THE IMPACT OF EDUCATIONAL ATTAINMENT TO THE EKC HYPOTHESIS WITHIN OECD COUNTRIES IN 1995-2021

Lappeenranta–Lahti University of Technology LUT

Bachelor's programme in Strategic Finance, Bachelor's Thesis

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ABSTRACT

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The impact of educational attainment to the EKC hypothesis within OECD countries in 1995-2021

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This thesis examines the relationship between economic growth, educational attainment and environmental degradation using the Environmental Kuznets Curve (EKC) as the theoretical framework. The EKC hypothesis suggests that as income rises, it initially increases environmental degradation but begins to decline after reaching a certain threshold.

This thesis introduces education as a complementary control variable to the EKC alongside the traditional EKC variables; CO_2 emissions and income. The goal is to examine how changes in mean years of schooling affect the EKC in different geographical and economic groups. The research is a quantitative panel data analysis using a dataset of 38 countries from the OECD and 6 regional groups within the OECD.

The results provide partial support for the EKC hypothesis at both OECD-wide and regional levels. The EKC relationship varies by region, confirming its context-dependent nature. Education was found to have an emission reducing effect OECD wide and some regions like Western Europe and Nordics and Baltics. This study highlights the importance of incorporating education as a key factor in environmental-economic research.

TIIVISTELMÄ

Lappeenrannan-Lahden teknillinen yliopisto LUT

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Koulutustason vaikutus EKC-hypoteesiin OECD maissa 1995-2021

Kandidaatintutkielma

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Tämän kandidaatintutkielman tavoitteena on tutkia talouskasvun, koulutustason sekä ympäristön kuormituksen välistä suhdetta ympäristötaloudellisen Kuznets-käyrän (EKC) avulla. EKC-hypoteesin mukaan tulotason noustessa ympäristöpäästöt kasvavat tiettyyn käännepisteeseen saakka, jonka jälkeen ne alkavat vähentyä.

Tutkielma esittelee koulutusta mahdollisena kontrollimuuttujana perinteisten EKC muuttujien, eli CO_2- päästöjen ja tulojen ohella. Tavoitteena on tutkia miten keskimääräiset koulutusvuodet ja niiden muutokset vaikuttavat eri taloudellisissa ja maantieteellisissä ryhmissä. Tutkimus on kvantitatiivinen ja hyödyntää paneelidata-analyysiä, jossa aineistona on 38:ta OECD-maata ja 6 eri maantieteellisestä ryhmää.

Tulokset tarjoavat osittaista tukea EKC-hypoteesille sekä koko OECD:n tasolla sekä alueellisten ryhmien tasolla. EKC- suhde vaihtelee alueittain, varmistaen sen kontekstisidonnaisuuden. Koulutuksella havaittiin olevan päästöjä vähentävä vaikutus koko OECD:n tasolla sekä alueellisesti Pohjoismaissa, Baltian maissa sekä Länsi-Euroopassa. Tutkimus korostaa koulutuksen huomioimista keskeisenä tekijänä ympäristöä talouskasvua tarkastelevassa tutkimuksessa.

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Abbreviations:

GHG= Greenhouse Gas

CO2= Carbon Dioxide

EKC= Environmental Kuznets Curve

GDP= Gross Domestic Product

OECD= Organization for Global Economic Development

OLS= Ordinary Least Squares

FE=Fixed Effects Method

RE= Random Effects Method

EDGAR= Emissions Database for Global Research

IMF= International Monetrary Fund

GDL= Global Data Lab

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1 Introduction

Climate change is one of the most pressing issues in the 21st century. The last few decades have witnessed never seen before increases in global surface temperatures, melting polar ice, rising sea levels and extreme natural disasters, which are all linked to human action. These changes are largely driven by the rise in Greenhouse gas (GHG) emissions, particularly CO_2 emissions have risen significantly in the last decade (see Figure 1), led by global industrialization. The increase of greenhouse gases threatens the natural ecosystems, food security, public health and economic security. (IPCC 2021)

Since the beginning of industrialization, economic growth has been closely tied to rising greenhouse gas emissions, as the increase in production and energy use has accelerated environmental degradation. A common way to measure economic activity through GDP or Gross Domestic Product, which refers to the total value of goods and services within a country's borders in each period. (Callen 2008) As a nation's economy grows, so does its emissions due to increased energy usage and energy consumption. However, after surpassing a certain level of economic development, emissions may begin to decline. This happens if the country decides to shift its focus from industrial expansion into cleaner technologies and service-based industries.

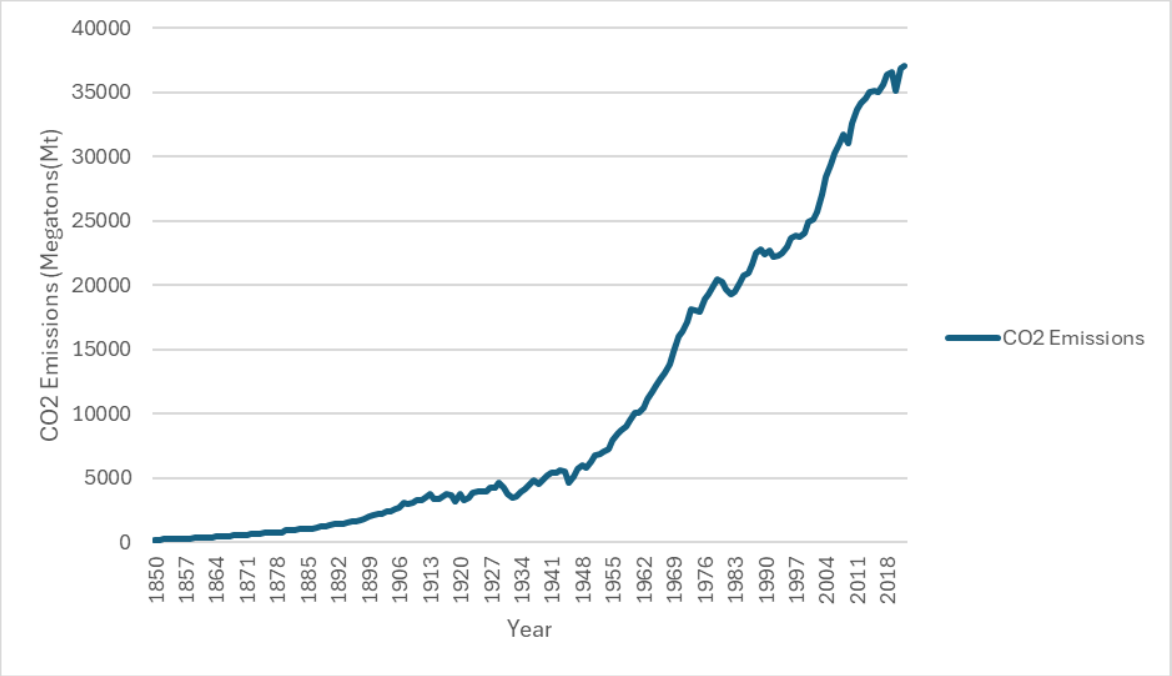

Figure 1. Yearly CO_2 levels from 1850 to 2022. Data obtained from Postdam Institute for Climate Research.

