LUND UNIVERSITY
School of Economics and Management

Master programme in Economic Growth, Innovation and Spatial Dynamics

Environmental Kuznets Curve: Evidence from the Nordic Countries 1961-2010

Siqi Zhao
siqi.zhao.751@student.lu.se

Abstract: The relationship between economic growth and the environment, based on the theory of the Environmental Kuznets Curve (EKC), has been a topic of controversies, and a considerable number of studies have been devoted to investigate such relationship. In the current research the validity of EKC theory is tested on the Nordic countries, namely, Sweden, Denmark, Norway and Finland, over the period 1961 to 2010, taking the carbon dioxide emissions as a proxy of environmental degradation. The results of fixed effects on panel data showed that these countries' growth and emission pattern are rather ambiguous, and there is no clear support of the EKC theory when taking the low significance level of the obtained coefficients into consideration. Nevertheless, the production of clean energy has been proved to have a negative effect on emissions.

Key words: CO_2 emissions, Economic growth, Environment, Nordic countries

EKHM52
Master thesis, second year (15 credits ECTS)
June 2016
Supervisor: Lars Coenen
Examiner: Astrid Kander
Word Count: 12160

Table of Contents

List of Tables

List of Graphs

List of Abbreviations

EKC *Environmental Kuznets Curve*

GDP *Gross Domestic Product*

PPP *Purchasing Power Parity*

OLS *Ordinary Least Squares*

Acknowledgement

I would like to express my gratitude to my supervisor, professor Lars Coenen, for his valuable guidance, positive attitude and patience. I would also like to thank my co-supervisor Fredric Bauer, for his help and encouragement. I am also grateful to all teachers at the Department of Economic History who have gave me valuable recommendations and advice. I am very grateful to my most loved ones for their love and great support.

1. Introduction

In recent decades, the world's economy has been undergoing tremendous changes. With rapid growth in different economies, the environmental outcome has become one of the most important issues. On the one hand, the economic growth definitely brings a lot of benefits to the people by creating more wealth and thus welfare, higher standards of living, more access to education, among a great number of others. On the other hand, the environmental degradation caused by the economic growth has drawn much attention in the recent years.

The implications of the fast economic growth on environment are very prominent, and in this regard, there is an eager necessity to address the problem by managing the payoff between growth and environment. In the early stages of economic development, the negative environmental outcomes are usually neglected, and economic growth is achieved by sacrificing the environment through high level of extraction of the natural resources and there is relative loose control over the emissions into the atmosphere, water and soil. With the increasing awareness of environmental protection after a certain level of development has been reached, efforts have been made to improve the environment while sustaining the growth rates. With the rapid changes in technology and innovation, the decreasing energy intensity has brought some positive results to reducing the degradation caused by economic development. The decrease in energy intensity implies an increase in energy efficiency, thus the cost of converting energy into GDP is lower when the energy intensity is lowered. As it was pointed out by Enflo *et al.,* energy productivity is crucial in order to achieve sustainable development (2009).

In recent years, economists have increasingly focused on the implications of environmental issues and growth (Todaro & Smith, 2011: 469). The increasing attention paid to the interaction between economic growth and environmental outcomes has led to discussions on a theoretical level. In 1950s, Simon Kuznets formulated a theory regarding the relationship between economic growth and income inequality (1955, 1963). It was suggested that with the increase in income per capita, which is seen as a measurement of economic development, the level of inequality first increases, and subsequently decreases after reaching some point of income. This theory has a graphical representation in the form of an inverse U-shaped curve, which was named after him, the Kuznets curve. Based on the theory of Kuznets curve, Grossman and Krueger (1991) formulated their own understanding of the relationship applying the assumptions to the environmental context. It was found that the environmental outcomes of economic growth could also be depicted by an inverse U-shape curve, exactly as Kuznets had suggested in his early works regarding income inequality. In 1993, Panayotou first proposed and elaborated the theory of the Environmental Kuznets Curve (EKC) using empirical studies from different counties in different stages of development.

The purpose of the current research is to investigate the relationship between economic growth and the environmental outcomes, based on the theory focusing on such relationship – the Environmental Kuznets Curve (EKC). The Environmental Kuznets curve captures such relationship by representing the concept graphically. It assumes that, similar to the Kuznets curve about the relationship between the economic development and level of inequality, the pollution and other forms of environmental degradation rise in the initial stages of economic development with the rise in production and income, and subsequently decrease due to more availability of means to combat such pollution and raising awareness and willingness to solve the problem. Thus, the graph takes the form of an inverse U-shape. A number of difference air pollutants have been used to test the validity of the EKC, where carbon dioxide is one of the most tested pollutants (Shafik & Bandyopadhyay, 1992; Kander, 2002; Al-Malali & Ozturk, 2015; Jebli *et al.,* 2015; Bilgili, 2015; Apergis, 2015), along with sulfur dioxide (Stern & Common, 2001; Halkos, 2003; Kaufmann *et al.*, 1998), and also some others pollutants such as nitrogen oxide, DDT (dichlorodiphenyltrichloroethane), chlorofluorocarbons and other chemicals released into the air and water.

Four Nordic countries have been chosen to test the theory – Sweden, Denmark, Norway and Finland. These countries are among the most innovative countries in the world, with Sweden being in the lead, according to the ranking made by the *Global Innovation Index*, where Sweden was in the 3rd place in 2015, for instance (GII, 2015). The Nordic countries are seen as a world-leading region in terms of innovation and sustainable growth (Nordic Innovation, 2012). The Scandinavian countries have managed to reduce the carbon emissions while achieving considerable economic growth, thus becoming the greenest in Europe. Environmental sustainability is a part of Nordic thinking and thus various governmental organizations and institutions are working hard aiming at meeting the challenges in climate change and environment. A balance for environmental sustainability while achieving economic growth and increase of social welfare has always been seen as the primary goals of the development strategy of the Nordic countries (Nordic Energy Research, 2016). Taking the region as a whole in terms of energy supply, 38% of total is renewable energy, consisting of hydropower, geothermal, wind and solar, as well as biomass and waste as sources of energy supply (Nordic Energy Research, 2016). Furthermore, 55% of the energy supply is CO_2-free. The Nordic countries have achieved an almost carbon-free electricity supply. In terms of energy use, Sweden has made significant progress towards a more secure and sustainable energy future. The goal of fossil-fuel-independent vehicle fleet by 2030 and no net greenhouse-gas emissions by 2050 has been set by Sweden (Nordic Energy Research, 2016). Other Nordic countries have set similar goals in energy use, for instance, Denmark has similar ambitions to that of Sweden of becoming independent from using fossil fuels by 2050.

To answer the research question by testing whether these four countries follow the Environmental Kuznets curve, data of 50 years, from 1961 to 2010, will be used in order to assess the relationship between economic growth and the environmental outcome, taking GDP per capita growth and carbon dioxide emissions growth as the prominent measurements. The CO_2 is produced in all kinds of production and all activities associated with economic growth, thus it is considered to be appropriate to view the relationship between CO_2 emissions and GDP as the closest proxies of environmental outcome and economic development. The four Nordic countries have been undergoing rapid economic growth in the post World War II period with intensive manufacturing production. In the more recent years, the Nordic countries have paid significant amount of attention to address sustainable development to reduce the negative impact the economic development has had on the environment. The efforts made in regard to developing green technology and introducing environmental-friendly means of production has benefited the society in a great extend. Through assessing the data of 50 years, effort will be made to draw a conclusion on the Nordic countries' development with particular focus on the interplay between economic growth and environment.

The structure of the research will be presented as following. In *part 2*, the theory and related literature on the topic of Environmental Kuznets Curve will be presented in order to gain an insight into the research topic. The theory and thus the major studies on the Environmental Kuznets Curve will be discussed, along with other studies of the EKC theory on carbon dioxide emissions. This will be followed by the presentation of data and methodology in *part*

3, where information regarding data sources, variables used in the study, data transformation, as well as research methods will be discussed thoroughly. The methods will be incorporated into the research question based on the common practices of panel data regressions. Data inspection will also be included, leading to model specifications that will be used for estimations and hypothesis testing. Empirical analysis will be presented in *part 4* with a detailed discussion of the results, and finally summarized in the conclusions of *part 5*.

1.1 Specific Research question

The interplay between the carbon dioxide emissions and economic growth are seen as the topic of interest. Since the Environmental Kuznets curve has been chosen as the main theory for viewing the causal relationship between economic growth and environmental outcomes, the major research question of the thesis is to investigate whether the Nordic countries prove the validity of the theory of EKC. Formulated more specifically, the major specific research question is:

- *Does evidence from the Nordic countries in the past 50 years prove the validity of the Environmental Kuznets Curve theory in the case of carbon dioxide emissions?*

The major relationship being tested for the Nordic countries is the one between the CO_2 emissions and GDP per capita. The hypothesis is that the there should be a positive, and after reaching a certain level of development, there should be a negative relationship between GDP per capita and emissions level. The GDP per capita is expected to have first positive, and then a negative impact on the emissions, since the theory suggests that more economic development would mean that there are more sources and willingness to invest into cleaner production and better technology that would have a positive impact on the environment.

At the same time, a number of other factors are also closely related to and have a significant impact on the emissions of carbon dioxide into the atmosphere. Thus, a number of independent variables, besides GDP per capita, are also included into consideration: urban population growth, clean energy production as a percentage of total, fossil fuel energy consumption as a percentage of total. In this regard, more hypotheses will be formulated based on the explanatory variables.

In order to carry out the research successfully, fixed effect model on panel data will be employed, which will be described thoroughly in the data and methods part of the thesis.

