Environmental Kuznets Curve in Sweden

A regression analysis of the relationship between CO_2 emissions and economic growth in Sweden during the years of 1960-2018

Daniel Forsström
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Abstract:

The Environmental Kuznets Curve (EKC) is a theory suggesting the existence of an inverted U-shaped relationship between emissions and economic growth. In today's world of environmental awareness, it is an interesting topic since it suggests that when economic growth reaches a certain point, pollution actually starts decreasing as economic welfare increases. Thereby implying that it is possible to enhance the living standards for the population of both developing and developed countries, without causing environmental decay.

This study aims to investigate whether the EKC theory holds true for CO_2 emissions in the case of a country at the very forefront of sustainability, namely Sweden. The method used in this investigation is a parametric regression analysis using quadratic, cubic, and quartic variables. Ultimately, the study finds evidence supporting the existence of an inverted U-shaped EKC type relationship between CO_2 emissions and GDP per capita in Sweden during the years of 1960-2018. However, it is not clear if this finding is due solely to economic growth or whether it is a consequence of other interfering factors like policies, public opinion, technological advancements, sectorial changes, or historical economic trends.

Bachelor's thesis in Economics, 15 credits

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1 | Introduction

This is a study of an interesting, yet somewhat forgotten, concept within the field of environmental economics. Initially, the EKC is explained in the context of today's world of climate change and economic growth. Consequently, this motivates the purpose, along with its aim and research question of this study.

1.1 Background

Out of all Greenhouse gases (GHGs) emitted by human activities, Carbon dioxide (CO_2) is by far the most abundant one on a global scale (IPCC, 2014). According to the 2014 IPCC report, CO_2 stands for more than three quarters (76 percent) of GHG emissions, and the rate of CO_2 emitted in the atmosphere increases every year (Boden, Marland & Andres, 2017).

Some practitioners and experts argue that this trend of increasing pollution traditionally has been a consequence of the urge to achieve economic growth (Gore, 2006). Nevertheless, we have seen through the course of history that increasing economic growth, usually correlates with reducing poverty (Adams, 2008). The way countries have pursued economic growth in the past has most often been through the exploitation of natural resources (Lindmark, 2002). Hence, one could argue that some emissions are justified by the fact that they are a direct consequence of bringing people out of poverty and increasing their living standards.

The theoretical concept called the Environmental Kuznets Curve, or simply EKC, addresses the relationship between pollution and economic growth. This concept was first mentioned in the early 1990s by Grossman and Krueger (1991). In short, the theory suggests that during the early stages of economic growth, the pollution level of a country increases as the country becomes wealthier, but only up to a certain point. At this *turning point*, income per capita reaches a level where the relationship is reversed. The pollution level of the said country then starts decreasing as economic welfare increases. Consequently, the relationship can be illustrated by an *inverted U-shaped* curve (Dasgupta, Laplante, Wang & Wheeler, 2002).

Since the Environmental Kuznets Curve addresses the correlation between economic growth and negative environmental impact in terms of pollution, we find EKC to be a highly relevant theory in the field of environmental economics. Essentially, proving the EKC hypothesis is a matter of assessing whether economic growth and environmental friendliness can go hand in hand. Since the EKC addresses both these issues, as it aims to make sense of the correlation between the two subjects, it is as relevant of a topic now as ever. Providing evidence supporting the EKC theory in the case of a developed country at the forefront of sustainable development can act as an example showing the rest of the world that welfare and sustainability can go hand in hand.

1.2 Relevance to the academic field

Most of the studies previously conducted on the subject of EKC are more or less limited by their empirical data (Dasgupta et al., 2002). One major factor as to why this has been the case is that these studies, aiming to prove the EKC, was conducted more than fifteen years ago. Hence, we believe that a great deal of the criticism regarding the EKC's practical implications has been a consequence of the significant limitations with regards to data needed to support (or disprove) the theory. The data regarding different countries' pollution levels are far more comprehensive in 2020, especially for developed countries like Sweden. Therefore, our firm belief is that it is now possible to collect sufficient empirical data to assess whether the EKC hypothesis holds in practice.

Stern, Common and Barbier (1996) suggest that a promising approach to study the real-life vitality of the EKC curve is to investigate time series data of a single country. Furthermore, according to He and Richard (2010), only a few studies have been conducted in this manner, due to the scarcity of data. A country that has become one of the wealthiest countries on earth is Sweden (The World Bank, 2020). Moreover, Sweden is often regarded as a country at the very forefront of sustainable development (UN, 2017). This notion is confirmed by Lindmark (2019), who goes on to stress that Sweden's low CO_2 emission levels can be due to the fact that it has the highest CO_2 tax of any country.

As to the case of Sweden, there have been a few studies investigating whether there could be an EKC type relationship. For example, Lindmark (2002, page 345), stresses towards the end of his paper on EKC in Sweden, that there is a "need for further studies on the EKC from a historical perspective." Furthermore, Lindmark (2019) states that there are apparent markers suggesting an EKC type relationship when considering historical data regarding Sweden. In summary, we believe that shedding light on EKC with regards to the case of Sweden will provide a sound foundation for an exciting and highly relevant research study.

1.3 Aim and Research Question

The aim of this paper is, therefore, to assess whether there is proof supporting the Environmental Kuznets Curve theory in Sweden. The study focuses on CO_2 emissions, due to its relevance to the development of the world and its gap in the available literature. Thus, the following research question is answered in this study:

Does the hypothesised relationship between CO_2 emissions and economic growth represented by the Environmental Kuznets Curve hold true in the case of Sweden?

1.4 Thesis outline

This paper starts with an introduction to the research study, presented in Chapter 1. A background to the study and its relevance to the academic field, followed by the aim and research question, are included in this chapter. Chapter 2 presents the theoretical framework, which defines and discusses topics relevant to the research study. Topics such as the Swedish economic-, sectoral- and economic climate, air pollution and the EKC are accounted for here. Chapter 3 encompasses the study's methodology and data collection, together with a reflection on the research approach. The empirical data representing all variables used as inputs for the model are introduced in Chapter 4. Moreover, the results and findings of the research are displayed in Chapter 5, using both numerical values and illustrations. Subsequently, Chapter 6 presents a discussion, building on the findings and anchored in the theoretical framework. The limitations of the study are also included here. Lastly, a conclusion, along with suggestions for future research, can be found in Chapter 7.

2 Theoretical framework

This chapter addresses the concepts, theories and information discussed in the subsequent chapters of this paper. Furthermore, the previous academical contributions to the field of EKC deemed relevant to this study are presented as well.

2.1 Sweden's economic growth and sectoral development

Gross Domestic Product per capita (GDP per capita) constitutes a good measure of standard of living (The Balance, 2020). It is a measure of how much is produced in a country per inhabitant and can be extrapolated to represent the amount of money an average individual has to spend (Eklund, 2013). Hence, increasing a country's GDP per capita, regardless of whether the country is a developing or a developed country, is usually positive for the inhabitants of that country. However, the increase may come at the cost of environmental decay, a trade-off that the EKC addresses.

Figure 2.1 illustrated how the Swedish GDP composition of economic sectors have developed between 1960 and 2010. The growth of the service sector, at the expense of the industrial and agricultural sectors, represents how the Swedish economy and the workforce within different sectors, have developed (SCB, 2018). From Figure 2.1, it is evident that Sweden has gone through a transformation of its economy, moving from an era of industrialisation to an era of servitisation.

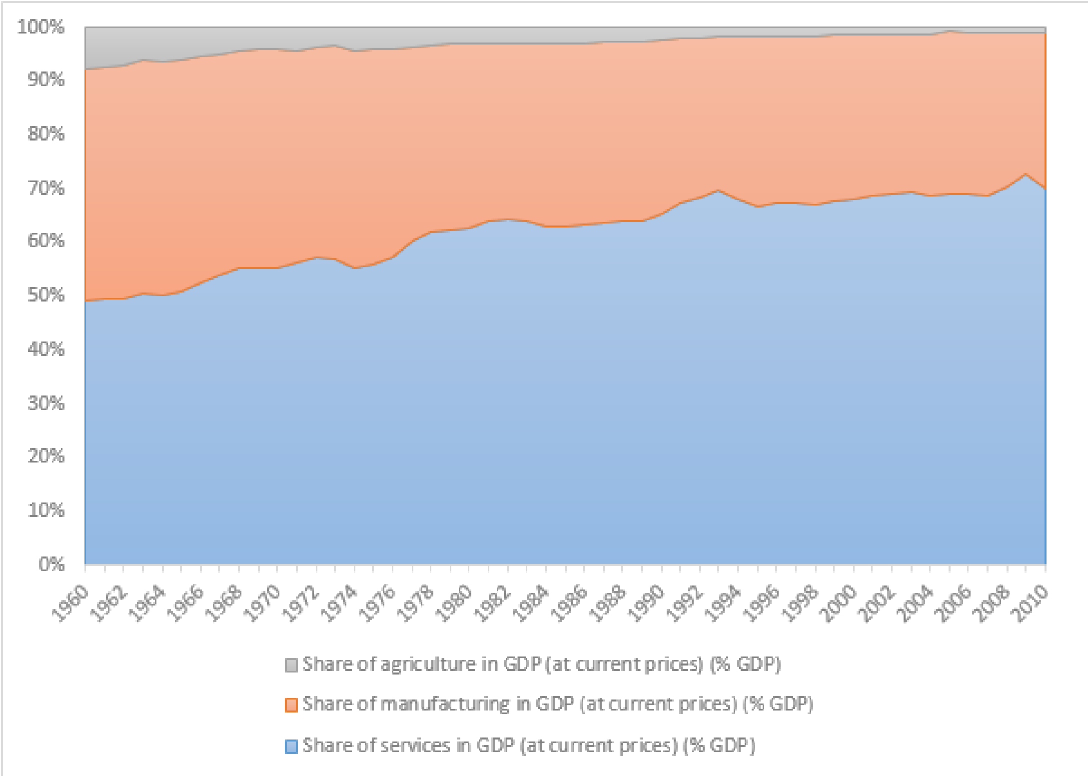

Figure 2.1: Shares of GDP by economic sector in Sweden during 1960-2010 (sourced from Ortiz-Ospina and Lippolis (2017))

Alongside international trade, *industrialisation* has long been the primary driver of economic growth for most countries (Wong & Yip, 1999). Developing from an agricultural society to an industrial one has historically been the cornerstone in bringing people out of poverty. However, over the last 30 years, there has been a significant shift in the Swedish economy, upsetting this century-old notion (Eklund, 2013). This disrupting trend is called *servitisation*. Kowalkowski, Gebauer, Kampdge, and Parry (2017) define servitisation as the "transformational process of shifting from a product-centric business model and logic to a service-centric approach." According to Clark (1941) and Kuznets (1957), the change from manufacturing to services is part of the economic development of a country. This change may constitute a way of obtaining economic growth without harming the environment in the form of increased CO_2 emissions.