The Environmental Kuznets Curve (EKC) is an environmental theory that states that there is an inverted U-shaped relationship between economic development and environmental degradation. (Grossman & Krueger, 1991) According to the hypothesis, environmental degradation initially increases as economies begin to develop but begins to decline once a certain income level is reached, as wealthier societies. The foundations of the EKC-hypothesis came from Simon Kuznets' theory about economic growth and inequality. The theory states that with economic growth and higher usage of resources comes more waste and pollution. Industrialization of agricultural societies weakens the quality of the environment. (Kuznets, 1955)

Education plays a central role in addressing climate change. Education has historically been a driver for economic growth and cleaner environments. It can increase critical thinking, environmental awareness and lead to sustainable solutions. Nowadays, education is also seen as a tool to implement cleaner technologies due to green innovations. Education not only equips people with knowledge to combat differing modern issues in our

society but also cultivates other important skills and values for collective action and new policies (Kagawa & Selby, 2009).

Although the EKC literature has traditionally emphasized income as the primary driver, education could serve as a key link that helps countries adopt sustainable policies earlier in their development. Empirical studies indicate that EKC hypothesis holds for most high-income countries, while lower income countries might not have reached this turning point yet. (Elvan & Cakir, 2021) Investing in education can be the missing piece for developing countries to take huge strides forwards in technology and economy. In highly educated countries, education often leads to advanced technology, as highly educated people are more inclined to adopt and invent new technologies. (Vaizey, 1972)

Education can also lead countries into adopting more strict regulations, which allow them to mitigate possible effects of climate change. For instance, mechanisms like the EU Emissions Trading System were introduced to combat some of these issues by incentivizing emissions reductions through market-based policies. (Pahle et al., 2025) The OECD countries researched in this research also work closely with other countries to achieve United Nations' Sustainable Development Goals (SDGs). OECD recommends all its member countries to develop a strategic vision to achieve the SDGs in an integrated and coherent manner (OECD Legal 2019a)

One of the driving forces for a better future is The Organization for Economic Co-Operation and Development (OECD). The OECD is an international organization with 38 countries and aims to preserve individual liberty and increase the economic and social well-being of their people. For example, OECD has legal instruments that work as legal frameworks to promote international policy challenges, including environmental protection. (OECD Legal 2019a). OECD offers a rich dataset to analyse developed and emerging economies in a larger scale.

1.1 Objectives and research questions

The aim of this study is to explore how differences in educational attainment influence the Environmental Kuznets Curve (EKC) within the OECD countries in 1995 to 2021. The goal of this study is to determine the role of education in the EKC hypothesis' context. The goal is to find out if education can work as a meaningful driver towards developing countries reach the point where economic growth doesn't lead to environmental degradation and developed countries into the point where they can further reduce environmental harm.

The timeframe for this thesis was chosen, because it will provide a rich set of data to analyze both economic and educational factors of the EKC hypothesis. During this time period there has been significant changes both the academic and economic contexts all around the world. These years also collide with key climate agreements like the Paris agreement (2015).

The research questions of the study are as follows:

Primary research question: How does education impact the EKC hypothesis in the OECD in 1995-2021?

Subquestions: SQ1. Are countries with higher levels of educational attainment more likely to support the EKC hypothesis?

SQ2. Does the impact of education on environmental degradation differ based on economic or geographical factors within the OECD countries?

1.2 Limitations to the study

This study focuses on the relationship between the EKC hypothesis and the role of education across OECD countries. One major limitation lies in the availability and

consistency of longitudinal over the timeframe chosen. The timeframe for this study is 1995-2021. The data is from 38 OECD countries and 6 different regions within the OECD.

Another limitation is capturing the effects of education correctly. Education is measured by mean years of schooling while CO_2 emissions and GDP are measured over time and per capita. While these indicators are widely used and accepted, the reader should be aware that this model doesn't capture all the effects and complexity of CO_2 emissions. For example, environmental policy or energy use isn't included in this model. This study will use a quantitative approach by using regressional panel data models to describe the data.

1.3 Structure of the thesis

This thesis is structured across five chapters. It begins with an introduction followed by a theoretical background section that expands on the research and concept introduced in the introductory part of the thesis. The third chapter focuses on the dataset and methodology of this research. In the fourth chapter the focus will be on the analysis and findings of this research focusing especially on the relationships between EKC hypothesis, education level and environmental degradation (see Figure 2). And after that the final chapter will focus on the findings done in the previous chapter and summarize the whole thesis.

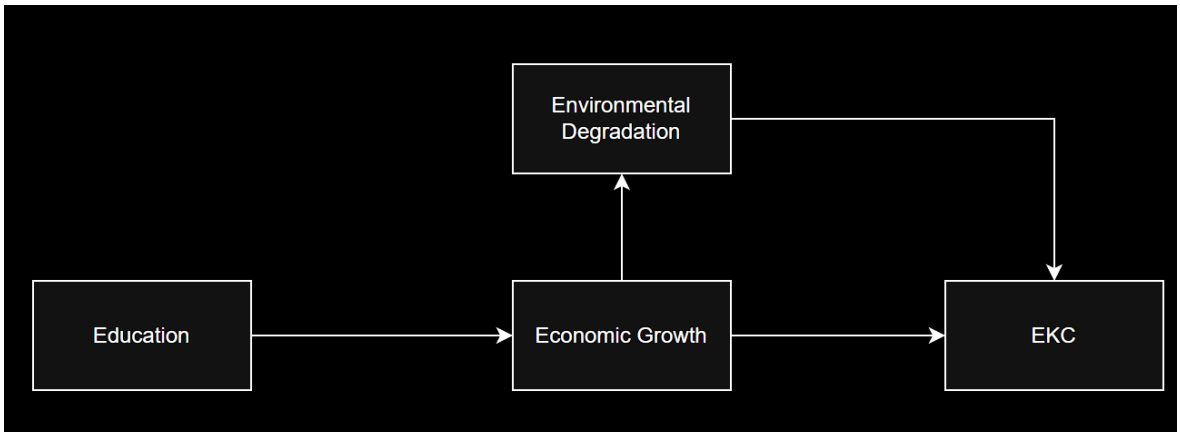

Figure 2: Arrow chart of researched concepts.