1.2 Implications of the study

The issue regarding the relationship between economic growth and environment has been a major topic since decades ago, and has been viewed as one of the most important topics that affects the well-being of the society in general since it digs into the relationship between environment and economic development – two of the most important aspects of life. A number of studies have been devoted to analyze such a relationship, departing from different perspectives and offering some varying results. The validity of the Environmental Kuznets curve has been a topic of controversies. From the energy supply perspective, the exploitation of finite resources (non-renewable sources of energy) has prominent effects to economic return, though it was neglected by the early studies on EKC and later questioned by some researchers, e.g. Arrow *et al.* (1995). It was criticized that the EKC models suggested by some of the earliest studies did not take into consideration the causal relationship from the environmental damages and constant extractions of natural, yet non-renewable energy sources, to economic production, and the long-term exploration of the environment may have profound impacts on economic growth. Thus, understanding the relationship between growth and environmental outcomes will contribute to gaining a deeper insight regarding the importance of achieving sustainable development. While some evidences from some countries show that there is clearly a trend as predicted by the EKC theory, other studies argue that the theory of environmental Kuznets curve is rather ambiguous and do not seem to be valid. Thus, the current research will make an effort to contribute to the debate by providing some empirical results from the Nordic countries from the last five decades. Through reading the previous studies in the field, no research has been found to be addressing the Nordic countries as a group, even though single case studies on some of the countries do exist (e.g. Kander, 2002). Furthermore, even though economic growth and environmental sustainability seem to be characterized as a pay-off relationship, the Scandinavian countries have embraced the concept of sustainable economic development with deep considerations of the environmental outcomes. Some of the studies have been focusing solely on one country, looking at its long-term time series data, while others were investigating the issue using data from a number of selected countries other than the Nordics. Thus, this paper will be positioning itself in academia by offering a new point of departure to the topic of EKC by assessing a new group of countries. In this regard, the contribution of the current research is to study the EKC for the Nordic countries, which are well known for the technological advancements.

2 Theory and related literature

2.1 Theory and hypothesis

The Environmental Kuznets curve suggests that there is a changing relationship between various indicators of environmental variables and indicators of economic growth, e.g. income per capita or GDP per capita. In the initial stages of economic growth, it is argued that the environmental degradation and pollution increase. Such an increase would be followed by a decrease after reaching some certain level of per capital income, suggesting that high-income growth would generate improvements in environmental conditions. For this reason, the Environmental Kuznets curve in its graphical representation is an inverted U-shaped function of per capita income, which is rather identical to the original Kuznets curve explaining the relationship between income inequality and growth, and that is where the name of the environmental Kuznets curve comes from (Stern, 2003).

The concept of Environmental Kuznets curve was first proposed by Grossman and Krueger's study of the potential impacts of NAFTA in 1991 and Shafik and Bandyopadhyays's study for the 1992 *World Development Report*. If the EKC theory were valid, economic growth would rather be the means to achieving environmental improvement in the long run than a threat to the environment. Grossman and Krueger studied on the impact of trade barriers on environment by expanding the scale of economic activity, "*...by altering the composition of economic activity, and by bringing about a change in the techniques of production*" (1991). Evidence on 42 countries showed that the relationship between air quality and economic growth is positive with per capita GDP at low levels of national income, but becomes negative with GDP growth at higher levels of income. Two years later, Panayotou has found that based on empirical results, the Environmental Kuznets curve is proved to be valid, using cross-sectional data, nominal GDP. Subsequently it was argued that "*At higher levels of development, structural change towards information-intensive industries and services, coupled with increased environmental regulations, better technology and higher environmental expenditures, result in leveling off and gradual decline of environmental* *degradation"* (1993). Based on such assumption, it can be said that there is a distinction between growth in the scale of the economy and growth accompanied with structural change. In absence of the structural and technological change in the economy, pure growth in the scale of the economy would lead to significant environmental problems, which can be characterized as the scale effect (Stern, 2003). Usually, it assumes that a 1 percent increase in scale leads to 1 percent increase in emissions, given that there is no change in the input-output ratio or in technology but with a proportional increase in aggregate inputs (Stern, 2003). Thus, in relation to the current research on the Nordic countries, the structural change will be tested indirectly, since the decreasing level of emissions after reaching the peak of the EKC curve reflects such structural transformation thanks to the technological advances. The scale effect can be well reflected in the thinking of the traditional researchers that economic development and environmental outcomes are conflicting goals. Thus, as Stern argues,

"There are both proximate causes of the EKC relationship – scale, changes in economic structure of product mix, changes in technology, and changes in input mix, as well as underlying causes such as environmental regulation, awareness, and education, which can only have an effect via the proximate variables" (2003).

Here is where the theory of ecological modernization steps in to support the validity of the EKC theory. The theory of ecological modernization is closely associated with the topic of interplay between growth and the environmental outcomes, where there is a strong emphasis on the importance of technology and it is argued that the economy would benefit from moving towards environmentalism. The theory's basic assumption is related to environmental readaptation of economic growth and industrial development. The ecological modernization is a rather optimistic school and assesses the relationship between growth and environment from a societal point of view. In their books Spaargaren *et al.* (2000) and Hajer (1997) the interaction of environment and development, as well as the importance of ecological modernization in the political discourse is being discussed. Spaargaren and Mol (1992) argues in the study about the role of ecological modernization as a theory of social change, where it is suggested that in order to minimize the environmental degradation, institutional reform within the modern society is needed, entering the topic from a policy recommendation point of view.

According to the new-classical growth model, economic growth is driven by capital accumulation, Total Factor Productivity (TFP) and labor force. Lopez (1994) took into consideration the environmental aspect into part of the TFP, based on the assumption that the consumption of non-renewable energy could be an obstacle to economic sustainability. In his work, it is argued that economic growth decreases the environmental degradation only if producers internalize their stock feedback effects on production. The study proves the validity of the theory of EKC, and suggests that the relationship between growth and pollution "depends on the elasticity of substitution in production between conventional factors and pollution and on the relative degree of curvature of utility in income" (Lopez, 1994). The empirical evidence shows that an inverted U-shaped relationship can be observed for pollution and income, as proxy of economic growth.

Energy intensity is a good indicator of the relationship between energy use that constitutes a large share of the sources of greenhouse gas emissions and economic growth. Energy intensity indicates the cost of converting energy into GDP. Thus, the higher the energy intensity, the higher the price to convert energy into production - GDP. In fact, the Environmental Kuznets curve can be linked with the notion of energy intensity in the sense that the first part of increasing emissions can be compared in a certain extent with production with high energy intensity, while the later stage of a decreasing level of emissions can be partly explained by lower energy intensity, which is achieved by adopting better technology and means of production, where energy can be used more efficiently to generate more growth. In the case of Sweden, for instance, such pattern was depicted by the study of Kander (2002), where it suggests that there is a decline in energy intensity since 1970s and the CO_2 intensity, including only fossil fuels, shows a long Environmental Kuznets curve.

However, the early studies on EKC have received some considerable critics. Among them, Arrow *et al.* (1995) pointed out that the EKC model, on the case of the 1992 World Development Report by Shafik and Bandyopadhyay and elsewhere, does not take into consideration the causal relationship from the environmental damages to economic production. This is caused by the fact that in their models income is assumed to be an exogenous variable. Thus, it suggests that the economy is sustainable, since the environmental degradation does not harm the economic activity sufficiently to hinder economic growth. However, if higher levels of economic development are not sustainable, for instance, taking the example of non-renewable sources of energy that is widely used for production, the fast growth in the initial stage of development may be counterproductive, and solutions to sustainable growth is thus needed (Arrow *et al.*, 1995).

Furthermore, Arrow *et al.* (1995) as well as Stern *et al.* (1996) argued that if the theory of EKC was valid, such relationship between economic growth and environmental degradation might be a results of a combination of different factors, for instance, the effects of trade on the distribution of polluting industries. According to the Heckscher-Ohlin trade theory, developing countries would tend to specialize in the production of goods that are intensive in the factors that they are endowed with in relative abundance – either labor or the natural resources (taken from Stern, 2003). Thus, the production of the goods that might have a higher level of emissions, given that the clean production is usually rather costly, and rely more on labor abundance, tend to move to the developing countries. In this connection, the production that leads to higher emissions will be moved out of the developed countries, in this case, the Nordic countries. As a result, this would exaggerate the decline in pollution with rising income of the more economically advanced countries.

2.2 Literature review on the topic of EKC for CO_2

The Environmental Kuznets curve has been a theory under constant debate, where different views exist on its applicability in practice. While some researches indicate that the theory of environmental Kuznets curve is valid based on evidence from different countries, the others argue that it holds only from the theoretical point of view. A number of studies have been devoted to test the theory in different countries. Two major categories of previous studies can be identified, as it always is the case with any topic within economics, especially with one that is characterized by controversies. The first group of studies argues that the theory holds based on the data analysis from certain countries (Bilgili *et al.,* 2015; Apergis, 2015), while the others impose some major critics on the methodology that leads to biased or imprecise results (Nasr *et al.,* 2015). At the same time, while some studies focus on a single country as a point of departure (Kander, 2002; Ben Nasr *et al.,* 2015; Egli, 2002; Li *et al.,* 2015; Song *et al.,* 2008; Xu *et al,* 2012), where long-time time series data are analyzed to investigate whether or not the country's development trajectory follows the tendencies suggested by the theory of Environmental Kuznets curve, the other group of researches seek the answer by comparing different countries, and look for evidence from countries with different backgrounds and growth patterns by using panel data regressions (Al-Malali & Ozturk, 2015; Jebli *et al.,* 2015). There are barely any studies investigating the environmental Kuznets curve on the regional level, but a closer look at the previous studies on the national level can be a good departing point for gaining more insight into the topic.

In some early studies on EKC (e.g. Lopez, 1994) it was found that local pollutants followed the inverted U-shape relation with income, while on the larger, global scope, the carbon dioxide emissions, for instance, did not. This finding is in line with the theory of environmental economics, where local impacts are internalized with a single economy and tend to promote environmental policies before it is done to globally externalized problems (Stern, 2003).

The results of Shafil and Bandyopadhyay's study (IBRD, 1992) estimated EKCs for 10 different indicators. Three functional forms have been included: log-linear, log-quadratic and log-arithmic cubic polynomial in PPP GDP per capita and a time-trend and site-related variables. It was found that the lack of clean water and lack of urban sanitation decrease uniformly with increasing income. Furthermore, the carbon dioxide emissions, along with dissolved oxygen in rivers and municipal waste, confirm the EKC hypothesis. As a proof to the theory of ecological modernization, the study has also worked in favor of improved environmental quality.

