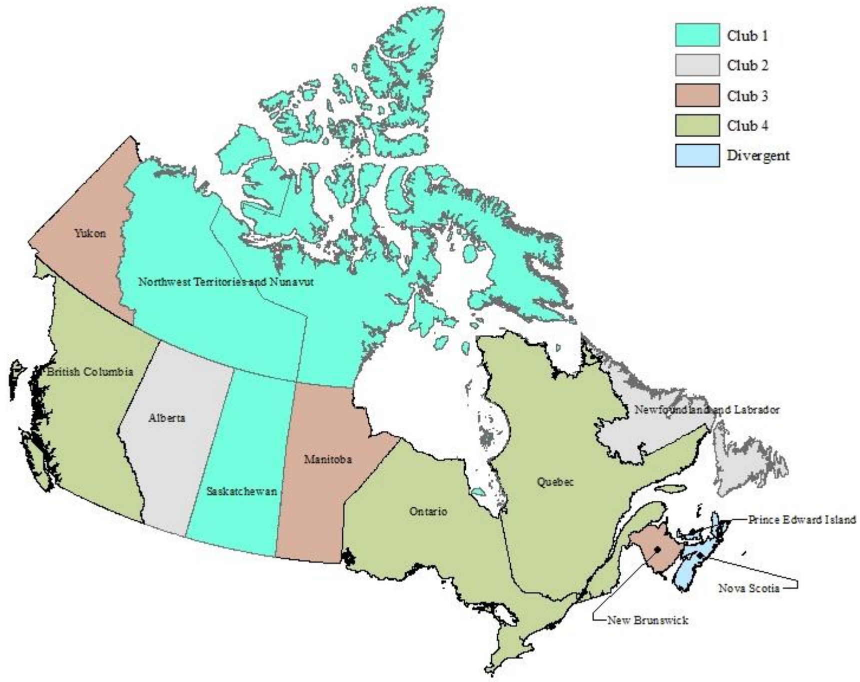

Figure 4-7. (Map: Transportation (c)).

Figure 4-5 through Figure 4-7 displays the geographical distribution of the clubs for aggregate, residential and transportation. It is worth to note that the figures are plotted based on the convergence-clustering algorithm testing results. Firstly, convergence club for aggregate seem to be spatially concentrated at least for the first two clubs. For instance, Alberta and Saskatchewan do not only share oil sands and heavy oil production but also share geographical connection. The provinces in the second club are also connected on geographic lines. A closer look over the geographical distribution of the clubs in the residential sector show also a geographical link for the set of divergent four provinces in western regions. With respect to the spatial connection of the transportation sector, it can be observed that the provinces in the first and the fourth clubs are also geographically connected.

4.6. Conclusions

In this chapter, we examined the environmental convergence hypothesis among Canadian provinces and territories. To serve this objective, we apply the testing approach of Phillips and Sul (2007, 2009). This methodology uses a non-linear factor model with a common and an idiosyncratic component allowing for technical progress heterogeneity across provinces. More specifically, we investigate whether per capita GHG emissions converge at aggregate and sectoral level for the period 1990 to 2014.

First, the testing results reject the null hypothesis of full convergence at aggregate as well as sectoral levels. To investigate the existence of segmentation in per capita GHG emissions across Canadian provinces and territories. We apply the clustering procedure to the aggregated and sectoral level data, the application of the convergence clubs testing identifies groups of provinces and territories that converge to different equilibria in aggregated per capita GHG emissions. The first club comprises of Saskatchewan and Alberta; these two provinces are the country's largest emitters. Indeed, in 2013, 91% of oil produced in Canada is from Alberta and Saskatchewan, which explain in part the above national average emissions for these two provinces. The province of Newfoundland and Labrador, Nova Scotia, New Brunswick and Northwest Territories and Nunavut form the second group. The third group comprises of Prince Edward Island, Ontario and British Columbia and finally, Quebec and Yukon come in the fourth club.

In terms of per capita GHG emissions convergence for residential sector, the club convergence algorithm identifies the presence of two convergent clubs and one divergent set of provinces. With respect to the convergence of per capita GHG emissions for transportation sector, the clustering algorithm classifies provinces in four convergence clubs and one set of diverging province.