2 Theoretical Background

This chapter is focused on laying the theoretical foundations on the key concepts this research will be focusing on. These concepts are education, GDP, economic growth, environmental degradation and the Environmental Kuznets Curve.

2.1 Education

Education has been a cornerstone of societal and economic transformation, playing a crucial role in shaping modern society. The education system's historic expansion alongside industrialization was essential in developing a skilled workforce. Research suggests that the rise of public-school systems and higher education institutions provided workers with much needed technical skills but also broader social awareness. That led to more democratic governances which led to economic stability within countries. Empirical evidence suggests that countries with strong education systems are more likely to experience higher levels of technological innovation, improved living standards and long-term sustainable economic growth (Goldin & Katz, 2007).

When talking about education, it's important to talk about the economy behind education that makes it possible in the first place. Economic models have had mixed opinions about education, with some treating it as a non-factor while others highlight its importance. Traditional economic models like the neoclassical Solow-Swan model focuses more on accumulating capital and exogenous growth, treating innovation that stems from education as a non-factor. (Solow 1956)

The human capital theory by Romer (1989) argues the importance of education and knowledge acquirement as endogenous drivers for economic expansion. Romer argues that these investments into human capital, especially education, create spillover effects that lead to technological progress and innovation. Romer's study was an important cornerstone of understanding the link between education, human capital and economic growth.

Empirical studies show that countries with higher educational attainment tend to have faster economic growth due to a more skilled workforce. (Romer, 1989)

Education is also important in the sense that it can be used as a tool to foster a society into environmentally aware and problem-solving people. An educated population is more likely to understand the consequences of long-term environmental degradation and benefits of sustainable practices. As Romer's endogenous growth theory suggests, education fuels technological progress and innovation. Educated people are more likely to contribute to the innovation of much needed green technologies and new ways of efficiently using the resources currently available.

Education in the modern world plays a pivotal part in fostering environmental innovation and sustainability. Integrating sustainability into the curriculum of educational institutions has been shown to increase pro-environmental behavior amongst students. A longitudinal study revealed that participation in sustainable development programs in universities enhanced students' environmental knowledge as well as resulted in more sustainable behaviors over time. (Collado et al., 2022)Investing in education can be crucial for advancing environmental innovation and achieving sustainability targets.

Education can also work as a gateway into addressing more global challenges. The OECD Development Centre's Working Paper (McDonnell et al,. 2020) talks about ways education can be used to combat issues across borders. McDonnell et al. emphasize how important it is to prepare societies for all the environmental challenges the human race will face in the 21st century. By promoting deep understanding of important and topical issues internationally, education can enable individuals with tools to tackle these issues. Raising awareness on a global scale is important as collective action is the best way to combat global issues.

OECD is a huge advocate for educating the masses. OECD regularly recommends countries to reform their education systems. This is referred by the economists as "improving human capital." A key component of this is OECDs Innovation Imperative report (2015) which emphasizes the importance of investing education in fostering

education. OECD is a firm believer in education's importance in meeting the demands of an innovation-driven economy. (OECD 2015) This aligns with OECDs broader goals in transitioning into a more inclusive, sustainable and prosperous economy. This focus on education is why restricting the sample size of this research to only OECD countries. These countries share a common commitment to advancing human capital through education policy.

2.2 Economic growth and GDP

Economic growth is an important driver of national prosperity, improved living standards, technological progress and also societal well-being. Traditionally economic growth has been measured by gross domestic product (GDP), which is the value of goods and services produced by the nation's economy subtracted from the value of goods and services used in production. GDP also equals the sum of personal consumption expenditures, gross domestic investment and net exports of goods and services, gross investment and government consumption (Dynan et al. 2018)

Historically, there have been many models that have been created to explain economic growth. The closest growth model to this research about the EKC model is perhaps the neoclassical Solow growth model. (Solow 1956) Solow's model emphasizes the roles of capital accumulation, technological progress and labor as the driving forces for long-term economic expansion. Solow's growth model has later also been used as the basis of the Environmental Kuznets Curve. (Dasgupta et al., 2002)

Endogenous growth theory, pioneered by Romer (1986), argues the importance of education, research and technological advancements, which create cycles of production and innovation. Unlike traditional exogenic growth models like the Solow growth model, the endogenous growth model treats investment in education as a driver for economic expansion through generating new ideas, improving long-term efficiency and providing the country with a skilled workforce. Empirical evidence states that countries with higher levels of educational attainment experience faster and more stable economic growth due to a more skilled workforce and greater innovation capacity. (Romer, 1994)

Economic growth almost always comes with its challenges. Rapid expansion of economies can lead to higher levels of income inequality, contribute to higher levels of environmental degradation and accelerate resource depletion if not managed with a focus on sustainability. (Stiglitz et al., 2009) In response to this, alternative ways of measuring progress have been created. For example, the Green GDP, which calculates and adjusts the traditional GDP calculations and accounts for environmental costs and the Human Development Index (HDI) which incorporates life expectancy alongside indicators in education (United Nations Development Programme 1990; Fernandes et al., 2021)

Economic growth is mostly a positive phenomenon for developing societies, however economic growth often comes with environmental challenges. Economic growth has a dual nature. While it drives prosperity and wealth into societies, it can create new problems for especially developing and newer economies. The EKC hypothesis is a great way to understand these problems created by economic growth in developing countries.