In the study conducted by Al-Malali and Ozturk (2015), 27 advanced economies have been chosen to test the nature of the relationship between energy prices and pollution, using panel non-stationary techniques to examine the economies during the period 1990 to 2012. Based on the panel Kao and Fisher cointegration results, it has been found that CO_2 emissions, GDP, renewable energy consumption, non-renewable energy consumption, trade openness, urbanization, and energy prices are cointegrated. In the study, the panel fully modified OLS and the vector error correlation Granger causality results have shown that GDP, non-renewable energy consumption and urbanization turn out to be the factors increasing CO_2 emission, while renewable energy consumption, trade openness and energy prices, on the other hand, reduce it. Thus, based on the evidence from these countries, the Environmental Kuznets curve has been proven to be true, where the relationship between GDP and CO_2 emissions was following the inverted U-shape that the theory suggests.

The causal relationships between per capita CO_2 emissions, Gross Domestic Output (GDO), renewable and non-renewable energy consumption, and international trade have been studied by Jebli et al. (2015). Panel data for 25 OECD countries have been analyzed over the period 1980 to 2010. Short-run Granger causality tests indicate that there is bidirectional causality between: renewable energy consumption and imports, renewable and non-renewable energy consumption, non-renewable energy and trade. In this case, once again, using the long-run fully modified ordinary least squares (FMOLS) and dynamic OLS estimates, it has been found that the EKC hypothesis holds for this sample of OECD countries. Moreover, it has been found that increasing trade or renewable energy reduces CO_2 emissions. Jebli et al. have come up with the conclusion based on the results that more trade and more use of renewable energy are efficient means to reduce the effects of global warming.

Similarly, another study on 17 OECD countries has also shown that the EKC is proven to be valid (Bilgili *et al.*, 2015). The findings support the theory, where GDP per capita and GDP per capita squared have an positive and negative impact on the CO_2 emissions respectively, showing the inverted-U shaped pattern. The study has also found out that the validity of EKC does not depend on the income level of the countries of panel, where EKC holds.

The validity of the Environmental Kuznets curve has been also tested by Apergis (2015) using data on per capita CO_2, emissions and per capita real GDP from 15 countries over the period 1960 to 2013. Both panel-based and time-series-based methodological approaches of cointegration have been used. In this research, the results have indicated that the EKC hypothesis holds in 12 out of 15 countries, which allows the study to stay in line with the ones that confirm the validity of the theory. For the other three countries, the hypothesis still holds at certain quantiles.

A number of studies estimate EKC for energy use. A study on Sweden was conducted by Kander (2002) investigating the interrelations of growth, energy and CO_2 in the scope of two centuries – 1800 to 2000. Evidence suggests that when only emissions from fossil fuels are counted, CO_2 intensity shows a pattern of one long EKC, interrupted by the Wars. If viewing them separately, having the Wars as the dividing points, then there are three separate EKCs. It has been found out that the main determinants of the CO_2 intensity are energy intensity and energy carrier composition, which is the most influential. Energy carrier composition is affected at different income levels by energy intensity, which in its turn is influenced by the purchasing costs, handling costs and environmental costs. However, Suri & Chapman (1998) and Cole *et al.* (1997), estimating EKCs for a proxy of total energy use, found that energy use per capita increases rather monotonically with income per capita.

In Li *et al.*'s study (2016) on three kinds of emissions in the case of China, all three types of pollutants, namely, per capita CO_2, per capita industrial waste water emissions and industrial waste solid emissions, supported the EKC theory. Furthermore, it has been found that energy consumption has positive effects on emissions, and in the long run, trade and urbanization deteriorate environmental quality. Similar results can be found in the study conducted by Song *et al.* also for China (2007). In addition, Xu *et al.* (2012) proved the validity of the Environmental Kuznets curve using data during the period 1980 to 2008 in China, showing that the carbon dioxide emissions has followed a patter as predicted by the EKC theory.

At the same time, there is a lot of criticism addressing the Environmental Kuznets curve. As it was pointed out by Stern (2003), since the EKC is a rather empirical phenomenon, the research methods play a large role in presenting good results. It was argued by Stern that little or even no attention at all has been paid to the statistical properties of the data used, including serial dependence or stochastic trends in time series, and, furthermore, few tests of model adequacy have been carried out or presented (Stern, 2003). Rather, as it was suggested in the article: *"…One of the main purposes of doing econometrics is to test which apparent relationships, or 'stylized facts', are valid and which are spurious correlations*". Stern argues that when such statistics are take into consideration, the theory of EKC does not hold anymore, since the environmental outcomes is not the sole result of changes in income per capita alone. Rather, in economically more advanced countries, growth is relatively slower, thus the pollution reduction efforts can overcome the scale effect – "This is the origin of the apparent EKC effect" (Stern, 2003). In this particular thesis, considerations regarding the stochastic trends, thus spurious regression, are taken into consideration and are handled with special attention to be avoided. This will be done by conducting the unit root tests to test for stationarity. Regressions will be run only after it is certain that the series are stationary, thus not suffering from the possibility of obtaining results with spurious regressions.

Furthermore, Nasr et al. (2015) also suggest that the results from South Africa do not support the EKC theory. A conclusion has been made that in order to reduce emissions while keeping the economic growth the policies aimed at increasing energy efficiency would be needed. Similarly, in the study on Germany the results are somewhat ambiguous, where only nitrogen oxide and ammonia can be argued to be following the pattern of the EKC curve, but for other kinds of emissions including carbon dioxide emissions, no sign of EKC curve could be observed (Egli, 2002). In addition to that, a case study on Finland by Kunnas and Myllyntaus (2007) also suggests that there is no clear evidence for the existence of the EKC based on Finnish data, since there was a steady increase in emissions in the beginning of the period of 1800 to 2003, but no results showing any decrease at a later stage for carbon dioxide emissions, even though support for the EKC theory was proved only for sulphur dioxide emissions and also for nitrogen oxides, but with some reservations.

A case study on Sweden has been conducted by Lindmark and Acar (2014). Here, a new method has been suggested to study the relationship between economic growth and the environment by constructing an aggregated environmental volume index. The findings show that the relationship take the form of a left-wise titled S, implying that the environmental impact first falls, and then increases, and once again falls with economic growth. Evidence suggest that the new knowledge of environmental problems is important for the changing relationship (by adding historical variables explaining environmental impacts), shedding a light into a new understanding of the growth-environment relationship, which differs from what the EKC suggests. As it was pointed by Copeland and Taylor (2004),
"Our review of both the theoretical and empirical work on the EKC leads us to be skeptical about the existence of a simple and predictable relationship between pollution and per capita income".

The preliminary conclusion based on the previous studies is that the theory of EKC for CO_2 seems to be valid in most of the cases. The differentiated results from various studies may be a result of different estimation methods. Furthermore, the countries that show no patter of EKC might be simply because the country's economy has not reached the point when the emission level starts to decline due to its current stage of development. Even though economic growth is not the only factor influencing the level of environmental degradation, the relationship suggested by the EKC theory seem to be logical both from theoretical and practical points of view. From the energy use perspective, improving technology plays a positive role in increasing energy efficiency, which would lead to decreasing emissions. Thus in some studies policy recommendation of increasing production and energy efficiency has been brought forward. As for the Nordic region, technological advances and high awareness of environmental protection gives us ground to expect that the development trajectories of the Nordic countries follow the EKC curve as suggested by the theory. More explicit conclusions will be drawn after the empirical results are obtained.

3 Data and methodology

In this section, the data will be described and inspected by both doing a correlation test and graphically. After that, the model specification will be presented.

3.1 Data

In order to investigate whether the selected Nordic countries follow the environmental Kuznets curve, panel data for Sweden, Denmark, Norway and Finland is used for hypothesis testing, covering the period from 1961 to 2010. The data are collected from different sources via datastream, namely, the AMECO database for CO_2 emissions (Annual macro-economic database of the European Commission) and the World Bank database for all other variables.
A total of 6 variables are used in the model as presented below:

The dependent variable:

- CO_2 emissions per capita, kiloton

The dependent variable carbon dioxide per capita is chosen as a proxy for environmental degradation, since it is a type of gas causing global warming, thus viewed as the one of the most to pay attention to and it is emitted in most types of productions and other economic and non-economic activities. CO_2 is emitted into the atmosphere during production, transportation, and consumption, which are all directly associated with economic activities in this case, thus viewed as a suitable dependent variable to test the theory.

Independent variables:

- GDP per capita, total at constant 2010 market prices

GDP per capita is the measure for economic development - one of the two components of the relationship analyzed in the theory. GDP per capita is one of the most popular measurements of economic development of a country, and thus is chosen to be the main independent variable in the models used to hypothesis testing.

- GDP per capita squared, to capture the inverse U-shape

Squared GDP per capita is included into the model to depict the non-linear relationship between CO_2 emissions ad GDP per capita, represented by a parabola with its downward-oriented planes. Correct signs of the coefficient for squared GDP per capita in the regressions presented in the empirical analysis would suggest the validity of the hypothesis of the U-shaped curve, and the squared variable is thus viewed as equally important independent variable alongside GDP per capita.

- Urban population growth, annual percentage

Urban population growth is selected to be independent variable, even though it is not included in the theory, since it is considered to be having a direct impact on the level of emissions. It is assumed that the growth in urban population would lead to increasing CO_2 emissions. Evidence has proved the carbon emissions are higher in more densely populated urban areas and tend to have a positive effect on emissions. Furthermore, the impact of urbanization on emissions is proved to be positive for all income groups (Poumanyvong & Kaneko, 2010). However, in general, the effect of urbanization on emissions is somewhat ambiguous, since it can also show both positive and negative impact at different stages of development (Abesamis et al, 2013; Sadorsky, 2013).