In context to Figure 2.1, some main attributes have played a part in shaping the Swedish economy in the last 60 years. To start with, Sweden is a relatively small domestic market, where many industries have become heavily reliant on export markets (Carlgren, 2015a). Hence, during the 1970s, the Swedish economy was quite severely affected by the changes in international trade conditions and its adverse effects on export (Carlgren, 2015b).

Schön (2008) describes the structural change that intensified within Sweden's economy during the 1980s, engaging both the public and private sector. Sweden experienced an industrial downfall, where a lot of heavy Swedish industry moved to less developed countries. Despite this downfall, new growth forces appeared with the electronic revolution and a more advanced service-based economy. As the Swedish economy reshaped into a more knowledge-intensive economy in the 1980s, new industries such as pharmaceutics, IT-based telecommunication, advanced technology, as well as new service industries emerged.

2.1.1 Swedish environmental movement and policies

Sweden is a country at the forefront of environmental economics and sustainable growth (UN, 2017). There are numerous examples of this throughout the course of history. Two such examples are that, in 1969, Sweden became the first country in the world to form an environmental protection act and that Sweden hosted the first UN conference on the global environment (The Swedish Environmental Protection Agency, 2012; Hinde, 2020)

Sweden has thereafter remained at the forefront of the global environmental movement (Hinde, 2020). For example, Sweden has been ranked top 10 in the globally respected Environmental Performance Index every year since the launch in 2006 ("Environmental Performance Index", 2019, 23 November). The Swedish grass-roots environmental movement has also intensified during the last few years with profiles like Greta Thunberg, concepts like "Flygskam" and growing social stigma against leaving a large carbon footprint (Lyn Pesce, 2019). Today, Sweden has robust policies and legislation aimed at reducing GHG emissions, including a national energy supply of more than 50 percent renewable energy (Hinde, 2020), and the highest CO_2 taxes of any country (Lindmark, 2019). However, Sweden shows no indications of slowing down its efforts, and the government has set ambitious sustainability goals for the future, including becoming fossil-free by 2045 (Hinde, 2020).

2.2 Air pollution

The effects of air pollution on various aspects of human health and the environment has been well known for several decades. Back in 1977, Arthur C. Stern provided evidence of the negative effects of air pollution on the "physical properties of the atmosphere," "human health" and "economic materials and structures" just to name a few (Stern, 1977). Air pollutants such as carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NOx) and respirable particulate matter (PM2.5 and PM10) are known to change the atmosphere as well as to inflict chronic and acute effects on human health (Kampa & Castanas, 2008). Furthermore, scientists and experts are nowadays remarkably unanimous in the fact that pollution (especially air pollution) has a considerable impact on climate change and the loss of biodiversity all over the globe (e.g. Sicard et al., 2016).

However, several studies conducted in the 1990s and 2000s assert that there is a lack of pollution data that consequently limits their ability to draw decisive conclusions regarding the EKC (e.g. Dasgupta et al., 2002). However, due to the increasing environmental awareness, regulations and initiatives, this has changed a lot over the last 20 years. Consequently, the prerequisites for conducting a study based on pollution data has changed accordingly. Nowadays, it is a lot easier to get access to quality pollution data for countries all over the world. The Kyoto protocol has especially contributed to the measuring and reporting of a select few GHGs.

Carbon dioxide is the most abundant out of all GHGs emitted by human activities (IPCC, 2014). In 2010, CO_2 emissions accounted for 76 percent of all global GHG emissions in terms of CO_2-eq (IPCC, 2014). The vast majority of CO_2 emitted by human actions comes from the burning of fossil fuels (EIA, 2019). In order to make different GHGs comparable, gases are usually converted to *carbon dioxide equivalent* ($C0_2$-eq), which is a metric that represents the difference in *Global Warming Potential* (GWP).

Due to human activities, like the industrialisation, the CO_2 in the atmosphere has increased exponentially from 284 ppm in 1850 to 409 ppm in 2018 (Ritchie & Roser, 2019). Over half of the world's CO_2 emissions nowadays come from Asia, where China alone stands for 27 percent of the global pollution volume (Ritchie & Roser, 2019). Furthermore, the US stands for 15 percent, and EU-28 stands for 9.8 percent of global emissions (Ritchie & Roser, 2019), whereas Sweden's CO_2 emissions account for about 0.12 percent of the global total (Ritchie & Roser, 2019; The World Bank, 2019b).

2.3 Environmental Kuznets curve

The theory behind the Environmental Kuznets curve was introduced by Grossman and Krueger (1991) in their paper: Environmental Impacts of a North American Free Trade Agreement. In their study of urban areas, they found that for some pollutants (sulphur dioxide and "smoke") the concentrations increased with economic growth when GDP per capita was low and then decreased when GDP per capita was high. A few years later the relationship was given its name, after the Nobel prize-winning economist and statistician Simon Smith Kuznets. Kuznets had, in his research, shown an inverted U-shaped relationship between economic growth and income inequalities in growing economies, called the *Kuznets curve* (Kuznets, 1966). The EKC displays a similar inverted U-shaped relationship, but between environmental degradation and economic growth (see Figure 2.2 below). The theory can be applied to different pollution types and their correlation to economic growth (Yandle, Bhattarai & Vijayaraghavan, 2004).

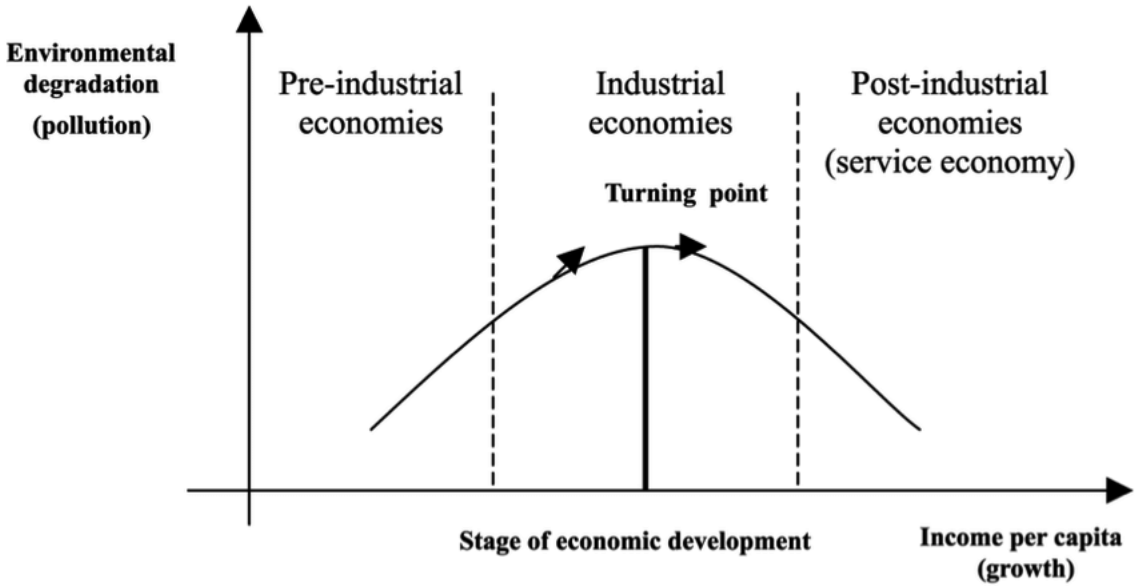

Figure 2.2: Environmental Kuznets Curve, illustrating the relationship between income per capita and pollution (Panayotou, 1993)

As illustrated in Figure 2.2 above, the theory suggests that in the early stages of economic growth, the pollution level of a country increases as the country get wealthier, in the form of a positive correlation between the variables. This is true as long as the country is in a pre-industrial state. However, as the country becomes industrialised, the economy reaches a *turning point*. In other words, income per capita reaches a level where the relationship is reversed. The pollution level of the country then starts to decrease as the economy grows, displaying a negative correlation between the variables. This occurs when the country reaches its service economy phase. As a result, the full relationship can be illustrated by an inverted U-shaped curve (Dasgupta et al., 2002).

2.3.1 Influential EKC studies in the world

Since Grossman and Krueger's report of 1991, there have been several studies supporting EKC with empirical data on different types of pollution. Most studies show empirical evidence in favour of EKC (Bruyn, Bergh & Opschoor, 1998). For example, Selden and Song (1994) find that all four air pollution types addressed in their study (SO_2, NOx, SPM and CO_2) follow an inverted U-shaped relationship with economic growth. Although their results are somewhat ambiguous, Shafik and Bandyopadhyay (1992) conclude in their background paper for the World Bank, that some indicators follow the EKC theoretical relationship. However, they state that "it is possible to grow out of some environmental problems, but there is nothing automatic about doing so" (Shafik & Bandyopadhyay, 1992, page 1). In addition to this statement stressing the importance of government involvement and policies, they also point out that technology seems to be an essential factor in reducing environmental decay (Shafik & Bandyopadhyay, 1992).

Maddison (1991; 2001) compares the CO_2 per capita levels from three different countries and points in time, with similar income levels: Great Britain in 1870, Sweden in 1913 and Indonesia in 1995. They find that the Swedish CO_2 per capita was 40 percent of the British and Indonesia was just 15 percent of the British, although all countries had the same GDP per capita (Maddison, 1991; 2001). The reason why the countries experienced similar income levels but very different CO_2 levels may be due to technological advancements and that the economic climate has changed over the years (Lindmark, 2002).