2.3 Environmental degradation

Rapid industrialization, driven by quick economic growth and urbanization increases the consumption of limited natural resources like fossil fuels and lumber. In the 1972 report, (Meadows et al., 1972) commissioned by the Club of Rome simulated the consequences of exponential growth around the globe. The study analyzed several different scenarios for what would happen to the world if the growth trends at that time stayed similar. The "standard run" simulation predicted that the world would be facing ecological crisis at the beginning of the 21st century. The projection predicted such challenges as climate change, biodiversity loss and resource depletion. This work underlined the possibilities of what would happen if economic activities surpassed the Earth's carrying capacity. (Meadows et al., 1972) The EKC hypothesis offers a useful framework to understand this phenomenon, with economies increasing their environmental degradation up to a certain threshold until societies adopt more sustainable practices after converting to more service-based societies.

While economic growth has its downsides with environmental degradation, it can be used to create positive changes within countries and societies. After expanding their economies,

countries have important decisions to make regarding their environmental policies. Government regulations such as emission limits and carbon taxes have historically been very effective at reducing environmental harm, while being able to foster economic growth. Empirical studies show that the relationship between national income and pollution levels can vary depending on the analytical methods used. This indicates that environmental policy can play a significant role in influencing environmental outcomes. (Harbaugh et al., 2002)

Market-based mechanisms like carbon pricing and cap-and-trade systems provide companies with economic incentives to adopt cleaner technologies. This further demonstrates the fact that economic growth and environmental protection don't have to conflict and there are possibilities to have both rather than just one or the other.

International regulation plays a crucial part in reducing emissions on a global scale. Reducing these emissions requires coordinated efforts in collaboration to implement policies, technologies and practices that decouple economic growth from environmental harm. Additionally international policies and agreements such as the Paris agreement emphasize the need for global co-operation when trying to address climate change. (UNFCCC 2016)

Another phenomenon that is crucial when talking about environmental degradation is the outsourcing of pollution. Some critics may argue that developed countries are simply outsourcing their pollution-intensive industries to nations with less strict pollution regulations. However, evidence suggests that the reality of it is more complex than that. Levinson (2023) points out that while imports and exports between developed and developing countries have increased, the goods being imported haven't shifted towards more pollution-heavy goods. In fact, the goods being imported have shifted towards cleaner industries in the past three decades. (Levinson 2023) This indicates that the amount of so called "pollution havens" have decreased globally.

2.4 Environmental Kuznets Curve

The EKC hypothesis is a concept introduced by Grossmann and Krueger (1991). These studies were inspired originally by Simon Kuznets' (1955) work on income inequality. The study focused on the environmental effects in the context of the North American Free Trade Agreement (NAFTA). They found that specific pollutants like sulfur dioxide (SO_2), airborne dust and smoke from industrial activities increase early economic development but seem to decline after a country reaches a certain level of economic status. This relationship followed an inverted U-shaped curve (see figure 3) with income per capita in the researched countries. (Grossman & Krueger 1991).

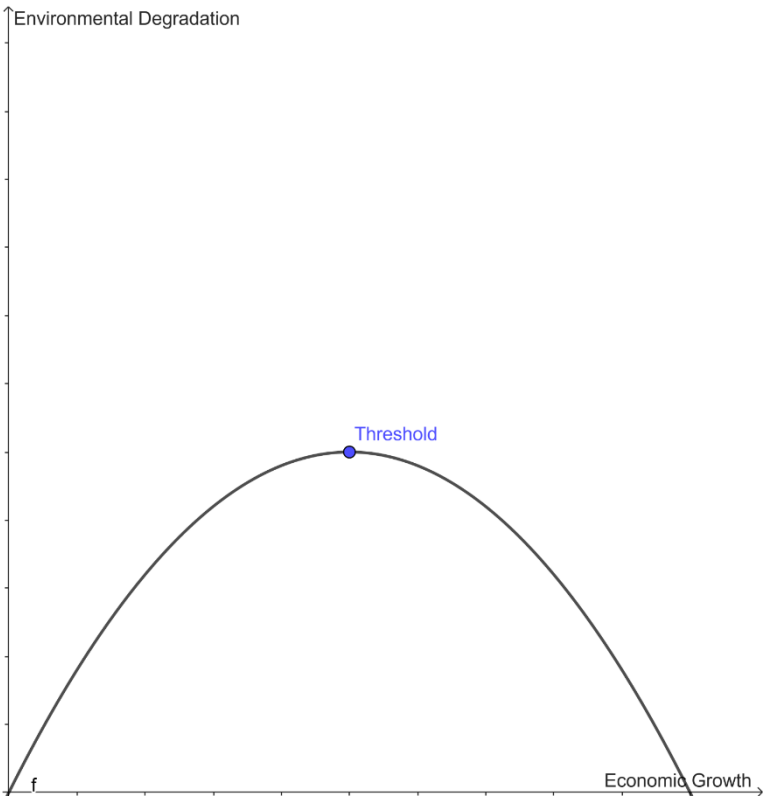

Figure 3: The Environmental Kuznets Curve

Traditionally the EKC curve has been modelled by this equation (Kijima et al., 2010)

$$Y_{it} = \alpha + \beta_1 x_{it} + \beta_2 x_{it}^2 + \beta_3 x_{it}^3 + \beta_4 z_{it} + \varepsilon_{it} \quad (1)$$

Where Y represents an environmental indicator, x describes income and z represents the other factors relating to the phenomenon relevant to environmental degradation and ε is the error term. The indice i stands for a local area, for this research it represents a specific OECD country and t stands for time. The constant term of the equation is denoted by α and each parameter is estimated by the coefficient β.

For the EKC hypothesis to work there are a few key requirements that need to be fulfilled. For there to be an inverted U-shaped relationship, which is a requirement for the EKC to work, these conditions need to be met $\beta_1 > 0$ and $\beta_2 < 0$ If these conditions are met, the EKC hypothesis holds. If a downward turning parabola is spotted, the turning point can be calculated by differentiating the previous equation and finding the zero of the derivatives. In this case, the calculation of the turning point is calculated as below:

$$x = -\frac{\beta}{2\beta_2} \quad (2)$$

For logarithmic variables which this research uses the turning point is calculated using the following formula:

$$e^{-\frac{\beta_1}{2\beta_2}} \quad (3)$$

There is also another case where if $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$ the result is a situation where the curve is an N-shaped relationship between economic growth and the environment. This situation happens when the relationship between economic growth and the environment at first seems like the EKC curve, but in the end the increase in income ends in more environmental degradation. Also, if $\beta_1 = \beta_2 = \beta_3$ there is no relationship between income and the environment. The other possible cases are not relevant to EKC (Kijima et al., 2010).