- Clean energy production as a percentage of the total

Clear energy production has been included into the model as an independent variable, since the type of energy has an important role in determining the level of emissions. The data collected for clean energy in this case includes renewables types of energy, namely, hydro, wind, and solar energy, which are environmental friendly energy sources compared to fossil fuels, as well as alternative energy (biomass) and nuclear energy. Thus, larger share of clean energy production of total energy use is expected to reduce the level of emissions. However, this indicator could be a bit ambiguous, since the commodity production is not distinguished. The locally produced energy is not necessarily consumed locally. The same can be said for fossil fuel energy production, for instance, oil produced in Norway is in a large extent exported rather than consumed locally. Nevertheless, this explanatory variable, along with fossil fuel energy production, is not in the center of the tested theory, thus focus of the results are mainly placed on the relationship between carbon dioxide emissions and GDP per capita.

- Fossil fuel energy consumption as a percentage of total

Fossil fuel energy includes the traditional sources of energy, including oil, natura gas and coal. Thus, the larger the share of fossil fuel energy consumption, the worse the environmental outcomes in regards to carbon dioxide emissions.

A summary of the variables used in the research can be found in *Table 1* below.

Variables	Definition	Unit of measurement
dependent variable		
1. CO_2	Per capita CO_2 emissions into the atmosphere	Kilotons
independent variables		
2. GDP per capita	GDP per capita in constant 2010 prices	Respective currencies of the countries
3. GDP per capita^2	Squared value of GDP per capita	-
4. Urban population growth	Urban population growth	%, annual percentage
5. Clean energy production	Total renewable energy production	%, share of total
6. Fossil fuel energy consumption	Total fossil fuel energy consumption	% share of total energy use

Table 1.Variables used in the study

3.1.1 Data transformation

Some data transformation has been made for the variables. The initial data for CO_2 emissions are given in absolute numbers (volumes, in kilotons). It has been transformed into logged values, and the same was done for GDP per capita, which was given in constant (2010) market prices (respective currencies of the countries). Thus, a log-log model is obtained for convenience reasons in further estimations. The unit root tests presented in the following part will show the existence of unit root in the variables, and thus the variables will be taken in the first difference to avoid spurious regression and biased results. In this regard, the regressions will use CO_2 emissions and GDP per capita growth (after taking the first difference of the logged values), and more discussion on that will be presented in the panel unit root test section. The data are very consistent for all countries and throughout the whole time span. However, three years (1968 to 1970) of fossil fuel consumption data is missing for Denmark. The problem is solved by estimating the average of the previous and following years. Inspecting the data for GDP per capita shows that the changes in growth rate are rather stable over the years, thus it is assumed that the growth rate throughout the three years was equal. Thus the gap in the data is filled. And since the numbers are rather similar throughout those years, its impact on the overall results should not be significant.

3.2 Descriptive statistics

In this section, the main properties of the panel data will be presented and discussed in order to have a better understanding of the data. First, the general characteristics of the data are presented, and this is followed by an inspection on the possible existence of the correlation between the variables. Moreover, graphical inspection on the data will also be presented before going further to testing the models to gain results for the research question.

3.2.1 Properties of panel data

In the table below, the basic properties of the each variable are presented. As it can be seen from the table, the data are highly balanced, since each variable has the same number of observations (200) for each country (Gujarati & Porter, 2009). In *Table 2* below, the overall description for each variable can be found.

Variable	Obs	Mean	Std. Dev.	Min	Max
Ln_co2	200	2.15	0.29	1.21	2.62
Ln_gdp	200	4.92	1.17	2.24	6.32
Urban	200	1.08	0.79	0.05	4
Clean energy pro	200	23.19	18.43	0.01	52.26
Fossil fuel energy con	200	65.27	19.61	31.98	99.66

Table 2. Descriptive statistics for variables in all countries

In order to have an even more detailed understanding of the data, the descriptive statistics for each of the countries' variables are presented in *Table 3*.

			Sweden						Denmark		
Variable	Obs	Mean	Std. Dev.	Min	Max	Variable	Obs	Mean	Std. Dev.	Min	Max
Ln_co2	50	1.99	0.24	1.55	2.44	Ln_co2	50	2.34	0.14	1.93	2.62
Ln_gdp	50	5.49	0.28	4.92	5.95	Ln_gdp	50	5.76	0.42	4.99	6.32
Urban	50	0.77	0.61	0.05	2.12	Urban	50	1.54	1.05	0.47	4
cleanen_pr	50	34.61	15.32	9.52	52.26	cleanen_pro	50	42	4.02	29.82	49.72
Ffen_con	50	52.31	18.4	31.98	81.83	Ffen_con	50	56.47	3.1	51.78	63.08
			Norway						Finland		
	Obs	Mean	Std. Dev.	Min	Max		Obs	Mean	Std. Dev.	Min	Max
Ln_co2	50	2.01	0.27	1.31	2.45	Ln_co2	50	2.24	0/31	1.21	2.58
Ln_gdp	50	5.42	0.29	4.81	5.84	Ln_gdp	50	3.01	0.41	2.24	3.62
Urban	50	0.71	0.5	0.06	1.68	Urban	50	1.2	0.56	0.4	2.55
cleanen_pr	50	0.77	1.15	0.01	3.57	cleanen_pro	50	15.37	7.63	3.85	25.26
Ffen_con	50	93.25	5.86	78.27	99.66	Ffen_con	50	59.03	9.52	45.13	79.1

Table 3. Descriptive statistics for each country separately

The descriptive statistics show that the mean value of logged CO_2 emissions is highest for Sweden and Norway, while the mean value of logged GDP is the highest for Sweden and Denmark. Urban population growth, on the other hand, is the fastest in Denmark and Finland. As for the share of clean energy production, as presented in *Table 3,* it is the highest for Sweden and Denmark, and it is in a great extend higher than that of Norway. And finally, for the fossil fuel energy consumption, Norway has the highest share of fossil fuel energy consumption compared to the other three countries.

3.2.2 Test on correlation

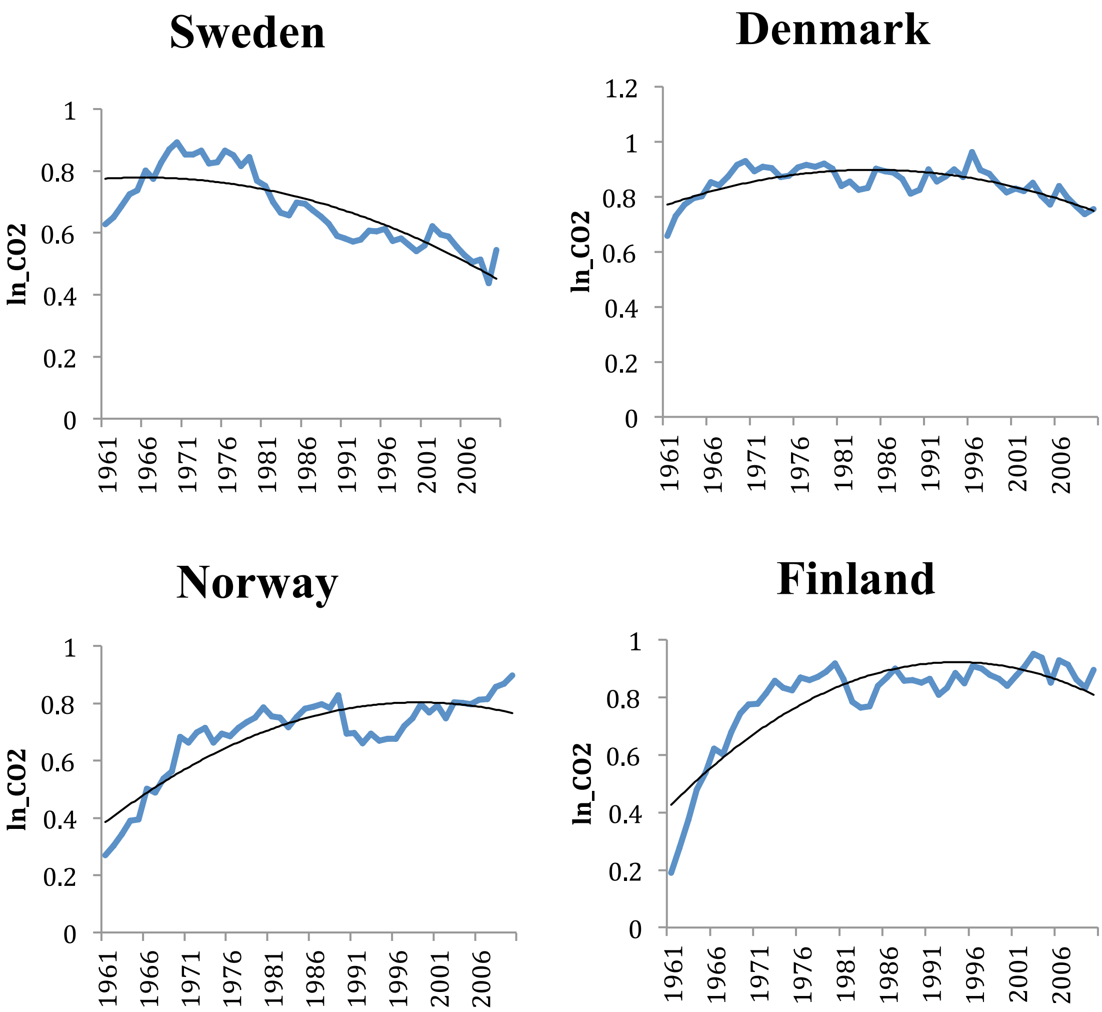
A test on correlation has been done on the variables to avoid biased results. In the table below the coefficients of correlation for each possible pair of variables are presented. The coefficient for correlation between clean energy production and fossil fuel energy consumption is rather high (-0.8503), implying that the two variables are highly, though not totally correlated, since they represent different indicators (production vs. consumption, clean vs. fossil fuel energy). As it was mentioned before, it can be explained by the fact that the energy production of clean/fossil fuel energy is not fully matching its consumption, since the energy produced in these countries can be exported elsewhere, while locally consumed energy does not necessarily be of local production. In this case, the two variables should not be included into the same model to avoid biased results. Furthermore, urbanization also seems to be correlated with ln_CO_2 emissions. It will be included into the model since it is considered to be an important explanatory variable for the hypothesis, but the interpretation of its significance will be taken cautiously.