Regarding the relationship between CO_2 and GDP per capita, an influential study on Canada was conducted using data from 1948-2004 (He & Richard, 2010). Utilising a regression analysis of parametric cubic models as well as more flexible estimation methods, they find little evidence supporting the existence of an EKC type relationship between CO_2 and GDP per capita (He & Richard, 2010). Neither do they find proof that any of the commonly used control variables like oil price, sectorial shifts or international trade fluctuations, have a significant impact on the CO_2 level (He & Richard, 2010).

2.3.2 EKC studies in Sweden

Regarding the literature on EKC in the case of Sweden, there are some valuable contributions to the field that this study takes into account. Lindmark (2002) investigates the historical relationship between CO_2 per capita and GDP per capita during a time period of 1870-1997. The study uses a logarithmic model, incorporating a stochastic trend to account for technological- and structural change, as it attempts to assess what factors affect the CO_2 per capita of Sweden (Lindmark, 2002). Lindmark (2002) concludes that over the time period, CO_2 per capita seems to depend on GDP.

Moreover, Lindmark (2002) finds that technological advancement may have had a constant effect on CO_2 per capita during the entire time period. In addition, the study concludes that price changes and structural changes also affect CO_2 emission levels (Lindmark, 2002). Lastly, Lindmark (2002) divides the Swedish economic development out of an environmental perspective into three parts: 1870 to World war 1 - High, but diminishing rate of increase in emissions, World war 1 to 1960s - High emission increase due to economic growth, and 1960s to 1997 - Decrease in emissions due to technological advancements.

Another study that divides the data into time intervals is Johansson and Kriström (2007). In their investigation of the potential EKC relationship between Swedish sulphur emissions to GDP during the time period of 1900-2002, they suggest four regimes: 1900–1918, 1919–1933, 1934–1967 and 1968– 2002 (Johansson & Kriström, 2007). Moreover, they do not find any clear evidence supporting the existence of an EKC curve in the case of Sweden (Johansson & Kriström, 2007). They conclude that preferences and technology affect emissions rather than economic growth (Johansson & Kriström, 2007). Neither does BEŞE (2018) find any evidence of EKC in his study on the relationship between CO_2 and GDP in Sweden. BEŞE (2018) goes on to state that economic growth is not likely to reduce emissions in Sweden. Instead, the government should continue to apply emission reduction policies since these policies do not decrease economic growth (BEŞE, 2018).

There are, however, some studies confirming the EKC for CO_2 in Sweden. In their study on Swedish municipalities, Marbuah and Amuakwa-Mensah (2017) find an EKC relationship for CO_2. Moreover, Urban and Nordensvärd (2018) confirm the presence of an EKC relationship for CO_2 per capita in Sweden, when conducting their study on EKC in Nordic countries. In summary, the studies on EKC in Sweden display ambiguity in their findings regarding whether there exists an inverted U-shaped relationship between pollution and economic growth. Moreover, they provide different insights as to which additional factors affect pollution levels.

2.3.3 Alternative theories

The EKC, at least in part, makes intuitive sense. Firstly, most types of pollution levels are bound to rise when economies grow and become increasingly industrialised (Dasgupta et al., 2002). Secondly, when countries' economic welfare grows beyond the turning point, they give more care to their environmental impact, and thus the pollution levels fall (Dasgupta et al., 2002). The first part of this reasoning is straight-forward and provides little subject for debate. However, there are controversies regarding whether the reasoning behind the second part of the curve holds in reality (Bruyn et al., 1998). In fact, there are many conflicting theories with sound empirical support that explains the relationship between economic growth and pollution, like *New Toxics*, *Race to the bottom* or *Revised EKC*, just to name a few (Dasgupta et al., 2002). Figure 2.3 below illustrates these alternative theories in a graph together with the Conventional EKC.

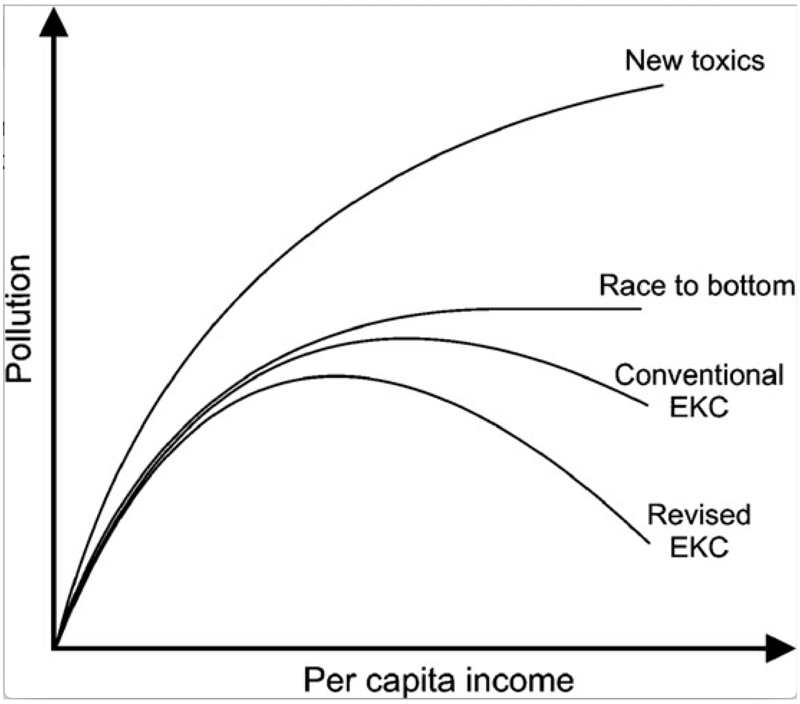

Figure 2.3: Conventional Environmental Kuznets Curve compared to three alternative theories: New Toxics, Race to bottom and Revised EKC (Dasgupta et al., 2002)

The *New Toxics theory* suggests that with increasing industrialism comes new types of pollution (Dasgupta et al., 2002). The reason for the ever-increasing pollution level is, according to the theory, that these new toxics are increasing at a faster pace than the governments of the countries can change their legislation in order to ban them by law. A second theory called the *Race to the bottom* theory also discourages the notion that there exists a decline in pollution with increasing economic growth. Instead, it suggests that the pollution levels will converge towards a horizontal line due to globalisation (Dasgupta et al., 2002). In contrast to these pessimistic theories, supporters of the *Revised EKC* theory believes that the EKC should actually be shifted to the left due to less pollution taking place in the early stages of industrialisation (Dasgupta et al., 2002).

In addition to these alternative theories, the actual shape of the EKC has been debated in the literature too. Some examples of such debates are the Logarithmic function of Stern (2004) or the N-shaped function suggested by Pezzey (1989) and Opschoor (1990).

3 Methodology

This chapter is dedicated to the methodology of the study, explaining the research approach and the data collection. A critical reflection on the research approach is also presented here.

3.1 Research approach

In general, the methodology of this study follows that of the 2010 article: "Environmental Kuznets curve for CO_2 in Canada" (He and Richard, 2010). In short, He and Richard (2010) conducted a study on whether Canada's CO_2 per capita emissions follows an inverted U-shaped relationship with regards to the GDP per capita, like the one suggested by the EKC theory. This study will also focus on the case of a single country, namely Sweden.

The research approach of this paper is of a quantitative nature. A quantitative approach involves, in most cases, a compilation of numerical data aiming to provide insight into stated hypotheses (Given, 2008). The quantitative approach is well suited for studies using empirical investigations of observable phenomena (Given, 2008). Furthermore, according to Given (2008), a quantitative approach suits a process like the one of this paper, which relies on measurements to provide quantitative relationships of empirical observations. Therefore, such an approach was deemed suitable for the research study of this paper.

To investigate the hypothesis of the EKC, this study first collects data to represent the outcome variable (CO_2 per capita) as well as the variable of interest (GDP per capita) and then visualises the relationship in graphs. The reason for using the graph as a starting point for the study is to gain an initial understanding of whether the proposed relationship of the EKC theory holds true in practice. At this first stage, the analysis is in the form of ocular inspection of the curve.

Subsequently, following the approach of He and Richard (2010), regressions using nonlinear models is run in order to test the EKC hypothesis. Since it cannot be concluded that the variables used for each model are the only ones affecting the output variable, all regressions are robust, meaning that they do not assume homoscedasticity. The results of the regressions using the following quadratic, cubic and quartic models in combination with control variables are analysed:

(1) $\text{co2percapita} = \beta_1 \text{ gdppercapita} + \beta_2 \text{ gdppercapita}^2 + \alpha_1 \text{ time} + U$

(2) $\text{co2percapita} = \beta_1 \text{ gdppercapita} + \beta_2 \text{ gdppercapita}^2 + \beta_3 \text{ gdppercapita}^3 + \alpha_1 \text{ time} + U$

(3) $\text{co2percapita} = \beta_1 \text{ gdppercapita} + \beta_2 \text{ gdppercapita}^2 + \beta_3 \text{ gdppercapita}^3 + \beta_4 \text{ gdppercapita}^4 + \alpha_1 \text{ time} + U$

(4) $\text{co2percapita} = \beta_1 \text{ gdppercapita} + \beta_2 \text{ gdppercapita}^2 + \beta_3 \text{ gdppercapita}^3 + \alpha_1 \text{ time} + \alpha_2 \text{ oilprice} + \alpha_3 \text{ exports} + \alpha_4 \text{ imports} + U$

The α and β values are the coefficients of the variables. For the sake of simplicity, the βs represent coefficients of the different degrees of the GDP per capita-variables. The αs, on the other hand, represent the time trend variable *time* as well as the control variables: oil price, imports and exports.

The first model is a quadratic model without the use of control variables (Model 1). This is considered a good starting point for investigating a U-shaped relationship since the slope of the curve is changing as the variable of interest is changing. Hence, it makes more sense for the starting point to be a quadratic model than a linear one.

Model 2 is a cubic function introducing the variable gdppercapita^3. The reason for this is to test whether there is an inherent cubic relationship present in the data. Model 3 adds yet another layer to the analysis by investigating whether the relationship can be quartic. Hence it includes gdppercapita^4 to the equation. Lastly, Model 4 incorporates some control variables (which are further explained and discussed in the next section). The degree of the function chosen for the adding of the control variable test is the cubic one.

3.2 Data collection

This section is dedicated to present the data collection process and the sources used for accessing data. All data gathered for this study is of secondary nature, meaning that the measurements are not done first-hand by the authors of this paper.