Therefore, we argue that the presence of multiple convergent clubs suggests that to achieve the emissions reduction targets, the federal and provincial governments should design specific environmental policy that equitably share the burden of GHG emissions among provinces that enable sustainable development, while reaching the national emission reduction goals.

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General conclusion

Main results

The rapid increase in global greenhouse emissions in recent times have ignited the debate about the consequences of emissions on the economy and the society. Now, there is a general agreement by scholars and policy makers that sustainable development cannot be achieved without a clear understanding of the interaction between environment, economic, political and socio-cultural characteristics of countries. As such, many countries throughout the world have started to integrate socio-economic, political and environmental considerations into their development agenda.

This thesis tries to empirically investigate the role played by socioeconomic, socio-demographic characteristics and contextual factors on individuals' tendency to contribute toward environmental quality improvements. And then move on by exploring the link between environmental degradation and economic growth as well as the factors that helped in reducing environmental degradation in developed and developing countries.

The first chapter seeks to examine the societal bases of public concern related to environmental quality by exploring the factors behind individuals' engagement in environmental protection. It applies a multilevel modeling approach on individual and contextual data. The results from this analysis show that both individual and contextual level factors played a major role in explaining individuals' involvement in environment protection. More specifically, the study reveals that, individual level covariates accounts for about 80.5% of total variability in explaining environmental awareness across nations. The remaining 19.5% is attributable to country level characteristics.

At the individual level, results show that determinants, such as education, relative income, post-materialistic values, religious beliefs and adhesion to environmental organization are associated with high levels of willingness to pay to protect the environment. Country level covariates show that population density as well as the quality of institutions contributed to individuals' willingness to pay for a better environmental quality. In sum, the findings from this study reveals that the disparities observed in the willingness to pay to protect the environment between countries can arise from both individual and contextual level factors. As it is evidenced by the impact of individuals and country level covariates on individuals' willingness to pay for environmental protection. The findings arising from this chapter may have major implications for economic and policy practice. It can be argued that organized and educated individuals can change the way government implements environmental policies.

The second chapter tries to contribute to the existing literature by empirically assessing the impact of economic growth, energy consumption, trade openness, industrialization, urbanization and quality of institutions on CO2 emissions. The overarching objectives of this chapter is to investigate whether or not the inverted U-shaped relationship between economic growth and environmental degradation is supported by the data, and then, it attempts to assess the role played by energy consumption, trade openness, industrialization, urbanization and quality of institutions in that relation. To serve these objectives, we apply the panel smooth transition regression (PSTR) model of González et al. (2005) to test the EKC hypothesis. The investigation provides no evidence of the inverted U-shaped relationship between economic growth and environmental degradation in both developing and developed countries. Instead, a non-linear relationship is found between CO2 emissions and economic growth. In other words, the result shows that CO2 emissions tend to rise rapidly in the early stage of economic growth, then continue to increase but at a lower rate in the later stage. With respect to the effects of the other covariates on CO2 emissions, we found relatively similar impacts than results reported by numerous previous studies. More formally, we observed that energy consumption, industrialization and trade openness present statistically significantly impact on CO2 emissions in both developing and developed countries. However, the result did not provide any evidence with regard to the impact of urbanization on CO2 emissions. With regard to the effect of democratic accountability of the government and government stability, it appears that both democratic accountability and government stability lead to CO2 emissions reduction rates mainly in developed countries.

In chapter 3, we explore whether or not clean energy technologies bolster economic growth. It is argued that renewable energy plays an important role in energy security, in improving health and quality of life by maintaining or enhancing the quality of the environment. But the question that remains to be understood is whether the adoption of clean energy technologies cause growth. To investigate this issue, we make use of data from 11 sub-Saharan African countries over the period 1971-2007 and apply a second generation of panel unit root and cointegration testing procedure that account for the presence of cross-sectional dependence and multiple structural breaks. The empirical evidence shows that there is a short and long-run relationship between clean energy consumption and economic growth. The finding indicates that a 10% increase in per capita clean energy consumption increases per capita economic growth by approximately 0.91% to 1.19%. Furthermore, the result of panel error correction model points towards the presence of unidirectional causality running from clean energy consumption to economic growth in both short and long run. These findings offer valuable insights for policymakers in crafting appropriate energy policy that aims to diversify the sources of energy and to find a stable and a safe energy supply for sub-Saharan African countries that will help create jobs and eradicate poverty.