	ln_co2	ln_gdp	urban	cleanen_pro	ffen_con
ln_co2	1.0000				
ln_gdp	-0.1059	1.0000			
urban	-0.4344	-0.249	1.0000		
cleanen_pro	-0.5528	0.3054	0.0623	1.0000	
ffen_con	0.5667	-0.3258	0.0063	-0.8503	1.0000

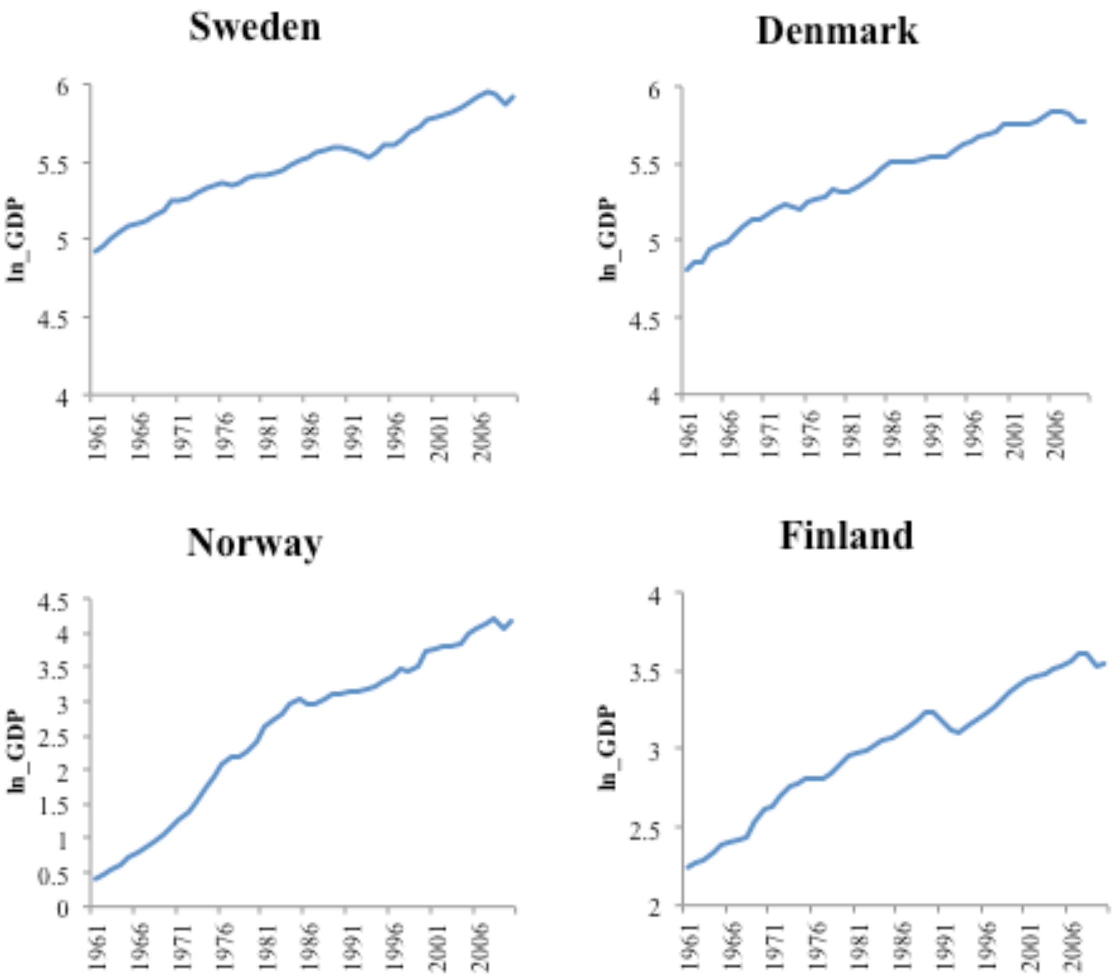
Table 4. Correlation between the variables

3.2.3 Graphical inspection

The panel data used in the paper is highly balanced, since each subject has the same number of observations. In order to check how the main variables behave throughout time, a graphical inspection has been carried out for each of the 4 countries respectively by plotting each variable against time. First, graphical inspection on CO_2 emissions has been made. A polynomial trend line has been added to the series to see whether there is an inverted U-shape in the data. Sweden and Denmark shows the patter of first increasing, and subsequently decreasing levels of emissions. The turning point for Sweden appeared rather early, around 1970s, and for Denmark it appeared in 1980s. However, in the case of Norway and Finland, the trend seems to be increasing throughout most of the selected time span, where for Norway the trend line shows that the level of emissions has stabilized in the latest years of the period, while for Finland slight decrease became observable after around 1995. The preliminary graphical inspection has shown ns inverted U-shape as predicted by the theory, even though it is not so prominent for Norway and Finland as it is for Sweden and Denmark. As for (logged) GDP per capita, it is increasing in all four countries over time, as shown in *Graph 2*.



Graph 1. ln_CO2 plotted against time with trend line



Graph 2. ln_GDP per capita through time

The above-presented graphical inspection is made in order to get a preliminary idea of the data, and more thorough conclusions regarding the behavior of the series will be drawn after the estimations are carried out. The results of the graphical inspection gives us ground to assume that the theory of EKC holds for the Nordic countries, where the increase in GDP per capita there is first an increase and then a decrease in levels of emissions. The existence of the EKC curve and the interaction between CO_2 emissions and GDP per capita will be found through regressions in the subsequent parts of the research.

3.3 Statistical Approach

In order to assess the data, panel fixed effects models are used. The data are structured as long-term balanced data over cross-sections. The reasons justifying the choice of doing regressions on panel data are that panel data capture the variations both over time and across countries. Furthermore, there are more observations in panel data, which mean there is better precision and less bias in the results. Through analyzing the panel data over a period of 50 years, a better understanding of the topic of research can be obtained. Even though the Nordic countries do have a number of similarities in their development trajectories and in the level of technological advancements, considerable differences in terms of energy intensity and use of innovative methods of production with a particular emphasis on energy use can still be traced. Based on the theory discussed in the previous sections, model specifications will be presented in the next section in more details.

3.4 Model Specification

Based on the theory, the most important relationship we are concerned about is the one between GDP per capita as a measurement of economic development and the CO_2 emissions as a prominent of environmental degradation. Thus in the first model, the basic model is considered based on the hypothesis of the EKC theory suggested by Grossman and Krueger (1991). The explanatory variables urbanization growth, clean energy production as well as fossil fuel energy consumption are included in the subsequent four model specifications. As it was detected by the correlation test on the variables, it became clear that the latter two variables are correlated, thus they will not be included into the same model. In this regard, two different models have been specified to assess the relationship. Furthermore, the time effects have also been included in addition to the model with clean energy production to test the consistency of the model when time-specific effects are added.

Model specification 1:

$$CO2_{it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP\_sq_{it} + \varepsilon_{it} \quad (1)$$

In this model the basic model will be assessed without any control variables. This will give a fundamental idea regarding how GDP per capita and CO_2 emissions interact. The squared (logged) GDP per capita is included to reflect the inverse U-shape if there is any. The coefficients obtained from this model should give some basis for preliminary conclusions. In this regard, the coefficient of the logged GDP per capita is expected to be positive, while its squared value is predicted to have a negative sign in order to depict the curve.

Model specification 2:

$$CO2_{it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP\_sq_{it} + \beta_3 urban_{it} + \beta_4 cleanen\_pro_{it} + \varepsilon_{it} \ ,$$

where the subscripts *i* denotes the panels at time *t*. (2)

In this model, the logged GDP per capita, urbanization growth and clean energy production are all seen as factors influencing the CO_2 emissions. GDP per capita is expected to have a positive effect on emissions in the initial period, after reaching some point its impact on the emissions is expected to turn to negative instead. The downward-oriented plane of the parabola showing the inverse U-shape is captured by the squared GDP per capita. Thus, the coefficient for the squared GDP per capita growth is expected to take a negative value, which would signify the relationship between the independent variable GDP per capita and CO_2 emissions by creating an downward sloping plane of the parabola, just as it is predicted in the first model. Clean energy production can be considered as a proximate of measurement of technology or innovation, and it should have a positive influence for reducing the emissions growth, since the larger the share of the production of clean energy among the total energy production, the smaller negative impact the energy production should have on the environment.

Model specification 3:

$$CO2_{it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP\_sq_{it} + \beta_3 urban_{it} + \beta_4 cleanen\_pro_{it} + \varepsilon_{it} \qquad (3)$$

The third model presented above includes equivalent control variables. The only difference is that the year specific effects have been added to test if the previous models are consistent. The year specific effect shows the different effects throughout the years, i.e. how does the relationship change over time. Thus, identical a priori expectations regarding the signs of the coefficients are accepted.

Model specification 4:

$$CO2_{it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP\_sq_{it} + \beta_3 urban_{it} + \beta_4 ffen\_con_{it} + \varepsilon_{it} \qquad (4)$$

The second model is similar to the fourth, but takes a different explanatory variable. In this case, the clean energy production has been substituted by the fossil fuel energy consumption. The data for fossil fuel energy consumption is taken as its percentage of the total. Therefore, it assumes that the larger the share of fossil fuel energy consumption, the worse impact it would have on the environment. In this regard, the coefficient for this variable is expected to be positive to indicate the positive influence it has on the levels of emissions. This model is similar to the second model, but use different explanatory variables, which influence the dependent variable in a different/opposite manner. In the empirical analysis, the hypothesis will be tested and discussion on the validity of the environmental Kuznets curve will be assessed based on the results.