The N-shaped relationship between economic and the environment was spotted as early as 1991, by Grossman and Krueger. The N-shaped relationship is a case where economic growth comes with a rise in environmental degradation, after reaching a certain threshold lowers while the economy grows. The difference from the inverted U-shaped curve is that in the N-shaped case the curve has two thresholds. After the second threshold the environmental degradation rises again with economic growth. The case of the N-shaped relationships was spotted in lower-middle income countries like India, Indonesia and Guatemala. This evidence supports the fact that the EKC hypothesis isn't the most straightforward, as it doesn't always show the inverted U-shaped relationship. (Allard et al., 2018)

There are two main ways to examine the EKC model from the view of the economy. It can be viewed from a static or dynamic perspective. (Kijima et al. 2010) When viewing EKC from a static perspective, it essentially takes a snapshot of it at a certain moment in time. Static perspective is good for analyzing several countries at a time, but it lacks proficiency in accounting for shifts in policy, technology and other relevant factors. From a dynamic perspective it examines how environmental impact develops over time from individual countries' perspective. This way of analyzing EKC is way more complete, and it gives meaningful data on things like policy shifts, technology and economic changes. (Kijima et al., 2010)

2.4.1 Theoretical explanation

At lower income levels, economic growth is heavily tied to higher industrial output, which requires more resources. This leads to higher levels of pollution. This phase is called the scale effect, a situation where a higher GDP results in significantly higher amounts of emissions and depletion of resources. (Grossman & Krueger, 1995) In the earlier stages of industrialization economies rely more on fossil-based fuels and pollution intensive manufacturing, leading to severe environmental degradation.

After economies develop, they start to shift from resource-heavy industrial societies towards service-based industries. This structural transformation is known as the

composition effect. The composition effect reduces pollution levels heavily due to transforming into more service-based industries. Empirical studies indicate that high-income countries experience a decline in emissions after transitioning away from energy-intensive industries. (Grossman & Krueger, 1995)

After transitioning into more service-based industries, developed countries often become more efficient with their resource usage and pollution control. This so-called technique effect happens when companies driven by higher incomes adopt cleaner technologies, become more environmentally aware and comply with stricter regulations. The adoption of greener technologies helps companies decouple economic growth from environmental degradation. However, some companies might require some regulatory pressure to adopt cleaner technologies. If there is no regulatory pressure some companies might try to cut costs by implementing sustainable practices.

2.4.2 Previous research & limitations

The field of EKC research is plentiful and has provided many different types of research (see Table 1), that contribute to the bigger picture. Earlier research like Grossman & Krueger (1991) and Panayotou (1993) found support for the EKC for pollutants like SO2 and deforestation and finding the link between GDP, pollution and trade-related variables. Stern (2004) made an important contribution to EKC literature and discovered that other factors are like energy type and model selection matter in the relationship between economic growth and environmental degradation. Stern critiques the EKC hypothesis for its overreliance on income as the primary driver for environmental improvements. His argument is built around the fact that policy decisions, structural decisions and technical advancements play a crucial role.

While the EKC has been studied a lot, it has yielded mixed results in previous research. Some pollutants showing the inverted U-shape, recently research has shown that the N-shaped relationship has been common, and some research shows no results of the hypothesis working. Mandal and Chakravarty (2016) conducted a comprehensive review of 150 studies on the EKC hypothesis. The review highlights a clear weakness in existing

literature. They argue that many studies fail to take heteroskedasticity and simultaneity into account when researching EKC. They also argue that studies with stationary tests often fail to find the EKC pattern.

Other recent studies present mixed findings, for example Lee, Chiu and Sun (2010) identify region-specific turning points for EKC including water pollution. Ng, Choong and Lao (2020) find EKC support for 24 countries out of 76 and finding an inverted U-shaped relationship in only 16 of them. This shows that EKC results might be difficult to generalize. Zhou et al. (2018) and Destek & Sarkodie (2019) both show support for EKC with CO2 emissions as the explained problem. Tunali (2022) confirms in his research that the EKC hypothesis holds with augmented education enrollment. Cil & Polat (2024) find validate the EKC for methane emissions, showing its applicability to different pollutants.

Research	Year	Dataset	Explained problem	Explanatory factors	Results
Grossman & Krueger (1991)	1979-1990	Countries involved in NAFTA negotiations (Mexico, USA, Canada)	Sulfur Dioxide (SO2), Fine smoke particles, suspended particular matter (SPM)	GDP, population density, trade intensity, political and geographical dummies	EKC is valid for certain pollutants
Panayotou (1993)	1987-1988	55 Countries	SO2, Nox, CO, Deforestation	GDP, population , local dummy	EKC is valid
Stern (2004)	1960-1990	Meta-analysis	SO2, CO2, Deforestation, Other air pollutants	GDP, Trade openness, Energy use, Technological development, Regulatory policies	EKC rejected, other factors like policy, model selection and energy trade matters more.
Lee, Chiu, Sun (2010)	1980-2001	97 Countries	Water pollution	GDP, regional classifications, biological oxygen demand (BOD)	Asia and Africa for BOD, threshold approximately 38000$ in Europe and 14000$ for Americas
Zhou et al. (2018)	1983-2013	10 countries with most carbon emissions	CO2	Economic growth, Energy consumption	Research supports EKC
Destek, Sarkodie (2019)	1977-2013	11 Newly industrialized countries	CO2	GDP, Energy Consumption, Financial Development	EKC holds
Ng, Choong, Lau (2020)	1971-2014	76 Countries	CO2	GDP, Asymmetry analysis, Cross-section dependance	EKC Holds for 24 countries out of 76, 16 of them show and inverted U-Shaped relationship
Tunali (2022)	1991-2018	21 EU countries	Environmental pollutants	GDP per capita & Tertiary education enrollment	EKC hypothesis holds with augmented Tertiary education enrollment
Cil, Polat (2024)	1993-2018	39 Countries	CO2, Methane	GDP, Energy consumption, Human Development Index, population, environmental patents	EKC is valid

Table 1: Examples on previous EKC research and the validity of EKC with different pollutants and factors

This research will have a few hypotheses for the research on the impacts of education level to the EKC curve. These hypotheses are based on the theoretical framework and literature review above. The hypothesis' formulated are as follows:

H1: The EKC hypothesis holds for most of the countries.

H2: Education (mean years of schooling) will have a negative effect on CO_2 emissions

H3: The relationship between education will differ across the regions researched.