Chapter 4 tests for convergence in emissions of greenhouse gases among Canadian provinces by using aggregate and sectoral level data for the period 1990 to 2014. In so doing, we employ the

Phillips and Sul (2007) notion of convergence, which allows technical progress to vary across provinces. We wonder whether Canadian's per capita greenhouse gases emissions converge to a single steady state or do cluster around multiple steady states. First, we test whether the per-capita greenhouse gases emissions in Canadian provinces share a common trend, and if so, have these provinces experienced convergence in the greenhouse gases emissions. The testing results reject the null hypothesis of full convergence across Canadian provinces at aggregate and sectoral levels. Then, we implemented the clustering algorithm to the aggregated and sectoral level data. The convergence clubs testing identifies groups of provinces that converge to different equilibria in per capita greenhouse gases emissions. We observe that per capita emissions of Canada's largest emitters (Saskatchewan and Alberta) form a single club. This can be explained by the fact that these two provinces are Canada most energy intensive provinces. About, 91% of oil produced in Canada is from these two provinces. The study also identifies the presence of multiples convergence clubs at the sectoral level.

Policy implications and future research

As environmental quality is the responsibility of all those whose actions have affected the environment. Public, government and non-governmental organizations are more than ever believe that collaborative efforts are needed to mitigate the effects of human activities on global environmental degradation. From a management perspective, the challenge is how to implement policies that protect environmental quality without dampening the economic development. Analysis conducted in this thesis focuses on the determinants of individuals' attitudes towards preventing environmental damage as well as the determinants of environmental degradation and concludes on how a better understanding of the sources behind environmental pollution can help define economic and environmental policies that may help achieve sustainable development.

Concerning the investigation of the role played by socioeconomic, socio-demographic characteristics and contextual factors, the analysis concludes that both individuals and contextual level covariates are correlated with individuals' willingness to contribute toward environmental quality improvements. For instance, the study reveals that educated individuals are more concerned about the environment than not educated ones. This finding suggests that environmental protection agency and governments should adequately sensitize the public on the need for attitudinal change towards environmental protection through education. Besides, the fact that richer people are more likely to pay for the restoration of the environment recommends that if a program to collect funds can be designed and implemented, it could help to alleviate the financial burden of the government while addressing environmental issues. On the other hand, the result also suggests that an improvement of the democratization process of a country shapes pro-environmental behaviour and attitudes. Although it is argued that some contextual factors may influence environmental protection, it is not yet clear how they influence individuals' environmental awareness. More research work is needed to determine if contextual features are more or less conducive to individuals' willingness to pay to protect the environment protection.

One of the observations arising out of this research is that the presumption that economic growth is not a threat to the environment is not supported by the data. A consequential implication of this conclusion is that efforts by governments and international bodies to improve environmental quality should therefore be seen as a priority. They should be resolute in the implementation and enforcement of environmental laws and regulations in a manner that guarantees sustained economic growth. As economic development and environmental regulation differ among countries, one may argue that the inverted U-shaped relation found in previous studies might be attributable to polynomial curve fitting rather than to underlying structural relationships. It is well known that countries' environmental data collection begins early 1970's which render cross country examination more challenging since many developed countries had already initiated downward trends for most pollutants. As such, in future research, it may be fruitful to focus on a country study by employing disaggregate level data. Since it may shed additional insight on the impact of economic growth on the environment degradation, and thereby provide new information to help policy makers to design appropriate economic and environmental policies.

With respect to the relationship between clean energy consumption and economic growth, the analysis demonstrates that there is a unidirectional Granger causality flowing from clean energy consumption to economic growth. Given the causal effect that clean energy consumption exert on economic growth, African countries should adopt clean technologies to foster economic growth. While there is a high initial costs of adopting clean technologies, it use will significantly increase access to electricity for a high proportion of the population, increase their productivity and competitiveness which lead to job creation, lower poverty rates and long term food security. Even though the study establishes empirical evidence for the effect of clean energy consumption on economic growth, it is not without limitations. Some important variables may have been left out from the models. Variables, such as trade openness and capital formation. Additionally, this study was conducted with a sample of 11 sub-Saharan African countries. It is therefore suggested that further research can be conducted with larger samples size and control for some relevant covariates, so as to improve the generalization of the result and eliminate possible sampling bias.