4 Empirical Analysis

After the models have been specified, we now will run the regressions, where fixed effects will be preferred over random effect due to the characteristics of the data. The data are long term panel data, which means the number of time variable T (50) is significantly more than the number of panels N (4). A comparison of one-way and two-way error component fixed effects models. The fixed effect models used in the current research are one-way error component models. The reason justifying the choice of one-way error component model above two-way error component models is that the two-way error component model takes into consideration the time-specific effect, which is needed when the time-specific events are considered to be affecting the outcome variable. However, in this research, the theory of environmental Kuznets curve does not look at the time effect in particular. The economic growth, represented by GDP per capita in this case, does naturally assume that there is a change over time, since growth is observed throughout time, but no accent is made on the time effects in the theory. The focus of the research topic is on the relationship between the proxy of economic development and the environment outcome. Thus, one-way error component model, which includes country-specific effect only, will be used. Before running the regressions the unit root test will be conducted. Subsequently, after running the regressions on the panel data, we will arrive at the final results of the models obtained. If the existence of the patter as predicted by the EKC theory exists, turning points of the EKC curve will be estimated. A more detailed discussion will be presented in the following parts.

4.1 Panel Unit Root tests

The unit root test has been tested on each variable included in the model. The series are tested both in series and in first differences. The intention of carrying out the unit root tests is to make sure that the data are stationary. Since running regression on non-stationary variables can cause incorrect inference and biased parameters, it is of utmost importance to detect such variables and adjust them to avoid imprecision in estimations. Four tests for unit root are used for panel data: Levin-Lin-Chu test, Im-Pesaran-Shin test, Maddala & Wu test, as well as Pesaran CIPS test. Due to their different nature, the tests may show somewhat different results when detecting unit root (Gujarati & Porter, 2009). The method used to draw conclusion regarding where there is unit root is to rely on the results of the majority of the tests.

First, the unit root tests are conducted for CO_2. As it can be seen from the results presented in *Table 5*, all tests for unit root suggest that the data do not have unit root except for the LLC test. The null hypothesis of all the tests for unit root is that the panels contain unit root. The p-value in most test are significant at the 5% level, thus we cannot reject the null of unit root except for when it's taken in differences. Based on the principle of drawing conclusion judging from what most test suggest, we conclude that the CO_2 data is non-stationary, and are thus taken in the first order of integration I(1).

Tests	Variable	Specification	Statistic	p-value
Levin-Lin-Chu test	ln_CO2	Unadjusted	-3.1595	
		Adjusted	0.6643	0.7468
	ln_CO2 time trend included	Unadjusted	-5.5999	
		Adjusted	0.5949	0.7241
	ln_CO2 first differences	Unadjusted	-5.9059	
		Adjusted	3.1288	0.9991
Im-Pesaran-Shin test	ln_CO2		-0.7758	0.2189
	ln_CO2 time trend included		-1.1671	0.1216
	ln_CO2 first differences		-2.8066	0.0025
Maddala & Wu test	ln_CO2	Inverse chi2	13.0808	0.1091
		Inverse normal	-0.6481	0.2584
		Inverse logit	-0.854	0.2008
		Modified inv. Chi2	1.2702	0.102
	ln_CO2 time trend included	Inverse chi2	10.5531	0.2283
		Inverse normal	-1.1087	0.1338
		Inverse logit	-1.0485	0.1524
		Modified inv. Chi2	0.6383	0.2616
	ln_CO2 first differences	Inverse chi2	22.0459	0.0048
		Inverse normal	-3.0262	0.0012
		Inverse logit	-3.0238	0.0029
		Modified inv. Chi2	3.5115	0.0002
Pesaran CIPS test	ln_CO2			1.000
	ln_CO2 time trend included			1.000
	ln_CO2 first differences			0.102

Table 5. Unit root test for ln_CO2

Similar results for the GDP variable can be found in the unit root test – the data are rather stationary, since most of the tests suggest that there is no unit root in the dataset. Results of LLC test suggest unit root in first differences and when time trend is included, while IPS and test rejects the null of unit root for GDP on the first differences. For GDP, in this case, it is significant on the 10% level. All in all, combined with the graphical inspection, it can be said that there is no unit root in the data judging from the results of the tests. However, as we have seen in the graphical inspection, ln_GDP has a very clear trend, since the level of GDP per capita is increasing throughout time. Thus, to avoid mistakes in estimations, the first difference of the data on ln_GDP will still be taken (first differences of logged value of a variable corresponds to its growth rate). The results of the tests are presented in the *Table 6*:

Tests	Variable	Specification	Statistic	p-value
Levin-Lin-Chu test	ln_GDP	Unadjusted	-4.1691	
		Adjusted	-4.0419	0.0000
	ln_GDP time trend included	Unadjusted	-2.8656	
		Adjusted	1.7188	0.9572
	ln_GDP first differences	Unadjusted	-4.5266	
		Adjusted	2.3810	0.9914
Im-Pesaran-Shin test	ln_GDP		-0.8898	0.1868
	ln_GDP time trend included		0.984	0.8374
	ln_GDP first differences		-1.4713	0.0706
Maddala & Wu test	ln_GDP	Inverse chi2	10.8967	0.2076
		Inverse normal	-0.8102	0.2098
		Inverse logit	-0.7857	0.2199
		Modified inv. Chi2	0.7242	0.2345
	ln_GDP time trend included	Inverse chi2	6.4122	0.6012
		Inverse normal	0.8790	0.8103
		Inverse logit	1.1724	0.8737
		Modified inv. Chi2	-0.3969	0.6543
	ln_GDP first differences	Inverse chi2	13.0203	0.1112
		Inverse normal	-1.4628	0.0718
		Inverse logit	-1.4109	0.0856
		Modified inv. Chi2	1.2551	0.1047
Pesaran CIPS test	ln_GDP			0.998
	ln_GDP time trend included			1.000
	ln_GDP first differences			0.245

Table 6. Unit root test for ln_GDP

Here the results of unit root for urban population growth are presented in *Table 7*. In contrast to the previous two variables, all the tests suggest that the data contain unit root but not when the first difference is taken for the Pesaran CIPS test. For the LLC test the Urban variable without trend looked fine. The results of the IPS test and Maddala & Wu showed that both urban and urban first differences looked fine. However, the Pesaran CIPS test showed no unit root only when it was integrated into the first differences. The series are thus I(1), which means that the series are integrated into the first order:

Tests	Variable	Specification	Statistic	p-value
Levin-Lin-Chu test	Urban	Unadjusted	-5.0331	
		Adjusted	-2.7199	0.0033
	Urban time trend included	Unadjusted	-3.9647	
		Adjusted	-0.3612	0.3590
	Urban first differences	Unadjusted	-4.9396	
		Adjusted	3.7767	0.9999
Im-Pesaran-Shin test	Urban		-2.1554	0.0156
	Urban time trend included		0.3219	0.6262
	Urban first differences		-1.9670	0.0250
Maddala & Wu test	Urban	Inverse chi2	19.9024	0.0107
		Inverse normal	-2.2470	0.0123
		Inverse logit	-2.3894	0.0125
		Modified inv. chi2	2.9756	0.0015
	Urban time trend included	Inverse chi2	4.6730	0.7919
		Inverse normal	0.6447	0.7404
		Inverse logit	0.6155	0.7280
		Modified inv. chi2	-0.8318	0.7972
	Urban first differences	Inverse chi2	16.5357	0.0353
		Inverse normal	-2.0223	0.0216
		Inverse logit	-2.0370	0.0264
		Modified inv. chi2	2.1339	0.0164
Pesaran CIPS test	Urban			0.191
	Urban time trend included			0.111
	Urban first differences			0.047

Table 7. Unit root test for urban population growth

The same can be said for the clean energy production as a share to total, where the data are stationary after they are integrated at the first order as shown in *Table 8*. IPS and Maddala & Wu showed no unit root when the variable is taken into the first differences, and the Pesaran CIPS test showed the same on the 10% significance level but not on the 5% level as for the other tests. The data suffer from unit root and are thus integrated into the first order I(1).

Tests	Variable	Specification	Statistic	p-value
Levin-Lin-Chu test	Cleanen_pro	Unadjusted	-2.3840	
		Adjusted	-0.1878	0.4255
	Cleanen_pro time trend	Unadjusted	-2.5117	
		Adjusted	1.2037	0.8856
	Cleanen_pro first differences	Unadjusted	-4.3449	
		Adjusted	2.5594	0.9948
Im-Pesaran-Shin test	Cleanen_pro		0.9862	0.8380
	Cleanen_pro time trend included		1.9933	0.9769
	Cleanen_pro first differences		-2.4773	0.0066
Maddala & Wu test	Cleanen_pro	Inverse chi2	3.5383	0.8962
		Inverse normal	1.2947	0.9023
		Inverse logit	1.2799	0.8936
		Modified inv. chi2	-1.1154	0.8677
	Cleanen_pro time trend	Inverse chi2	0.9854	0.9983
		Inverse normal	2.5747	0.9950
		Inverse logit	2.5272	0.9908
		Modified inv. chi2	-1.7536	0.9603
	Cleanen_pro first differences	Inverse chi2	26.8146	0.0008
		Inverse normal	-2.5265	0.0058
		Inverse logit	-3.3008	0.0015
		Modified inv. chi2	4.7037	0.0000
Pesaran CIPS test	Cleanen_pro			0.913
	Cleanen_pro time trend included			0.418
	Cleanen_pro first differences			0.116

Table 8. Unit root test for Clean energy production

Once again, similar results have been obtained for fossil fuel energy consumption as a share of total. The LLC test shows unit root in all cases, but IPS and Maddala & Wu test are showing unit root but not for the first differences. In this regard, the series are integrated into the first order as well. The summary of the tests are presented in *Table 9* below:

Tests	Variable	Specification	Statistic	p-value
Levin-Lin-Chu test	Ffen_con	Unadjusted	-2.0441	
		Adjusted	-0.3156	0.3761
	Ffen_con time trend included	Unadjusted	-2.8922	
		Adjusted	2.5476	0.9946
	Ffen_con first differences	Unadjusted	-4.3628	
		Adjusted	2.5962	0.9953
Im-Pesaran-Shin test	Ffen_con		1.5153	0.9351
	Ffen_con time trend included		1.9183	0.9725
	Ffen_con first differences		-1.7361	0.0413
Maddala & Wu test	Ffen_con	Inverse chi2	2.9561	0.9371
		Inverse normal	1.7412	0.9592
		Inverse logit	1.8498	0.9617
		Modified inv. chi2	-1.2610	0.8963
	Ffen_con time trend included	Inverse chi2	4.1845	0.8401
		Inverse normal	2.1428	0.9839
		Inverse logit	2.3707	0.9869
		Modified inv. chi2	-0.9539	0.8299
	Ffen_con first differences	Inverse chi2	14.0239	0.0811
		Inverse normal	-1.7735	0.0381
		Inverse logit	-1.6925	0.0517
		Modified inv. chi2	1.5060	0.0660
Pesaran CIPS test	Ffen_con			1.000
	Ffen_con time trend included			1.000
	Ffen_con first differences			0.592

Table 9. Unit root test for Fossil Fuel energy consumption

Summarizing the unit root tests for each variable, it has been found that almost all variables are non-stationary, thus in the subsequent regressions, the first differences of the variables will be taken, i.e. they are integrated into the first level.