3 Methodology

Based on the theoretical research from last chapter, the goal of this research is to create econometrical models that are used to examine the EKC hypothesis. The models are estimated from datasets collected from various trusted sources.

3.1 Data

The CO_2 per capita dataset is obtained from Emissions Database for Global Atmospheric (EDGAR). The CO_2 dataset in is in tons per capita. GDP per capita dataset is obtained from the International Monetary Fund (IMF). GDP is measured in USD. The mean years of schooling dataset is obtained from Global Data Lab (GDL) which is an institution connected to the Radboud University in Netherlands. The data from the dataset is between the years of 1995 and 2021. Note that on the CO_2 dataset countries like Israel, Spain, Switzerland, Italy and France include small nations like Palestine, Andorra, Liechtenstein, Vatican and Monaco in their CO_2 per capita dataset. However, this shouldn't have much meaningful impact on the data as these are all relatively small nations with relatively small CO_2 emissions.

The selection of the variables was based mostly on previous research. Education is the factor that hasn't been researched much, which will be measured by mean years of schooling to reflect the effects of education on environmental degradation and the economy. Environmental degradation is measured by CO_2 emissions, because it's the model that has gotten most attention in prior EKC research. CO_2 emissions is a widely accepted proxy for environmental degradation due to its direct link to industrial activity, economic growth and energy consumption. Previous studies have mainly focused on the relationship between CO_2 emissions and economic growth. However, the dynamic between education within this dynamic remains relatively underexplored.

To capture these effects in a practical way mean years of schooling as the explanatory variable was chosen to measure education and its positive effects into the economies and environments of the OECD countries. This model provides a standardized measure for education attainment across different countries over time. The goal of this research is to

examine whether higher educational attainment accelerates the transition towards reduced emissions, potentially shifting or flattening the EKC curve.

The dataset spans multiple OECD countries ranging from emerging economies and fully developed economies. Examining the OECD countries gives this research nuanced examination of how education interacts with interacts with economic and environmental factors at different stages of development.

This research will be using panel data of 38 different OECD countries and analyse the relationships between different regions of the OECD countries. The regions analysed in this thesis are: 1. Western Europe, 2. Nordic and Baltic countries, 3. Southern Europe 4. Eastern Europe, 5. Asia-Pacific and Oceania 6. Americas. By examining different regions of the OECD, the goal is to find correlations between each region and what effects education and mean years of schooling have on each country's economies and CO_2 emissions. The countries will be analysed individually and after gathering all the results in a region, they will be further analysed.

The countries in each group are as follows:

G1, Western Europe: Austria, Belgium, France, Germany, Ireland, Luxembourg, Netherlands, Switzerland & United Kingdom

G2, Nordic and Baltic countries: Denmark, Finland, Iceland, Sweden, Estonia, Lithuania & Latvia

G3, Southern Europe and Israel: Greece, Italy, Isreal, Portugal, Spain & Türkiye

G4, APAC and OCE: Japan, South Korea, Australia & New Zealand

G5, Eastern Europe: Czech Republic, Hungary, Poland, Slovenia & Slovakia

G6, Americas: Chile, Colombia, Costa Rica, Canada, USA

3.2 Estimation methods

EKC has often been modelled with panel datasets. The most common estimation methods to estimate panel data are Pooled Ordinary Least Squares Method (Pooled OLS), Fixed Effects method (FE) and the Random Effects method (RE). In the selection process of the choice these tests will be used to determine the correct one for this dataset: F-test, Hausman-test, and the Brauch-Pagan-test.

The Pooled OLS method or Pooled Ordinary Least Squares method involves estimating a single regression model by combing all cross-sectional and timeseries data while ignoring all individual specific effects. The method assumes that the estimated parameters don't change in time or change between cross sections, meaning that heterogeneity in the dataset will be ignored (Hill et al. 2018, 650-653).

Pooled OLS is commonly modelled by the following equation:

$$Y_{it} = \alpha + \beta x_{it} + \varepsilon_{it} \quad (4)$$

In this equation (3) The dependant variable Y_{it} is explained by a variable, α is a constant, x_{it} is an explanatory variable, β is the coefficient of the variable and ε_{it} is the error term. Each cross section is represented by i and each time units are represented by t.

The Fixed Effects method takes heterogeneity into consideration, which is the biggest difference from the Pooled OLS. Heterogeneity can be tested with the F-test which estimates if the dataset has unit-specific differences in the data. If there are unit specific differences FE-test works better than Pooled OLS. The coefficients are estimated for the units, reflects the differences between the units. That means that this constant term varies from one unit to another but does not change over time. Since the constant term reflects all the differences in the dataset, the estimated coefficients for the selected parameters are the same for all units (Hill et al. 2018, 650-651.).

The Fixed Effects method with two explanatory variables can be expressed in this following form:

$$Y_{it} = \beta_{1i} + \beta_2 x_{2it} + \beta_3 x_{3it} + \varepsilon_{it} \quad (5)$$

Equation (4) represents the Fixed Effects method. In this model Y is the dependent variable for the units i and t. x_{2it} and x_{3it} are explanatory variables for the same unit and time period.

The coefficient β_{1i} accounts for unit specific effects between the units (countries in the case of this research). The coefficients β_2 and β_3 are the estimated effects of the explanatory variables on the dependant variable which control heterogeneity. ε_{it} is the error term in this equation. If the value of dependant variables doesn't change much over time, the Random Effects method should be the method of choice.

The Random Effects Method assumes that the unobserved specific individual effects are random variables drawn from a larger population and uncorrelated with the explanatory variables within the model. The RE model treats the intercepts as part of the error term instead of the structure like the FE model. According to Hill et al. (2018, 647-652.) the biggest strength of the RE model is having both within-unit and between-unit variation, which allows for more efficient estimation given that the omitted effects aren't related to the regressors. This model should be used when there are time-invariant variables. The decision to choose between the FE or RE method can be done by doing the Hausman test which tests if the RE assumptions are correct.