3.2.1 Data collection for the regression analysis variables

He and Richard (2010) used a time-series data set, ranging between 1948 and 2004 in their study. Furthermore, they collected data representing eight variables namely: CO_2 per capita, GDP per capita, crude oil price, industry share of production, exports of oil, imports of oil, exports to the US, imports from the US (He and Richard, 2010). This study will collect data regarding five variables: CO_2 per capita, GDP per capita, crude oil price, total imports and total exports. The reason for incorporating control variables in econometrics is to be able to measure the effects of the variable of interest on the outcome variable accurately (Dzemski, 2019). For this reason, along with the fact that using control variables is standard practise when it comes to EKC, this study adds control variables as well (He and Richard, 2010).

The reason for not including exports or imports of oil is that Sweden, unlike Canada, does not produce oil. Furthermore, instead of using exports and imports to a specific country, like the US in the case of He and Richard (2010), this report will use Sweden's total exports and imports as control variables. This is due to the fact that Sweden, again unlike Canada, does not have a single country that dominates the international trade (Helmfird et al., 2020; Morton, Bercuson, Krueger, Nicholson & Hall, 2020). In the case of Sweden, the largest single export and import countries: Norway and Germany, represent 10.7 and 17.9 percent of Sweden's exports and imports, respectively (Carlgren, 2020). Compared to Canada, where the US makes up 75.2 and 65.7 of the total exports and imports (Morton et al., 2020). Therefore, it makes more sense to include the total exports and imports rather than that of a specific country when considering the case of Sweden.

Concerning the variable named; industry share of production, it would be interesting to review the outcome of incorporating this variable. However, due to lack of sufficient data in this matter, this variable is unfortunately excluded. The reason for using the oil price as a control variable is because the consumption of oil, and subsequently the CO_2 emissions, intuitively should depend on the price of oil, due to supply and demand. Another supporting argument for using oil price as a control variable is that previous studies suggest that some countries exhibit inverted U-shaped relationships due to oil shocks (He and Richard, 2010).

Lastly, a variable called time is incorporated in order to account for the fact that the data has inherent time dependency. According to (Wooldridge, 2012), a linear time trend can be used to eliminate the problem of having time-dependent variables. The problem of having a relationship between two or more variables due to changes in time is called a *spurious regression problem* (Wooldridge, 2012). This study attempts to solve the issue of technology and other societal advancements interfering with the data by incorporating the variable of time. He and Richard (2010) also uses a deterministic time trend variable to represent technological progress. Moreover, Lindmark (2002) finds that in the case of Sweden, there seem to be a constant effect of technology on CO_2 emissions, further supporting the use of a linear time trend.

3.2.2 Data sources used for data collection

The input data for the linear regression models comes from three sources: *The World Bank's DataBank*, *BP's Statistical Review* and the *Global Carbon Project (GCP)*.

The raw data for the annual CO_2 emissions is from the Global Carbon Project (GCP) and is collected via the *Climate Watch data* webpage. Climate Watch is an online platform that visualises various types of environmental data for the public (Climate Watch, 2020). Selecting GPC as the source of CO_2 emission data is motivated by the fact that they are a well-known, established and non-biased institute specialised in climate data collection (GCP, 2020).

When it comes to Swedish population data, GDP, import and export data, the study uses the World Bank DataBank as the source (The World Bank, 2019c). According to The World Bank (2019e; 2019f; 2019a), the raw data source for the GDP per capita, exports and imports are The World Bank National Accounts data and OECD National Accounts data files. However, regarding the Swedish population data, the raw data is gathered from Eurostat (The World Bank, 2019d).

The Brent crude oil price data is obtained from BPs Statistical Review. Since 1951 BP has released the annual Statistical Review, summarising the important numerical statistics of the oil and energy industry (BP, 2020). Brent is a trade classification of crude oil originating from the North Sea and is often used as a reference for the global oil price (One financial market, 2016). Since Sweden is a country at the shores of the North Sea, and since the Brent crude oil price is a global reference, this is considered the most viable source of oil price data.

3.3 Reflection

This section presents a reflection on the study method. It does so in the form of a discussion on the research validity, reliability and generalisability.

3.3.1 Validity

Validity is a concept that deals with whether the study's results meet the requirements set by the study's method (Shuttleworth, 2008). This means in plain text that it addresses whether or not the system corresponds to reality, i.e. whether the results obtained can be expected to equal the results of a real system. The concept of validity can be divided into internal validity and external validity (the latter is also called generalisability). The level of internal validity depends on how the study is structured, which incorporates all the steps on which the study's method is based (Shuttleworth, 2008). A poorly constructed research design has consequences for the credibility of the study. Hence, it does not matter how good the results of the study are if the design of it is questionable.

Golafshani (2003) states that validity is the extent to which the study measures what it is supposed to measure, or in other words, how well it answers the research question. In order to be able to accomplish this, the techniques and tools of the method have to be appropriate (Golafshani, 2003). Regarding the methodology of this study, it does answer the research question well. The regression analysis, including control variables, provides a solid basis for assessing whether the EKC hypothesis holds for Swedish CO_2 emissions. It has proven to be a valid method in various similar studies like He and Richard (2010), Lindmark (2002) and BEŞE (2018). Furthermore, accounting for control variables also increases the internal validity since it excludes noise from unwanted interfering factors. Lastly, the data sources are carefully selected, and the data gathered regarding CO_2, GDP, imports, exports and oil price is double-checked against several additional sources.

3.3.2 Generalisability

Denscombe (2010) describes the concept of generalisability as the ability to take the results of a study and further apply it to other similar studies. Thus, according to Denscombe (2010), the concept aims more specifically to whether the results have the ability to describe a more general and universal case than the particular one of the study in question. In this study, the apparent matter regarding generalisability is whether the findings can apply to other countries, pollution types and circumstances.

Whether the findings can be generalised for other pollution types is also hard to assess, especially since CO_2, unlike many other pollution types, causes issues on a global scale. Furthermore, the fact that all data analysed in this study concerns Sweden causes limitations in terms of geographical generalisability. Several previous studies, like Lindmark (2002) and Johansson and Kriström (2007) conclude that structural, political and technological differences do impact the CO_2. Since Sweden has a specific political- and structural climate that differs from other countries, one needs to be cautious when generalising the findings of this study to other countries.

Moreover, different countries are located at different positions on the EKC curve. Emerging economies and developing countries, for example, might not have reached their turning point yet and hence do not display a U-shaped relationship between environmental decay and economic growth yet. As a consequence, it is difficult to apply the result of Sweden directly on other countries. Nonetheless, the notion that this study can apply to these countries in the future is not entirely discarded. Furthermore, the findings of this paper can already act as a basis for climate policy decision making in less developed countries as well. Lastly, similar societies, like those of other Scandinavian or western European countries might, however, be subjects for more direct generalisability.

3.3.3 Reliability

Reliability is defined as the ability to reproduce a study's results (Shuttleworth, 2008). The idea of the concept is that other researchers should be able to replicate the study's findings by performing the same examination under the same conditions as the original study (Shuttleworth, 2008). Denscombe (2010) states that the answer to the question "will the study get the same result at execution at a different time, everything else equal" determines the reliability of the study.

Provided that a future study was to replicate this study, and it used the same time period for their data gathering, the probability of replicating this study's findings is high. The fact that there is a lot of secondary data available can be regarded as a sign of the high reliability of the study.

4 Empirical data

The empirical data for this study is time-series data for Sweden between the years of 1960 and 2018. Table 4.1 below illustrates the variables (the outcome variable, the variable of interest and three control variables) used in the study, along with descriptive statistics. A full table of the data points for each variable is found in Appendix A.

Variables (unit)	**Mean**	**Std.Dev**	**Max(year)**	**Min(year)**
CO_2 per capita (tCO_2-eq)	7,24	1,94	11,47(1970)	4,03(2018)
GDP per capita (2010 USD, K)	37,42	11,63	57,92(2018)	18,05(1960)
Oil price (2018 USD per Barrel)	50,25	33,12	124,20(2011)	11,63(1970)
Export (2010 USD, Bn)	106,20	71,59	269,97(2018)	23,16(1960)
Import (2010 USD, Bn)	109,48	85,01	289,77(2018)	16,15(1960)

Table 4.1: Variables, along with descriptive statistics. The unit of measure as well as year of maximum- and minimum values are in parentheses

4.1 CO_2 per capita

CO_2 per capita represents the outcome variable in the equation, and hence, it constitutes the y-value on the two-dimensional EKC graph. This variable is a ratio between the total annual CO_2 emissions and the total population of the country at this specific year (see formula below).

$$CO_2 \ per \ capita = \frac{total \ annual \ CO_2 \ emissions}{midyear \ population}$$

The unit of measure is tonnes of CO_2-eq (tCO_2-eq) or simply tonnes of CO_2 since the CO_2-eq = 1 for CO_2. The CO_2 data is the form of *CO_2 emissions from total fossil fuels and cement*. Figure 4.1 below shows a graph of how CO_2 emissions have changed during the years of 1960-2018. In summary, the CO_2 level increased between the years of 1960 and 1970. After 1970, it reached a plateau that lasted to about 1980, after which a declining trend started continuing into 2018.