4.2 Results Fixed Effects Models

The results of the econometric estimates using fixed effect for the four model specifications are summarized in *Table 10*. As it was proposed in the hypothesis, the Environmental Kuznets curve can be observed in the selected countries from the results of the regressions.

The estimations give the expected results in terms of the signs of the coefficients for each variable. The statistical significance and the positive and negative signs respectively for per capita GDP (ln_GDP) and GDP per capita squared ($\ln\_GDP^2$) confirm the quadratic formulation of the environmental Kuznets curve in all models. In the basic model (1), it can be seen that the positive sign of the coefficient 1.608 for the GDP per capita (logged ln_GDP) indicates the positive impact of GDP growth on CO_2 emissions, while the inverse U-shape is depicted by the negative sign of the coefficient -0.096 for squared GDP. In the second model specification (2), other explanatory variables are added, namely, urban population growth and clean energy production. In this case, the negative coefficient -0.013 of the clear energy production variable confirms the expectations that it would have a negative impact on level of emissions, where the higher the share of clean energy production, the less emissions it leads to. The coefficient for urban population growth has obtained a negative sign (-0.001, which does the predictions made in the hypothesis and gives rather ambiguous results. However, the insignificant coefficient assumes that the result cannot be trusted in this case.

As for the third specification (3), fixed-effects with a control over years have been added. The results are similar to the one stated above in (2), which also confirm the validity of the expectations when the year-specific effects are controlled. The third specification gives relatively similar coefficients compared to the second specification, even though most of them are not significant when referring to the p-value. However, this model is set for demonstrating the validity of the theory, thus no particular attention needs to be paid. The last specification (4), substitutes the explanatory variable of clean energy production to fossil fuel energy consumption. The positive sign of its coefficient (0.027) indicates that an increase in fossil fuel energy consumption leads to more emissions. In all four model specifications, the existence of the inverse U-shaped curve has been observed, depicted by the corresponding signs of the coefficients for the main independent variables GDP per capita and GDP per capita squared. The results of fixed effect panel regression models have provided ambiguous results regarding the validity of the hypothesis suggested in the beginning of the research. On one hand, the coefficients have met our preliminary expectations presented in the beginning of the thesis. But on the other hand, the low significance level of the coefficients leaves us rather uncertain about the reliability of the obtained results.

Dependent variable ln_CO2	**(1)**	**(2)**	**(3)**	**(4)**
ln_GDP	1.601*	1.323*	0.798	0.569
	(0.874)	(0.811)	(0.746)	(0.597)
ln_GDP^2	-0.093	-0.067	-0.069	-0.001
	(0.094)	(0.087)	(0.081)	(0.064)
Urban population growth		-0.002	-0.006	-0.003
		(0.026)	(0.025)	(0.019)
Clean energy production		-0.013***	-0.005**	
		(0.002)	(0.002)	
Fossil fuel energy consumption				0.027***
				(0.002)
Constant	-0.0044	0.002	0.083***	0.006
	(0.008)	(0.008)	(0.034)	(0.006)
Observations	200	200	200	200
Number of groups	4	4	4	4
Year FE	no	no	yes	no
overall R^2	0.064	0.212	0.592	0.58

*Standard errors in parentheses *** p<0.01. ** p<0.05, * p<0.1*

Table 10. Fixed effect results

To summarize, empirical results for all four model specifications have demonstrated an ambiguous results regarding the validity of the theory of Environmental Kuznets curve in the case of Nordic countries, and with the increase in GDP per capita the level of CO_2 emissions first increase, and subsequently decrease as a results of more environmental regulations due to rising awareness and willingness to combat the negative environmental degradation caused by economic growth. The low significance level of the coefficients keeps us alert that the results are not highly reliable.

4.3 Results fixed effects through classification

In order to get a more deepened understanding of the EKC in the selected countries and to confirm the hypothesis by acquiring some more results, the countries have been grouped before running regressions. As it has been seen from the graphical inspection on the CO_2 emissions data (*Graph 1*), Sweden and Denmark seemed to have a more prominent trend of first increasing, and substantially decreasing level of CO_2 emissions compared to Norway and

Finland. Thus, Sweden and Denmark are combined into the first group, while Norway and Finland into the second. The results of the fixed effects results are presented in *Table 11*.

The empirical results show the validity of the EKC theory in the case of the Nordic countries. However, as it was seen from the graphical inspection, the selected four Nordic countries have considerable differences in the level of CO_2 emissions throughout years. Each country has its own slope and shape of EKC curve reflecting their stages of development and thus the changing relationship between growth and emissions. In this connection, it would be rather interesting to investigate the specific characteristics of each country's EKC. Thus, we will use the coefficients obtained in *Table 11* to estimate the turning points of EKC for each group of countries. In order to capture the point at which the relationship between GDP per capita and level of emissions started to become negative, i.e. downward sloping EKC curve, the turning points for each of the groups has been estimated as presented in *Table 12*. The third model has been excluded here, since its purpose is to show the consistence of the results when the time-specific effects are added, but it is not essential to the interpretation of results – the second model is sufficient to show the results.

Dependent variable: ln_CO2	**Sweden & Denmark**			**Norway & Finland**		
	(1)	**(2)**	**(4)**	**(1)**	**(2)**	**(4)**
ln_GDP	6.802*	6.244*	4.567*	2.569***	2.226**	0.812
	(4.104)	(4.044)	(2.531)	(1.073)	(0.953)	(0.814)
ln_GDP^2	-0.525	-0.473	-0.357*	-0.281**	-0.244**	-0.049
	(0.378)	(0.373)	(0.233)	(0.137)	(0.122)	(0.104)
Urban population growth		0.001	-0.016		-0.009	-0.003
		(0.053)	(0.033)		(0.031)	(0.025)
Clean energy production		-0.010***			-0.013***	
		(0.004)			(0.003)	
Fossil fuel energy consumption			0.029***			0.025***
			(0.002)			(0.003)
Constant	-0.023**	-0.019**	0.003	0.019*	0.019**	0.012
	(0.011)	(0.10)	(0.007)	(0.013)	(0.012)	(0.009)
Observations	100	100	100	100	100	100
Number of groups	2	2	2	2	2	2
overall R^2	0.125	0.178	0.677	0.036	0.259	0.501
*Standard errors in parentheses *** p<0.01. ** p<0.05, * p<0.1*						

Table 11. Fixed effect results through classification

As we can see from the fixed effect results and results after classification, the expected signs of the coefficients show better results regarding the existence of the curve compared to the fixed effect results in Table 10. The significance of the coefficients are higher in this case, which would indicate more appropriate results. However, the still low statistical significance reminds us that the reliability of the results are not so convincing, except for the coefficients for clean energy production. This can be explained by the fact that the effect of clean energy production is more observable. To connect this with the notion of changing energy intensity over time that was touched upon in the theory part, we can see that it is affected by the changing relationship between energy and output, and thus the changing relationship between output and emissions.

The corresponding GDP per capita value for the turning point of the EKC curve has been obtained through the formula used for estimating the turning point of a second order polynomial graph using the coefficients of the linear term and the coefficients for the squared form, or more specifically (Stern, 2003, revised),

$$\tau = [-\beta_1/(2\beta_2)] \quad (5)$$

Table 11 shows the turning points measured in logged GDP per capita for each of the groups model specifications (the third one is excluded since it was just for demonstrating the results when time-specific effects are added). The coefficients of the squared GDP are not very low compared to some of the other studies (e.g. Arbulu *et al.,* 2015), which is related to a relatively low turning point. Though it might look surprisingly at the first sight, but the results actually correspond to the graphical inspection presented earlier. As it is shown in *Table 11*, the group of Sweden and Denmark has a higher turning point in terms of logged GDP compared to the group of Norway and Finland, which indicates that Sweden and Denmark had to reach a higher level of GDP per capita before the emissions level started to decrease.

	(1)	(2)	(4)
Sweden & Denmark	6.478	6.601	6.089
Norway & Finland	4.571	4.561	8.286

Table 12. Turning points of EKC, ln_GDP

However, the obtained results are rather reasonable, since it means that even though the first group had to reach a higher level of GDP before the emissions started to decrease, it happened much earlier than it started in Norway and Finland. Put it in another way, Norway and Finland reached the turning point at a lower level of GDP per capita, but the change in emissions begun at a much later point of time. Such interpretation can also be proved by the graphical inspection done previously (refer to *Graph 1*).

5 Conclusion

The outcomes of economic growth on environment has created ground for scientific research. A number of studies have approached the topic using different proxies for growth and the environmental degradation based on the theory of the Environmental Kuznets Curve (EKC). Among them, the impact of growth on carbon dioxide emissions is one of the most researched relationships. Different studies have provided rather varying results.