The coefficient β_{1i} describes unit-specific differences. It includes the mean of the population β_1 and the random term u_i.

$$\beta_{1i} = \beta_1 + u_i \tag{6}$$

The error term also includes u_i which cant correlate in any unit since they are included in all the terms of the full RE equation. The most important part is that u_i doesn't correlate with ε_{it}, the full error term equation is as follows:

$$v_{it} = u_{it} + \varepsilon_{it} \tag{7}$$

Otherwise, the full FE equation is very similar to the FE equation but just involves this more complex error term which takes random effects into account. The equation goes as follows:

$$Y_{it} = \beta_{1i} + \beta_2 x_{2it} + \beta_3 x_{3it} + v_{it} \tag{8}$$

(Hill et al. 2018, 640-642.)

3.3 Model specification

This research will analyse different regions with two different models. The key explanatory variables are the natural logarithms of GDP per capita and its square $(GDP)^2$, included to capture any potential relationships consistent with the EKC curve. For the dependant variable $CO_{2_{it}}$ is the CO_2 emissions per capita for country *i* in time *t.* The error term is ε.Model 2 also includes the natural logarithm of mean years of schooling as an additional explanatory variable to explore its role in EKC context. This allows the model to assess the impacts of education on CO_2 emissions.

The modelled equations go as follows:

Model 1: $\ln(CO_2) = \alpha_i + \beta_1 \ln (gdp)_{it-1} + \beta_2 \ln (gdp)^2_{it-1} + \varepsilon_{it}$ (9)
Model 2: $\ln(CO_2) = \alpha_i + \beta_1 \ln (gdp)_{it-1} + \beta_2 \ln(gdp)^2_{it-1} + \beta_3 \ln (edu)_{it-1} + \varepsilon_{it}$ (10)

Table 2: The estimated models

This study has transformed the main dependant variable, environmental degradation and explanatory variables, income and educational attainment into natural log-log variables (See table 2). This is done to help reduce skewness and heteroskedasticity in the dataset. By applying these natural logarithms to both the dependant and explanatory variables these can be interpreted as elasticities which means they represent percentile changes rather than absolute changes (Hill et al. 2018, 173-179).

The explanatory and control variables in this study have been lagged by a period to capture the realistic effect between income, educational attainment and environmental degradation. Lagged variables are important tools to mitigate autocorrelation, which means correlation between variables one time period apart from each other (in this case a year). (Hill et al, 2018 423-426). The use of lagged variables is highly common EKC research, for example (Destek & Sarkodie, 2019), use lagged variables in their research to capture effects between growth and emissions over time.

This study has also employed cluster-robust standard errors to mitigate possible heteroskedasticity and serial correlation within countries. Using cluster-robust standard errors requires many observations compared to time-period observed, which does happen in this study with 38 OECD countries observed over 27 years. (Hill et al. 2018, 649).

For the Pooled OLS- test, it has been found that the estimator remains consistent even with the usage of cluster-robust standard errors. However, when using the Fixed Effects (FE) and Random Effects (RE) tests along with cluster-robust standard errors can lead to possible problems. In the FE-test unobserved heterogeneity and heteroskedasticity can make the cluster-robust errors higher than standard errors. In the case of the RE-test the cluster-robust standard errors can lead to problems with endogeneity. The following reasoning is why this study uses the Hausman-Mundlak-test over the FE- and RE- tests, which provides a more reliable framework while being able to use cluster-robust standard errors. (Hill et al. 2018, 648-652, 656- 658).

Based on the correlation matrix (See Table 3) a high correlation can be seen between GDP and its squared term. (logarithmic version in Appendix 2) While such high collinearity can indicate multicollinearity, this is expected and very common in EKC research. The correlation between the other variables is moderate and doesn't raise too many concerns. Since the primary focus of this study is on the broader relationship between education, economic development and environmental degradation these do not invalidate the model. Additionally, the log-log model has reduced the skewness of this model (see appendixes 3 and 4).

	CO2	Gdp	Gdp^2	Mean_Schooling
CO2	1			
Gdp	0.4223	1		
Gdp^2	0.3421	0.9278	1	
Mean_Schooling	0.4657	0.5295	0.3887	1

Table 3: Correlation matrix for the researched variables.

4 Results

This section presents the empirical results of the panel dataset researched of 38 OECD countries and 6 regional groupings. Prior to conducting an econometric analysis to the dataset, it is important to choose the most appropriate econometric estimation method to obtain reliable estimates. In the selection of estimation method this research is using a 95% confidence interval.

The results are combined into Table 4. The Breusch-Pagan LM-test shows that all the results are under 5%, which means that the RE-estimator is more consistent than Pooled OLS. From the F-test results, all the results are under 5%, which means that the null hypothesis of the F-test is rejected and there are fixed effects. This means that the FE-estimator is preferred over the Pooled OLS. The results of the Mundlak-based Hausman-test indicate that since all the values are below the 5% confidence interval, the FE-estimator is preferred over the RE-estimator.

	Hausman (Mundlak)	Breusch-Pagan LM	F-Test	Method
Model 1	0,000	0,000	0,000	FE
Model 2	0,013	0,000	0,000	FE

Table 4: Estimation method selection results.

4.1 Estimation results

After determining the Fixed Effects (FE) Method as the most appropriate estimation method for this research, the empirical analysis proceeds with two FE-estimated models. Model 1 includes logarithmic versions of GDP and GDP squared as the explanatory variables. Model 2 uses these as well as also including the natural logarithm of mean years of schooling variable to evaluate education's role in shaping CO_2 emissions.

Turning points, which are often derived from the coefficients of GDP & GDP squared to identify the income level when emissions start to decline are not included in this study. This decision was made due to several methodological reasons: the use of a log-log-model, usage of cluster robust standard errors and relatively small group sizes for some regional clusters.

These factors complicate the computation and reliability of the turning point results, potentially leading to inaccurate or misleading results. This approach follows earlier EKC research that has decided to omit turning point estimates under similar conditions (e.g., Stern (2004); Ng, Choong & Lau (2020).

Instead of having turning points as the primary focus the analysis focuses on coefficient signs, statistical significance and explanatory power (R-squared) to assess the validity of the EKC and education's role within the dynamic.

For the EKC to hold the coefficient for GDP needs to be positive and significant and the coefficient for GDP squared needs to be negative and significant to prove the existence of EKC in a particular region or dataset. For mean years of schooling the coefficient needs to be negative and significant to prove that increased years of education decrease CO_2 emissions.