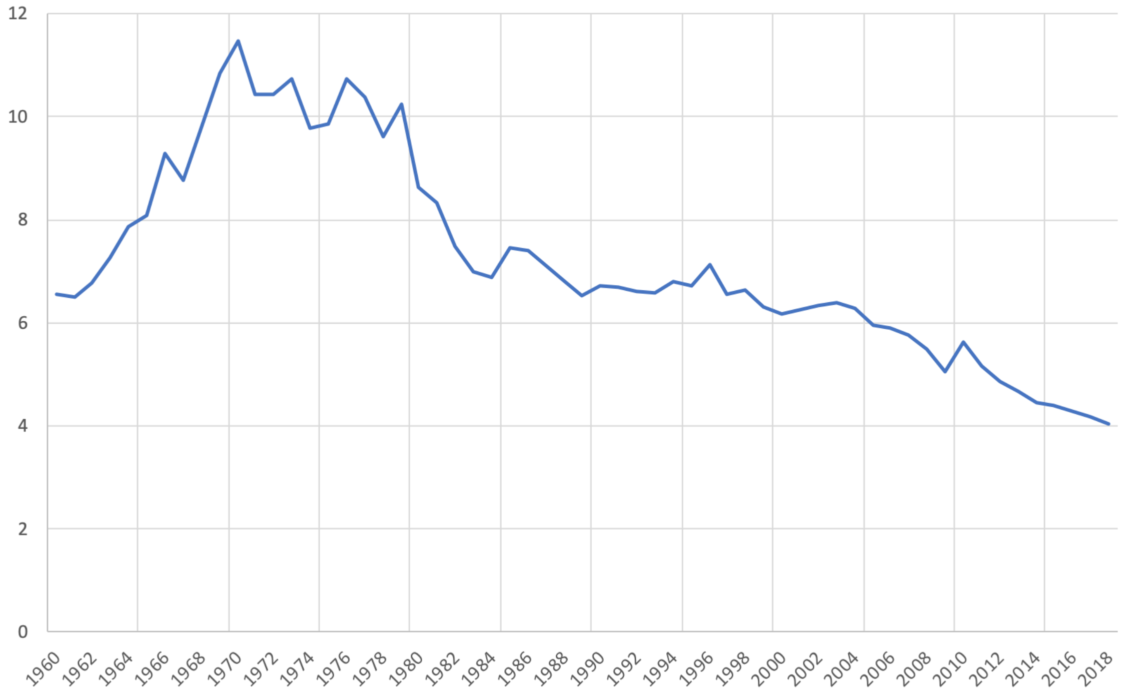

Figure 4.1: Graph illustrating the development of CO_2 per capita, in tCO_2-eq, between 1960 and 2018

4.2 GDP per capita

The GDP per capita represents the variable of interest which is illustrated along the x-axis of the EKC graph. This measure is calculated as GDP divided by midyear population (The World Bank, 2019d).

$$GDP\ per\ capita = \frac{total\ annual\ GDP}{midyear\ population}$$

Since the effect of inflation was unwanted in order to analyse the results relevant, the data chosen for GDP was in constant 2010 US Dollars (more accurately, thousand USD). Figure 4.2 displays a graph of Sweden's GDP per capita development over time, illustrating that Sweden has experienced a relatively constant economic growth over time, except for a few years of recession.

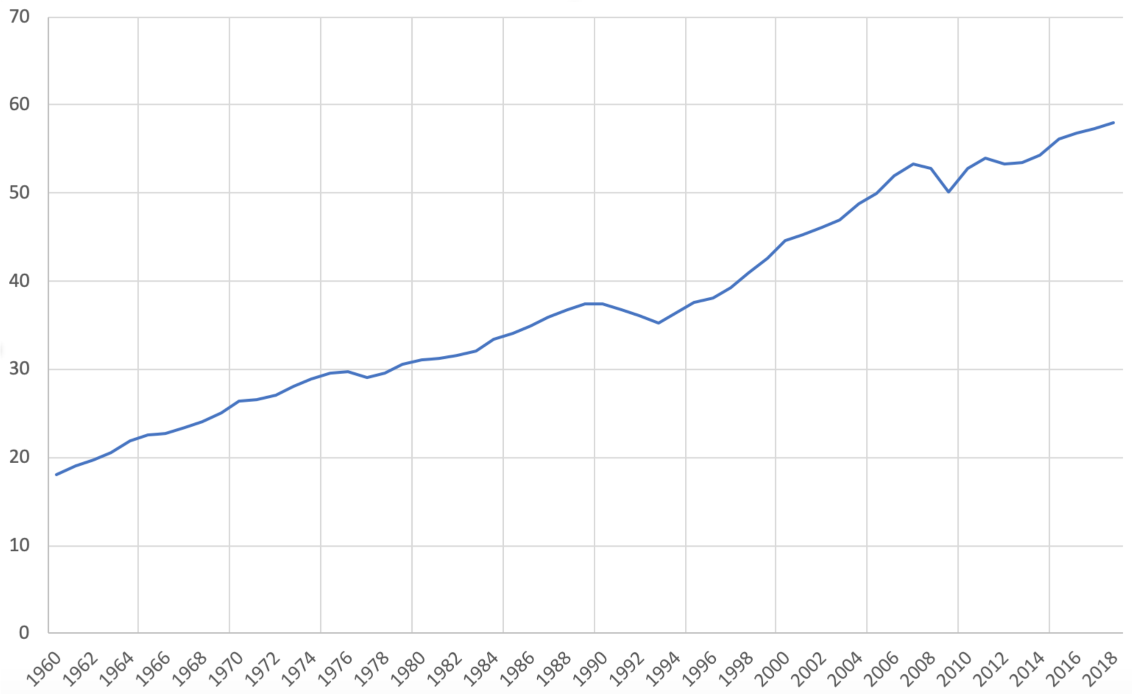

Figure 4.2: Graph illustrating the development of GDP per capita, in Constant 2010 Thousand USD, between 1960 and 2018

4.3 Control variables

There are three control variables used in the modelling of this study: oil price, exports and imports.

4.3.1 Oil price

The oil price data is measured in 2018 USD per barrel (Our World in Data, 2020). The reason for using the 2018 USD unit is yet again to exclude the effect of inflation during the time period, a reasoning that goes for all three control variables. The crude oil price fluctuations from 1960-2018 are illustrated in Figure 4.3. It seems that the oil price has been fairly volatile over the time period. Two dominant peaks depict the oil crises of the 1970s and the oil price surges of the 2000s/2010s.

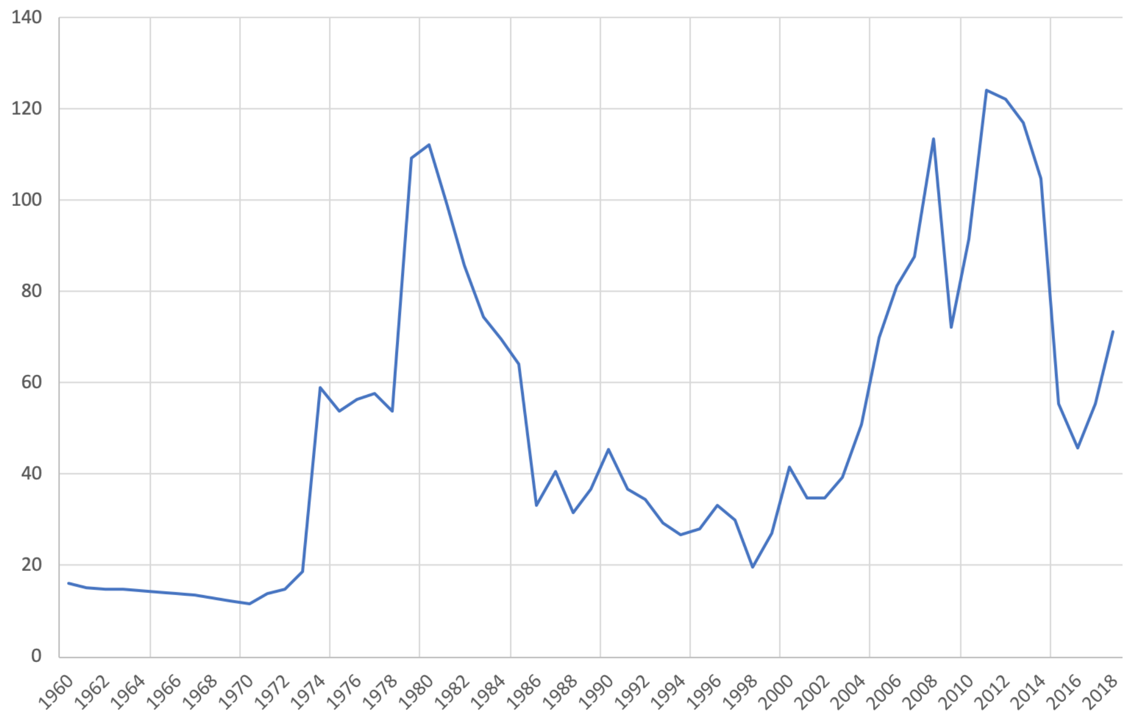

Figure 4.3: Graph illustrating the development of the Brent crude oil price index, in Constant 2018 USD per barrel, between 1960 and 2018

4.3.2 Exports and Imports

The data representing the annual exports and imports are stated in the unit of constant 2010 USD (The World Bank, 2019e; The World Bank, 2019f). In order to make the coefficients adapt to more reasonable numbers, a unit of Billion USD was chosen as a measurement unit. Like with the GDP per capita and Oil price, a constant (2010 USD) currency is chosen in order to exclude the unwanted effect of inflation on the data.

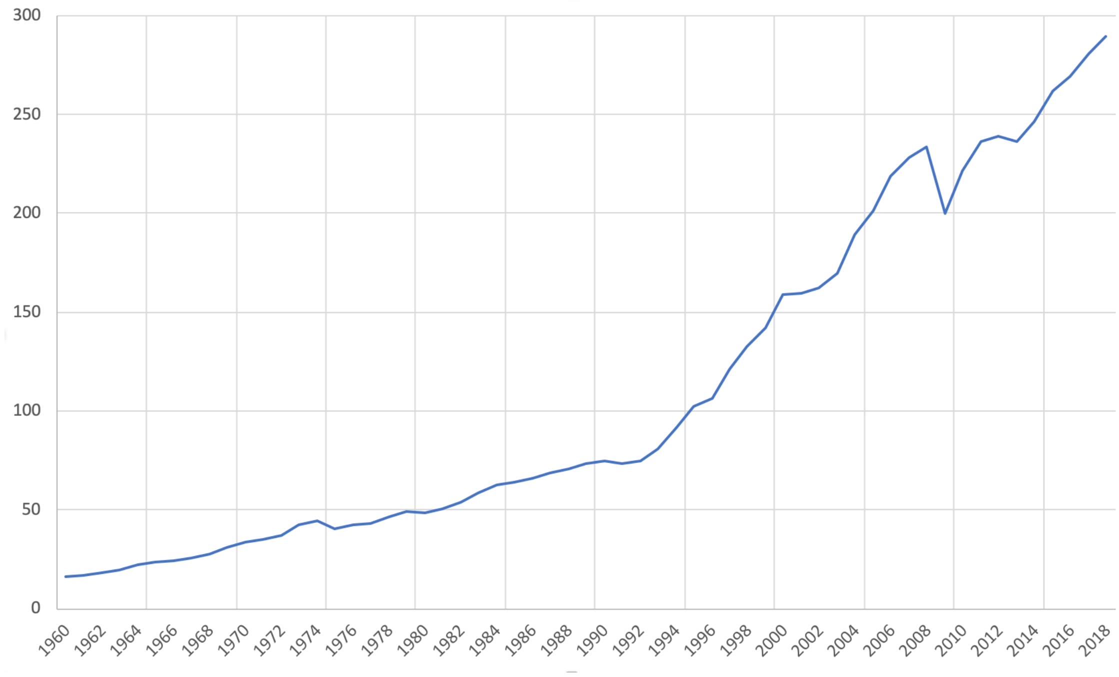

Figure 4.4: Graph illustrating the development of exports, in Constant 2010 Billion USD, between 1960 and 2018

Comparing the graphs of Figure 4.4 and Figure 4.5, one can see that the time trends of the export data and the import data, in general, seem to follow the same pattern. Overall, the trade balance of goods and services was lower (or even negative) during the years of 1960-1993 (The World Bank, 2019e; The World Bank, 2019f). However, during the years of 1994-2018, Sweden has experienced a period of positive trade balance, meaning that the exports were higher than the imports. Much like the GDP per capita, exports and imports have been increasing apart from a few years.