In this research, the empirical results of the relationship between GDP per capita and carbon dioxide emissions have provided rather ambiguous results regarding the validity of the theory for the Nordic countries. The results of the panel data for the period 1961 to 2010 have shown first an increase, and subsequently a decrease in levels of emissions with the increase of GDP per capita. This should indicate the validity of the inversely U-shaped curve as proposed by the theory. However, the low significance level of the obtained coefficients suggests that the results are rather ambiguous. Thus, there is no clear support of the theory even at 10% significance level. Nevertheless, clean energy production, on the other hand, improves the environmental conditions by having a negative impact on the carbon dioxide emissions.

Moreover, results after grouping the countries into pairs of two, Sweden & Denmark and Norway & Finland, it has been found that the two groups have shown different patterns. The results after classification provided with similar results as those prior to classification. The first group has a higher turning point of GDP per capita after which the levels of emission started to decrease, even though the decrease started at an earlier point of time. In contrast to that, the second group of countries reached the turning point later, but with a lower turning point of GDP per capita, which can be explained by the advantage of a late-comer by adoption of more advanced technologies which were already used in practice. Reflecting the results with scale effect suggested by Stern (2003), in more advanced economies like the Nordic region, emissions-reducing technological change is able to overcome the scale effect of economic growth on emissions. This is in line with the main idea of the ecological modernization theory, where the technological development is considered to be crucial for achieving sustainable growth with reduced burden to the environment.

The research on the EKC of the Nordic countries made an attempt to contribute to the debate of the validity of the EKC theory, and has added more to the proponents of the theory. However, this research, just like the others in the field, has a number of limitations. First, the period of consideration is 50 years, which may not be sufficient to understand the broader picture of the long-term relationship between growth and emissions. Moreover, the selection of explanatory variables was rather modest, thus it might not reflect other factors that have had an impact on the increase/decrease of the levels of emissions. Just as Stern (2003) pointed out, "*Rigorous answers to such questions are central to the debate on globalization and the environment"*. Thus, room for future research on the topic of EKC is still expected to be filled with new researches.

6 References

Abesamis, J., Campos, J. C., Castello, C. (2013), "Estimating the effects of urbanization on carbon emissions: evidence in the Philippines", *Young Economists' Perspective,* Vol. 7, No. 1

Al-Malali, U. and Ozturk, I. (2015), "The investigation of environmental Kuznets curve hypothesis in the advanced economies: the role of energy prices", *Renewable and Sustainable Energy Reviews,* 54, pp.1622-1631

Apergis, N. (2015), "Environmental Kuznets curves: New evidence on both panel and country-level CO_2 emissions", *Energy Economics,* Vol. 54, pp.263-271

Arbulu, I., Lozano, J. and Rey-Maquieira, J. (2015), "Tourism and solid waste generation in Europe: A panel data assessment of the Environmental Kuznets Curve", *Waste Management,* 46, pp. 628-636

Arrow, K., Bolin, B., Constanza, R., Dasgupta, P., Folke, C., Holling, C. S., Jansson, B.-O., Levin, S., Mäler, K.-G., Perrings, C.A., and Pimentel, D. (1995), "Economic growth, carrying capacity, and the environment", *Science,* 268, pp.520-521

Ben Nasr, A., Gupta, R. and Sato, J. R. (2015), "Is there an Environmental Kuznets Curve for South Africa? A co-summability approach using a century of data", *Energy Economics,* 53, pp.136-141

Bilgili, F., Kocak, E. and Bulut, U. (2015), "The dynamic impact of renewable energy consumption on CO_2 emissions: A revisited Environmental Kuznets Curve approach", *Renewable and Sustainable Energy Reviews,* Vol. 54, pp.838-845

Cole, M. A., Rayner, A. J., & Bates, J. M. (1997), "The environmental Kuznets curve: An empirical analysis", *Environment and Development Economics*, No. 2(4), pp. 401– 416

Copeland, B. R. and Taylor, M. S. (2004), "Trade, growth and the environment", *Journal of Economic Literature,* 42, pp.7-17

Egli, H. (2002), "Are Cross-Country Studies of the Environmental Kuznets Curve Misleading? New Evidence from Time Series Data for Germany", *Climate Change Modelling and Policy,*

accessed online on Social Science Research Network on
http://papers.ssrn.com/sol3/papers.cfm?abstract_id=294359

Enflo, K., Kander, A. and Schön, L. (2009), "Electrification and energy productivity", *Ecological Economics,* 68, pp.2808-2817

Global Innovation Index (2015), "Global Innovation Index 2015: Effective Innovation Policies for Development", accessed online 26 April, https://www.globalinnovationindex.org/userfiles/file/reportpdf/GII-2015-v5.pdf

Grossman, G. M. and Krueger, A. B. (1991), "Environmental Impacts of a North American Free Trade Agreement", *National Bureau of Economic Research Working Paper 3914*, NBER, Cambridge MA

Gujarati, D. N. and Porter, D. C. (2009), *Basic Econometrics,* 5th edition, Boston: McGraw Hill

Hajer, M. A. (1997), *The Politics of Environmental Discourse: Ecological Modernization and the Policy Process,* Oxford University Press

Halkos, G. E. (2003), "Environmental Kuznets Curve for sulfur: evidence using GMM estimation and random coefficient panel data models", *Environment and Development Economics,* Issue 4, pp.581-601

Jebli, M. B., Youssef, S. B. and Ozturk, I. (2015), "Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries", *Ecological Indicators,* 60, pp.824-831

Kander, A. (2002), *Economic Growth, Energy Consumption and* CO_2 *Emissions in Sweden 1800-2000,* Lund Studies in Economic History, Vol. 19, Almqvist and Wiksell International, Stockholm

Kaufmann, R. K., Davidsdottir, B., Garnham, S. and Pauly, P. (1998), "The determinants of atmospheric SO_2 concentrations: reconsidering the environmental Kuznets curve", *Ecological Economics,* Vol. 25, Issue 2, pp.209-220

Kunnas, J. and Myllyntaus, T. (2007), "The Environmental Kuznets Curve Hypothesis and Air Pollution in Finland", *Scandinavian Economic History Review*, Vol. 55, Issue 2

Kuznets, S. (1955), "Economic Growth and Income Inequality", *The American Economic Review,* Vol. 45, No.1

Kuznets, S. (1963), "Quantitative Aspects of the Economic Growth of Nations: VIII. Distribution of Income by Size", *Economic Development and Cultural Change,* Vol. 11, No. 2, Part 2, pp.1-80

Li, T., Wang, Y. and Zhao D. (2016), "Environmental Kuznets Curve in China: New evidence from dynamic panel analysis", *Energy Policy,* 91, pp.138-147

Lindmark, M. and Acar, S. (2015), "The environmental Kuznets curve and the Pasteur effect: environmental costs in Sweden 1850-2000", *European Review of Economic History,* 18, pp.306-323

Lopez, R. (1994), "The environment as a factor of production: The effects of economic growth and trade liberalization", *Journal of Environmental Economics and Management*, No.27, pp.163-184

Nasr, A. B., Gupta, R. and Sato, J. R. (2015), "Is there an Environmental Kuznets Curve for South Africa? A co-summability approach using a century of data", *Energy Economics,* Vol. 52, Part A, pp.136-141

Nordic Energy Research (2016), "Nordic Energy Technology Perspectives 2016: Cities, flexibility and pathways to carbon-neutrality", *Nordic Energy Research*, Oslo

Nordic Innovation Publication (2012), "Towards a new innovation policy for green growth and welfare in the Nordic Region", *Nordic Innovation,* Oslo

Panayotou, T. (1993), "Empirical tests and policy analysis of environmental degradation at different stages of economic development", *Working Paper WP238*, Technology and Employment Programme, International Labour Office, Geneva

Poumanyvong, P. and Kaneko, S. (2010), "Does urbanization lead to less energy use and lower CO_2 emissions? A cross-country analysis", *Ecological Economics,* Vol. 70, Issue 2, pp.434-444

Sadorsky, P. (2013), "The effect of urbanization on CO_2 emissions in emerging economies", *Energy Economics,* 41, pp. 147-153

Shafik, N. and Bandyopadhyay, S. (1992), "Economic Growth and Environmental Quality", *World Development Report,* Working papers WPS 0904

Song, T., Zheng, T. and Tong, L. (2007), "An empirical test of the environmental Kuznets curve in China: A panel cointegration approach", *China Economic Review,* 19, pp. 381-392

Spaargaren, G. and Mol, A. (1992), "Sociology, environment, and modernity: Ecological modernization as a theory of social change", *Society & Natural Resources: An international Journal,* Vol. 5, Issue 4, pp.323-344

Spaargaren, G., Mol, A., Buttel, F.H. (2000), *Environment and Global Modernity,* Edited, Sage Publications, London

Stern, D.I. (2003), "The Rise and Fall of the Environmental Kuznets Curve", *World Development,* Vol. 32, No.8, pp.1419-1439

Stern, D. I. and Common, M. S. (2001), "Is There an Environmental Kuznets Curve for Sulfur?", *Journal of Environmental Economics and Management,* Vol. 41, Issue 2, pp.162-178

Stern, D. I., Common, M. S. and Barbier, E. B. (1996), "Economic growth and environmental degradation: The environmental Kuznets curve and sustainable development", *World Development,* 24, pp.1151-1160

Suri, V., & Chapman, D. (1998), "Economic growth, trade and the energy: Implications for the environmental Kuznets curve", *Ecological Economics*, Issue 25, pp.195–208

Todaro, A. P. and Smith, S. C. (2011), *Economic Development,* Addison-Wesley, The Pearson series in economics

Xu, B., Wennersten, R. and Brandt, N. (2012), "A project turning point in China's CO_2 emissions – an Environmental Kuznets Curve analysis", *Int. J. Global Warming,* Vol. 4, No. 3/4

Data sources:

The World Bank database: http://data.worldbank.org/, accessed on 25 April

AMECO database (Annual Macro-economic database of the European Commission):

http://ec.europa.eu/economy_finance/ameco/user/serie/SelectSerie.cfm, accessed on 26 April