The presence of multiple convergent clubs found among Canadian provinces suggests that to better align emissions reduction across provinces, the federal and provincial governments should design specific environmental policy that equitably share the burden of greenhouse gases emissions among provinces that enable sustainable development, while reaching the national emission reduction goals.

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Abstract

This thesis comprises four empirical essays on environmental and development economics. In the first chapter, we examine to what extent individual and contextual level factors influence individuals to contribute financially to prevent environmental pollution. We find that rich people, individuals with higher education, as well as those who possess post-materialist values are more likely to be concerned about environmental pollution. We also observe the country in which individuals live matter in their willingness to contribute. More precisely, we find democracy and government stability reduce individuals' intention to donate to prevent environmental damage mainly in developed countries. The second chapter deals with the relation between economic growth and environmental degradation by focusing on the issue of whether the inverted U-shaped relation exist. The study discloses no evidence for the U-shaped relation. However, the empirical result points toward a non-linear relationship between environmental degradation and economic growth, that is, emissions tend to rise rapidly in the early stages with economic growth, and then emissions continue to increase but a lower rate in the later stages. The third chapter investigates the long-run as well as the causal relationship between energy consumption and economic growth in a group of Sub-Saharan Africa. The result discovers the existence of a long-run equilibrium relationship between clean energy consumption and economic growth. Furthermore, the short-run and the long-run dynamics indicate unidirectional Granger causality running from clean energy consumption to economic growth without any feedback effects. The last chapter of this thesis concerns with convergence of emissions across Canadian provinces. The study determines convergence clubs better characterizes Canadian's emissions. In other words, we detect the existence of segmentation in emissions across Canadian provinces.

Keywords: World Value Survey; Multilevel modelling; WTP; Environmental Kuznets Curve; CO2 emissions; Economic development; Clean energy; Cross-sectional Dependence; Structural breaks; Club convergence; clustering; Canadian provinces

Résumé

Cette thèse comporte quatre essais et porte sur les questions fondamentales sur la relation entre l'environnement et le développement économique. Le premier chapitre cherche à identifier les déterminants individuels et contextuels qui affectent la volonté de contribuer des gens à la lutte contre la pollution environnementale. Nos résultats révèlent que les individus riches, les personnes éduquées ainsi que les personnes possédant des valeurs post-matérialistes sont plus susceptibles d'être préoccupées par la pollution environnementale. On remarque que la caractéristique du pays de ces individus affecte leur volonté à contribuer. Ainsi, dans les pays à forte démocratie avec une forte stabilité gouvernementale, les individus sont réticents à faire des dons pour prévenir les dommages environnementaux. Le deuxième chapitre examine la relation entre la croissance économique et la dégradation de l'environnement en s'interrogeant sur la relation U inversée de Kuznets. Nos résultats empiriques ne révèlent aucune preuve de ladite relation. Cependant, nous notons l'existence d'une relation non linéaire entre la croissance économique et la dégradation de l'environnement. Les émissions ont tendance à augmenter à un rythme plus rapide dans les premiers stades de la croissance économique puis dans les dernière étapes, cette hausse persiste mais à un rythme plus lent. Le troisième chapitre étudie la relation de causalité de long terme entre la consommation d'énergie propre et la croissance économique dans un groupe de pays de l'Afrique subsaharienne. Le résultat révèle l'existence d'une relation d'équilibre à long terme entre la consommation d'énergie propre et la croissance économique. En outre, la dynamique de court terme et de long terme indiquent une relation de causalité à la Granger unidirectionnelle de la consommation d'énergie propre vers la croissance économique sans aucun effet rétroactif. Le dernier chapitre de cette thèse cherche à investiguer sur la convergence des émissions de gaz entre les provinces canadiennes. L'étude montre que les émissions de gaz des provinces canadiennes sont caractérisées des convergences de clubs. En d'autres termes, on détecte l'existence d'une segmentation des émissions entre les provinces canadiennes.

Mots-clés: World Value Survey; Modélisation multi-niveau; WTP; Courbe de Kuznets environnementale; Émissions de CO2; Développement économique; Énergie propre; Dépendance transversale; Ruptures structurelles; Club convergence; clustering; Provinces canadiennes