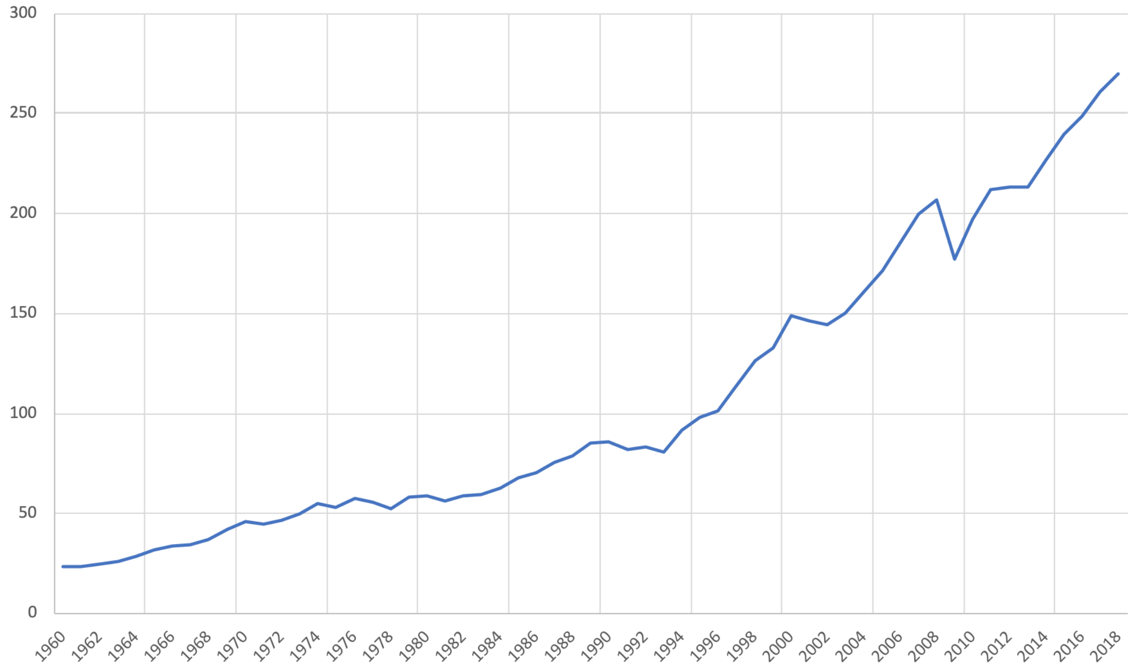

Figure 4.5: Graph illustrating the development of imports, in Constant 2010 Billion USD, between 1960 and 2018

5 | Results and Analysis

This chapter presents the results of this study and the analysis of these results. The analysis builds on the visual examination of plots illustrating the relationship and the outputs of the regression analyses.

5.1 EKC relationship curve

Figure 5.1 below illustrates the relationship between CO_2 per capita and GDP per capita for Sweden. According to the EKC theory, this relationship should display an inverted U-shaped curve.

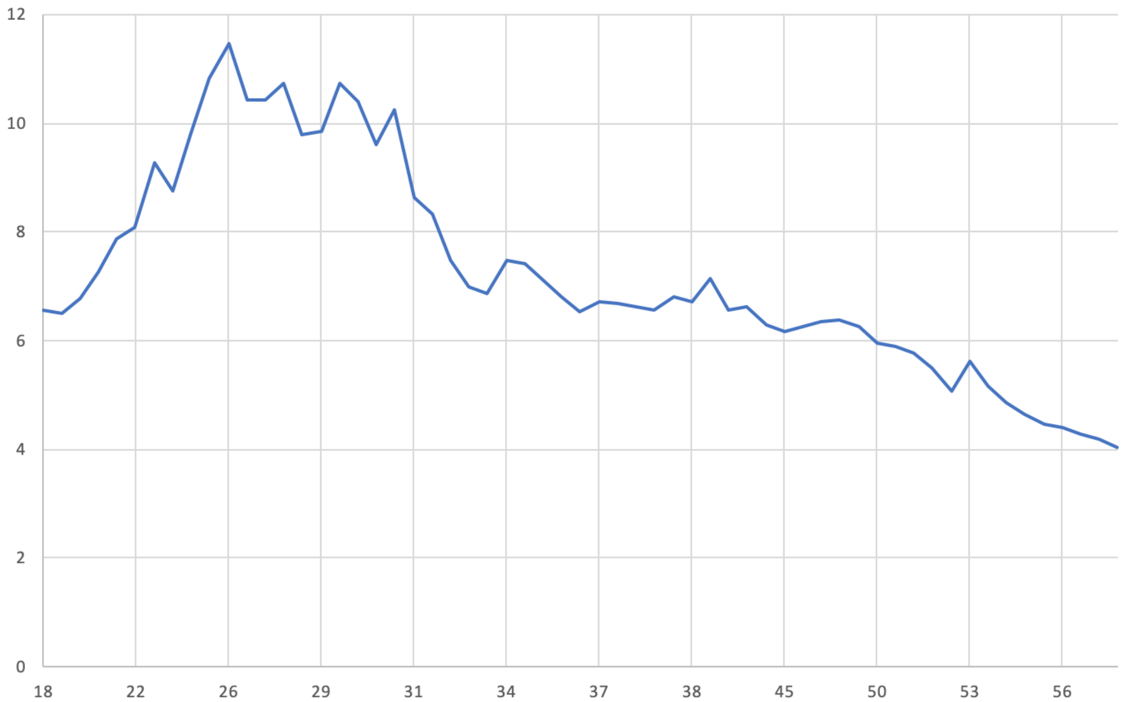

Figure 5.1: Graph illustrating the relationship between CO_2 per capita (tCO_2) and GDP per capita (Constant 2010 Thousand USD)

The observant reader can see that the graph of Figure 5.1 looks similar to the one illustrated in Figure 4.1, illustrating the development of CO_2 per capita between 1960 and 2018. This is because annual GDP per capita has increased fairly linear almost every year during this time period, except for 1977, 1991-1993, 2008-2009 and 2012.

From visual observation, it seems that CO_2 per capita shows a positive correlation with GDP per capita up until a certain point. CO_2 per capita reaches its maximum at a GDP of around 26000 USD per capita (more specifically 26440 in 1970), and then declines as GDP per capita increases, with a few exceptions. Basically, the graph can be divided into three sections. First, the CO_2 per capita increases from a GDP of 18000 USD to 26000 USD per capita. Between 26000 and 30500 USD per capita, the CO_2 per capita seems to have reached a plateau of between 10-12 tCO_2. The CO_2 per capita then decreases (rapidly initially and more slowly towards the end) between 30500 and 58000 USD per capita. In summary, this initial visual analysis points to the fact that there might exist an inverted U-shaped relationship in Sweden during this specific time period. The following section presents a deeper analysis through a regression analysis assessment of this notion.

5.2 Parametric regression models

Table 5.1 illustrates the outputs of running the regressions on all the four studied models (full versions of the regression outputs can be found in Appendix B).

Coefficient (variable)	**Model 1**	**Model 2**	**Model 3**	**Model 4**
β_1 (GDP per capita)	0.9317372*** (0.1781025)	2.617035*** (0.319207)	10.59743*** (1.78063)	3.417987*** (0.415586)
β_2 (GDP per capita^2)	-0.0074515*** (0.0014627)	-0.0565233*** (0.0080066)	-0.4115725*** (0.0754298)	-0.0757061*** (0.0120359)
β_3 (GDP per capita^3)	-	0.000437*** (0.0000686)	0.0069111*** (0.0013347)	0.0004988*** (0.0001113)
β_4 (GDP per capita^4)	-	-	-0.0000423*** ($8.52*10^{-6}$)	-
α_1 (Time)	-0.3300996*** (0.0529785)	-0.3011157*** (0.0394148)	-0.1449*** (0.0408058)	-0.4010685*** (0.0486696)
α_2 (Oil price)	-	-	-	-0.000305 (0.0034115)
α_3 (Exports)	-	-	-	0.0575396*** (0.0187561)
α_4 (Imports)	-	-	-	0.0214647 (0.0303636)
U	-6.296835** (3.11342)	-24.56857*** (3.887348)	-87.84061*** (15.06795)	-34.87389*** (4.447732)
R^2	0.7642	0.8359	0.8882	0.8895

Table 5.1: Regression analysis output, with heteroskedasticity robust standard errors in parenthesis. *, ** and *** denote asymptotic statistical significance at the 10%, 5% and 1% levels respectively

Regarding Model 1, the quadratic model of CO_2 per capita with regards to GDP per capita, there seems to be some evidence supporting the EKC. The negative $\beta 2$

implies that there exists a maximum that potentially could be considered a turning point for the curve.

As to Model 2, the study incorporates GDP per capita^3 in addition to the previous variables. As in the case of Model 1, Model 2 also has statistically significant coefficients for all levels of GDP per capita when accounting for time. Hence, this supports the existence of a cubic relationship between CO_2 per capita and GDP per capita.

Model 3 adds yet another layer to the analysis as it includes the quartic term: GDP per capita^4. Again, all GDP per capita coefficients are statistically significant, supporting the existence of a quartic relationship between CO_2 per capita and GDP per capita. However, the robustness of a function, not accounting for control variables is questionable. Therefore, the tree control variables: oil price, exports and imports (motivated in Chapter 3), were added to form an additional model.

These control variables were added on to the cubic model (Model 2), forming Model 4. There are two main reasons for choosing Model 2 for this purpose. Firstly, according to He and Richard (2010), there is support for using cubic functions in the academic literature, which is why they use a cubic function in their study of CO_2 emissions in Canada. Using cubic GDP terms is among the most common methods for modelling the EKC relationship in the academic field (Lindmark, 2002; He and Richard, 2010). Secondly, the model with the lowest p-values on all the regressors is Model 2, i.e. the cubic model (see Appendix B for specific values).

Conducting the regression with the control variables, the signs of the β variables are the same as for the regression without control variables. However, the coefficients now have smaller absolute values. The smaller absolute values make intuitive and economic sense since the control variables account for some of the effects on the outcome variable. It seems from the results of the Model 4 regression that the coefficients representing the oil price and imports variables are statistically non-significant. This means that the null hypothesis, stating that there is no relationship between these variables and the outcome variable, cannot be rejected. Still, the export variable is statistically significant and shows a positive linear relationship with regards to CO_2 per capita. Hence, based on the results, it can be concluded that exports affect CO_2 per capita.

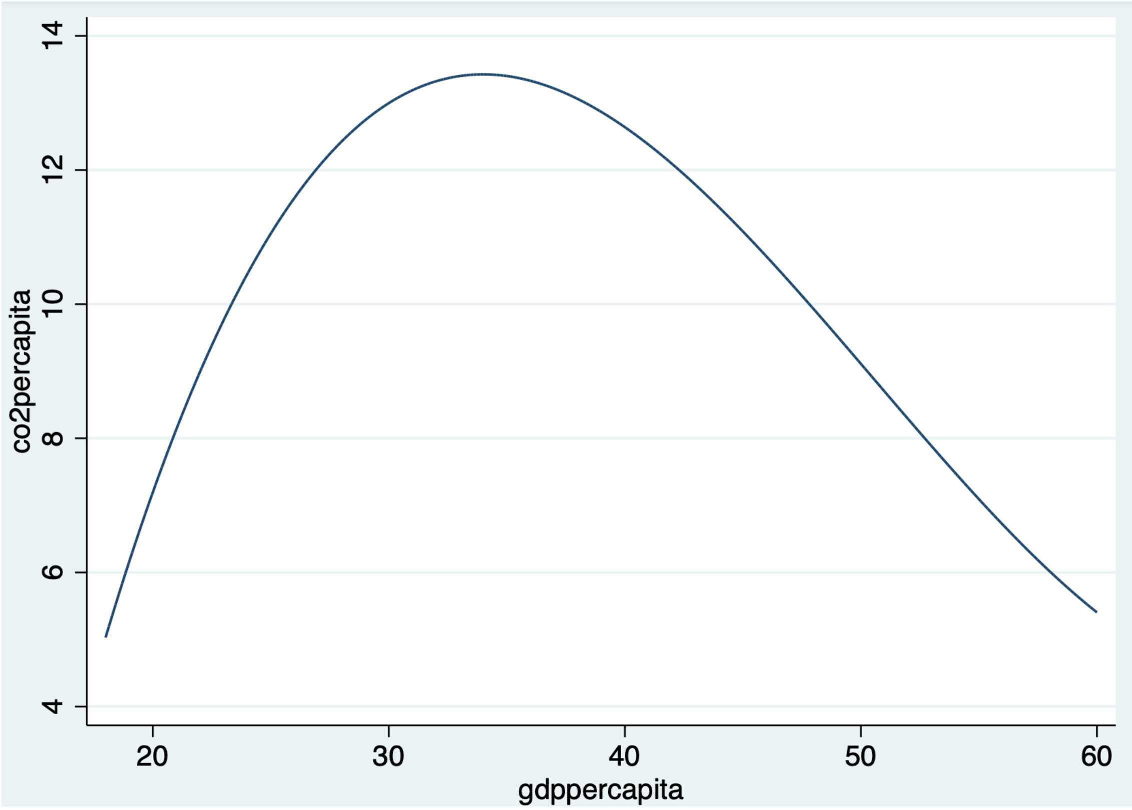

Figure 5.2: The relationship of GDP per capita to CO_2 per capita based on the coefficients of Model 4, looking at a range of 18 to 60 kUSD. The function illustrated is: co2percapita = 3.417987*gdppercapita - 0.0757061*gdppercapita^2 + 0.0004988*gdppercapita^3 - 34.87389

Figure 5.2 illustrates a plot of the relationship between GDP per capita and CO_2 per capita, based on the output of the Model 4 regression. The graph is of Model 4, excluding control variables, and hence it is a cubic, two-dimensional graph. Looking at Figure 5.2, it seems that the curve displays an inverted U-shaped relationship, with a maximum value of 13.4246 tCO_2 at a GDP per capita of approximately 33.9962 kUSD. Comparing this plot with the real data plotted in Figure 5.1, it becomes evident that model 4 makes up a good fit for the real data.

5.3 Summarised findings based on the results

In summary, the regression analysis, supported by visual inspection of the true relationship between CO_2 per capita and GDP per capita, provides evidence supporting the existence of an EKC type relationship regarding CO_2 emissions in Sweden. Looking at emission- and economic growth data, there seems to be an inverted U-shaped relationship with a turning point at around 30000 (+/- 5000) USD. Moreover, it seems that the slope of the curve is steeper before reaching this turning point than it is after the turning point, meaning that the CO_2 increases rapidly leading up to its peak and then decreases slowly when it has reached its maximum.

However, what happens to the CO_2 levels as the GDP continues to grow is unknown. It cannot be concluded whether the decreasing trend approaches 0 or if it stabilises at a number somewhere above (or even below) 0. Moreover, when extrapolating the curve to incorporate a range exceeding 60 kUSD, again using the coefficients of Model 4, there is a local minimum at 67.1881 kUSD of GDP per capita and 4.30626 CO_2 per capita after which the curve increases towards infinity. Nevertheless, the main takeaway from the analysis is that there is evidence supporting EKC in Sweden.

6 | Discussion

Even though the study shows that GDP affects the CO_2 emissions, this does not mean that as a country experiences economic growth, their pollution levels are automatically decreasing. In addition to being a major conclusion of this study, it is also supported by both Lindmark (2007) and Shafik and Bandyopadhyay (1992). Therefore, we strongly argue that countries should apply policies working towards solving the climate crisis in order to ensure sustainable development and not expect to grow out of their environmental issues.

Additionally, as mentioned in subsection 3.3.2, the fact that EKC proves to be true for one country does not mean that it holds on a global scale. An arguable example of this is when Sweden started moving their heavy industries to less developed countries during the 1980s, due to heavy competition. A consequence of relocating production in this manner could be that emissions are simply transferred abroad. In general, the lowering of emission levels due to the transformation of one country's economy can cause an increase in emissions for other, often less developed, countries' or even a global increase in emissions.

Moreover, this study does not find any evidence supporting the fact that oil prices or oil shocks affect the CO_2 per capita in Sweden. This might be the effect of Sweden's emission-reducing policies, i.e., CO_2 tax, and the strong Swedish environmental movement mitigating the effects of the oil price fluctuations on emissions. It could be the case for Sweden that oil price is just not that vital part of the economy as for some other countries. As a consequence, the change in oil price may not affect the emissions to a great extent. This could be derived from the fact that knowledge-intensive industries, in general, are less dependent on oil.

Lindmark (2002), however, concludes, in contrast to our study, that oil price fluctuations affect the CO_2 emission levels in Sweden. Why our findings differ from those of Lindmark (2002) might be purely due to methodical reasons. As opposed to our study, Lindmark (2002), uses a logarithmic model for investigating the EKC relationship and incorporates a stochastic trend, accounting for technological- and structural change. Besides, our study uses data from a more recent time period (1960-2018 compared to 1870-1997), hence allowing us to account for a longer period of emission decrease. This increases the probability of finding a U-shaped type relationship.

Exports, however, does seem to affect CO_2 emissions. This is quite predictable as Sweden is a heavily export-dependent country. Imports, on the other hand, does not seem to affect the CO_2 emission level. This is somewhat unintuitive since there seems to be a relationship between CO_2 per capita and exports. It would make sense if imports too were correlated with CO_2 since the imports follow the pattern of exports closely. One explanation could, however, be that CO_2 emissions caused by the "production" of imported goods and services to a greater extent are counted abroad since they are produced abroad.

Furthermore, the inverted U-shaped relationship can also be discussed with regards to the transformation of the Swedish economy towards servitisation, i.e., linking Figure 2.1 and Figure 5.1. The EKC relationship could be a consequence of the fact that the growing service sector has provided the possibility of economic growth without causing environmental decay. Thus, it is possible that the Swedish economic transformation could have resulted in a more environmentally friendly economic growth. As Sweden has experienced a strong trend of servitisation, it is important to bear in mind that this transformation in itself can cause the formation of the EKC curve.

Even though this paper does find the support of an inverted U-shaped relationship between CO_2 per capita and GDP per capita for the studied time period, there are a few alternatives when it comes to shapes of the curve that cannot be discarded. The assessment of the shape of the curve is complicated since it tells nothing about whether the trend of decreasing CO_2 per capita continues as the economy grows beyond the level of today. For example, the curve of the cubic recession model reaches a local minimum and then increases towards infinity if extrapolated. This provides evidence supporting an N-shaped curve like the one suggested by Pezzey (1989). Although an increase of CO_2 emissions towards infinity is not likely in reality, considering the societal and strong environmental trend of Sweden as well as the world, we cannot entirely discard it. Neither can we reject the New Toxics theory, since it would require an analysis of several additional pollution types and this study only includes CO_2 emissions. The Race to the bottom theory can, however, be discarded with high certainty.

Although the methodology of this study largely follows that of He and Richard (2010), our findings differ somewhat to those of their paper on EKC in Canada. The most significant difference is that we find a U-shaped relationship between CO_2 per capita and GDP per capita, whilst they do not find such a relationship. There are several possible reasons why this is the case. The first and arguably the most probable explanation is that the countries differ in culture, economic structure and political climate. For example, Canada is an oil-producing country which may cause political incentives not to reduce oil consumption and thus CO_2 emissions. A second reason why the findings differ can be due to methodological differences. In addition to using parametric models, the Canadian study uses more flexible models like PLR models, Hamilton's model a model using two nonlinear variables. A third reason could for the differences could be because we use a more recent time period than that of the Canadian study (1960-2018 compared to 1948-2004).

Lastly, in line with the findings of Lindmark (2002) and Johansson and Kriström (2007), this study finds that Swedish CO_2 emissions can be divided into different historical time periods. Period 1: 1960s, is characterised by a rapid increase in CO_2 as a consequence of stable economic growth, increased exports and low oil prices.

During period 2: 1970s, the CO_2 emissions seem to have reached a plateau at a high, but stable level, although the economy of this period is still growing quite constantly (excluding 1977). One explanation of this could be that the crude oil price increased almost tenfold between the years of 1970 and 1980. Period 3: 1980-2018, is a period of decreasing CO_2 per capita, initially at a rapid pace and slowly towards the end of the period. We believe that this is due to legislation, public opinion, servitisation and technological development.

6.1 Limitations

He and Richard (2010) includes a control variable called: industry share of production. Accounting for how Sweden has increasingly moved from industrial- to a service society, during the years of 1960-2018, would indeed be interesting for this study as well. However, as mentioned in Subsection 3.2.1 due to lack of sufficient data, there is no such control variable included in this study. Furthermore, finding reliable data, going back earlier than 1960 has limited the time period investigated in this study. Moreover, partly due to the finite time period, the findings of this study cannot be extrapolated to predict what the future holds regarding the relationship between CO_2 emissions and economic growth.

7 | Conclusion

This study investigates the relationship between CO_2 per capita and GDP per capita in Sweden during the time period of 1960-2018. The purpose of the investigation is to examine whether there exists an EKC type relationship between these two variables. In answering this question, the method used is that of a regression analysis, supported by visual observations of the plotted relationships. The paper finds support of an inverted U-shaped relationship, as suggested by the EKC, in Sweden. However, this conclusion is arguable due to the effect of control variables. There could be structural, political, technological, sectorial and historical factors interfering with the results. Consequently, we cannot conclude that pure economic growth causes a decrease in CO_2 emissions after a particular turning point.

7.1 Future research

We have some suggestions for future research with regards to EKC and its implications. Firstly, an interesting topic would be to do further studies on EKC in the case of Sweden, focused on other pollution types than CO_2. Carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NOx) and respirable particulate matter (PM2.5 and PM10) are a few suggestions for interesting research topics. Although there are some studies on other pollution types than CO_2 in Sweden, Johansson and Kriström (2007) suggest that most of them are outdated and would benefit from using updated input data. Secondly, investigating the CO_2 vs economic growth relationship for other countries also represents exciting topics for future research papers. Additional studies on different geographical regions would be interesting in order to determine the generalisability of this paper.

Thirdly, when conducting a regression analysis, there is always the question of whether the right control variables are used. Therefore, additional- or different, control variables could be incorporated in future research studies. Fourthly, other time periods could be studied in addition to the one ranging between 1960 and 2018. Periods going back further in time, like the one of Lindmark (2002), could be studied in order to investigate the EKC from a historical perspective. Lastly, we believe that the link between related subjects like the field of macroeconomics, human psychology and philosophy can be accounted for in future studies. This would provide a deeper understanding of exactly why the trends identified in the data exist. It could also offer actionable recommendations for governments and businesses, on how to utilise the findings of this paper to minimise climate change.

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List of Appendices

Appendix A

Year	CO_2 per capita	GDP per capita	Oil price	Exports	Imports
1960	6,57	18,05	16,09	16,15	23,16
1961	6,49	18,99	15,10	16,99	23,20
1962	6,78	19,69	14,93	18,36	24,53
1963	7,27	20,62	14,76	19,70	26,27
1964	7,88	21,86	14,55	22,07	28,82
1965	8,09	22,48	14,31	23,30	32,07
1966	9,29	22,74	13,92	24,45	33,45
1967	8,76	23,32	13,53	25,79	34,29
1968	9,81	24,03	12,99	27,75	37,13
1969	10,84	25,06	12,32	30,94	41,92
1970	11,47	26,44	11,63	33,60	46,28
1971	10,44	26,50	13,87	35,22	44,76
1972	10,43	27,03	14,89	37,29	46,55
1973	10,73	28,05	18,60	42,40	49,76
1974	9,78	28,87	59,00	44,65	54,69
1975	9,86	29,49	53,82	40,50	52,77
1976	10,73	29,69	56,47	42,24	57,52
1977	10,39	29,11	57,64	42,87	55,34
1978	9,60	29,54	54,00	46,22	52,29
1979	10,23	30,60	109,33	49,03	58,36
1980	8,63	31,06	112,24	48,74	58,59
1981	8,34	31,16	99,25	50,25	56,34
1982	7,48	31,54	85,79	53,65	59,00
1983	7,00	32,12	74,50	58,75	59,60
1984	6,87	33,45	69,56	62,91	62,76
1985	7,47	34,12	64,32	63,71	67,71
1986	7,41	34,95	33,06	65,93	70,12
1987	7,11	36,00	40,75	68,59	75,26
1988	6,81	36,76	31,68	70,88	79,04
1989	6,54	37,48	36,91	73,13	85,14
1990	6,71	37,47	45,58	74,82	86,10
1991	6,69	36,79	36,87	73,35	81,88
1992	6,62	36,15	34,58	74,93	83,22
1993	6,58	35,20	29,49	80,78	80,95
1994	6,81	36,34	26,80	91,74	91,36
1995	6,71	37,60	28,04	102,08	97,85
1996	7,14	38,14	33,08	106,63	101,25
1997	6,57	39,30	29,87	121,48	113,74
1998	6,63	40,95	19,59	132,44	126,58
1999	6,30	42,69	27,09	141,96	133,07
2000	6,16	44,69	41,55	158,99	148,68
2001	6,26	45,23	34,66	159,82	146,28
2002	6,34	46,07	34,93	162,53	144,50

Year	CO_2 per capita	GDP per capita	Oil price	Exports	Imports
2003	6,38	46,93	39,35	169,94	150,09
2004	6,27	48,77	50,87	189,11	160,22
2005	5,96	49,98	70,10	201,17	171,40
2006	5,90	51,99	81,14	218,45	185,81
2007	5,77	53,37	87,67	227,95	200,08
2008	5,49	52,83	113,43	233,34	207,08
2009	5,06	50,16	72,18	199,92	177,23
2010	5,64	52,82	91,54	221,57	197,39
2011	5,18	54,02	124,20	236,34	211,79
2012	4,87	53,28	122,13	238,97	213,48
2013	4,66	53,41	117,12	236,45	213,54
2014	4,45	54,33	104,95	246,56	226,65
2015	4,39	56,14	55,50	262,04	239,63
2016	4,29	56,78	45,76	269,36	248,81
2017	4,18	57,37	55,52	280,90	260,64
2018	4,03	57,92	71,31	289,77	269,97

Table A.1: Input data from the time period of 1960-2018 on all variables included in the regression analysis. The variables are stated in the following units: tCO_2-eq, 2010 USD Thousand, 2018 USD per Barrel, 2010 USD Billion and 2010 USD Billion

Appendix B

Linear regression		
	Number of obs	= 59
	F(3, 55)	= 72.98
	Prob > F	= 0.0000
	R-squared	= 0.7642
	Root MSE	= .96684

co2percapita	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
gdppercapita	.9317372	.1781025	5.23	0.000	.5748118	1.288663
gdppercapita2	-.0074515	.0014627	-5.09	0.000	-.0103829	-.0045201
time	-.3300996	.0529785	-6.23	0.000	-.4362708	-.2239284
_cons	-6.296835	3.11342	-2.02	0.048	-12.53627	-.0574021

Figure B.1: Regression output of Model 1

Linear regression		
	Number of obs	= 59
	F(4, 54)	= 90.63
	Prob > F	= 0.0000
	R-squared	= 0.8359
	Root MSE	= .81398

co2percapita	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
gdppercapita	2.617035	.319207	8.20	0.000	1.977063	3.257006
gdppercapita2	-.0565233	.0080066	-7.06	0.000	-.0725756	-.040471
gdppercapita3	.000437	.0000686	6.37	0.000	.0002996	.0005745
time	-.3011157	.0394148	-7.64	0.000	-.3801375	-.2220939
_cons	-24.56857	3.887348	-6.32	0.000	-32.36223	-16.77491

Figure B.2: Regression output of Model 2

Linear regression

	Number of obs	=	59
	F(5, 53)	=	104.36
	Prob > F	=	0.0000
	R-squared	=	0.8882
	Root MSE	=	.67806

co2percapita	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
gdppercapita	10.59743	1.78063	5.95	0.000	7.025934	14.16892
gdppercapita2	-.4115725	.0754298	-5.46	0.000	-.5628654	-.2602795
gdppercapita3	.0069111	.0013347	5.18	0.000	.0042341	.0095881
gdppercapita4	-.0000423	8.52e-06	-4.97	0.000	-.0000594	-.0000252
time	-.1449	.0408058	-3.55	0.001	-.226746	-.0630539
_cons	-87.84061	15.06795	-5.83	0.000	-118.0631	-57.61812

Figure B.3: Regression output of Model 3

Linear regression

	Number of obs	=	59
	F(7, 51)	=	55.66
	Prob > F	=	0.0000
	R-squared	=	0.8895
	Root MSE	=	.68733

co2percapita	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
gdppercapita	3.417987	.415586	8.22	0.000	2.583664	4.252311
gdppercapita2	-.0757061	.0120359	-6.29	0.000	-.0998693	-.0515429
gdppercapita3	.0004988	.0001113	4.48	0.000	.0002754	.0007222
time	-.4010685	.0486696	-8.24	0.000	-.4987767	-.3033602
oilprice	-.000305	.0034115	-0.09	0.929	-.0071538	.0065439
imports	.0214647	.0303636	0.71	0.483	-.0394929	.0824223
exports	.0575396	.0187561	3.07	0.003	.0198851	.095194
_cons	-34.87389	4.447732	-7.84	0.000	-43.80308	-25.9447

Figure B.4: Regression output of Model 4

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