4.1.1 OECD-wide results

The OECD-wide results in Table 5 show the results of the validity of EKC and impact of education. In model 1, which includes only the GDP and GDP squared coefficients, the coefficient for GDP (1.7019) is positive and GDP squared (-0.0925) is negative and both are significant at the 1% level. These results suggest that the EKC-hypothesis holds in the dataset with the entire OECD, so emissions initially rise with economic growth but begin to decline at higher levels of income. The R-squared value (0.2283) indicates a moderate explanatory power for the model. R-squared values as low as 0.20 are very typical for EKC studies. (Stern 2004)

The results for model 2, mean years of schooling is added to test whether education has an independent effect on CO_2 emissions. The signs and coefficients for EKC remain consistent from model 1. The coefficient for mean years of schooling is negative (-0.5298) and significant at the 10% level. This indicates that increased education has a moderate negative effect on CO_2 emissions in the OECD. The explanatory power of this model (0.2707) is slightly improving from model 1.

These findings suggest that EKC is present within the OECD level and education may play a role in decreasing CO_2 emissions. However, the modest size and significance of education indicates that it would be beneficial to analyse it more in a region-specific context.

OECD	Model 1 coef (FE)	Robust std. Errors	P-value
cons_	-5.682774	0.2911601	0***
ln_gdp	1.701929	0.0154165	0***
ln_gdp_sq	-0.092503	1.371567	0***
R-squared	0.2283		
	Model 2 coef (FE)	Robust std. Errors	P-value
cons_	-4.82418	0.3058921	0,009***
ln_gdp	1.692913	0.0173541	0***
ln_gdp_sq	-0.0875594	0.3009012	0***
ln_mean_schooling	-0.529829	0.3009012	0.087*
R-squared	0.2707		

Table 5: FE-regression results for the OECD (*, **, *** are explained in appendix 1)

4.1.2 Region-specific analysis

This chapter analyses the region-specific differences and the relationship between economic growth, CO_2 emissions and mean years of schooling.

Group 1: Western Europe

In Western Europe the results don't show significant support the EKC (see Table 6) In model 1, both the coefficients are insignificant, and the GDP coefficient is negative instead of positive as is expected in EKC. This sign pattern contradicts the typical EKC pattern. The explanatory power of this model (0.38776) is relatively high, which suggests that the model explains quite a lot even if the key findings don't support EKC.

In model 2, when education is included, the GDP variables remain insignificant and also deviates from the typical EKC pattern. However, education seems to play an important role in this region, being statistically significant (0.004) and the coefficient being negative (-1.2356). This suggests that increased years of schooling leads to lower CO_2 emissions. The

explanatory power in this model (0.5196) is significantly than model 1, which also indicates the importance of education in this region. These results suggest that other factors than economic growth like education may play an important role in this region.

Group 1: Western Europe	Model 1 coef (FE)	Robust std. rrors	P-value
cons_	5.245604	1.403421	0.506
ln_gdp	-0.2590767	0.0653247	0.858
ln_gdp_sq	-0.0023049	7.532352	0.973
R-squared	0.3876		
	Model 2 coef (FE)	Robust std. Errors	P-value
cons_	8.735376	1.454657	0.308
ln_gdp	-0.6352688	0.0697894	0.674
ln_gdp_sq	0.0287962	0.3096078	0.691
ln_mean_schooling	-1.235675	8.01968	0.004***
R-squared	0.5196		

Table 6: FE-regression results for Western Europe

Group 2: Nordics and Baltics

In Nordic and Baltic countries, the results show support for the EKC hypothesis (see table 7). In model 1 both GDP and GDP are statistically significant (p = 0.033 and p= 0.039) with the expected signs for EKC, positive for GDP and negative for GDP squared. This indicates an inverted U-shaped relationship in this region. The explanatory power of this model is modest (0.2402). Model 2 also confirms the existence of EKC in this region with the GDP maintaining significance and correct coefficient signs. Education, while not statistically significant (0.13) shows a negative coefficient (-1.048), which indicates a potential emission-reducing effect that is close to statistical significance. These results imply that both economic and educational factors may play a role in influencing emissions in this region.

Group 2: Nordics and Baltics	Model 1 coef (FE)	Robust std. rrors	P-value
cons_	-6.203234	2.963652	0.075*
ln_gdp	1.820463	0.6889747	0.033**
ln_gdp_sq	-0.0986003	0.0387917	0.039**
R-squared	0.2402		
	Model 2 coef (FE)	Robust std. Errors	P-value
cons_	-4.189044	3.24761	0.238
ln_gdp	1.824855	0.6824608	0.032**
ln_gdp_sq	-0.0930761	0.0387925	0.048**

ln_mean_schooling	-1.048186	0.6111926	0.13
R-squared	0.2729		

Table 7: FE-regression results for Nordics and Baltics

Group 3: Southern Europe

In Southern Europe, there is clear support for the EKC hypothesis in both models (see table 8) with GDP and GDP squared having a P-value of 0.000 in both models and following the expected sign pattern. This means that there is a clear inverted U-shaped relationship between economic growth and CO_2 emissions. The explanatory power improves from model 1 (0.2748) to model 2 (0.3693) which once again suggests that education clearly improves this model. However, the education variable isn't significant in this region (0.347), while having a negative coefficient, so its impact remains inconclusive in this region.

Group 3: Southern Europe	Model 1 coef (FE)	Robust std. rrors	P-value
cons_	-17.18438	1.89983	0***
ln_gdp	4.041251	0.4160366	0***
ln_gdp_sq	-0.2133456	0.0227327	0***
R-squared	0.2748		
	Model 2 coef (FE)	Robust std. Errors	P-value
cons_	-19.3588	0.3811879	0***
ln_gdp	4.575626	0.0124898	0***
ln_gdp_sq	-0.2292472	0.6806872	0***
ln_mean_schooling	-0.7059288	1.425093	0.347
R-squared	0.3693		

Table 8: FE-regression results for Southern Europe

Group 4: APAC & OCE

In the Asia-Pacific and Oceania region, the regression results show support for the EKC (see table 9). In both models the signs aligned with the theoretical expectations, positive for GDP and negative for GDP squared. These are both statistically significant with model 1 (0.054 & 0.049) and model 2 slightly stronger with (0.042 & 0.036). This suggests that the EKC holds for both models in this group, at 10% risk level for model 1 and 5% risk level for model 2. The explanatory power also slightly improves model 1 to model 2 (from 0.2748 to 0.3581), indicating that including mean years of schooling improves the model. However,

education itself is insignificant (0.318) and a positive coefficient (0.8775). This means that against the hypothesis in this region it seems that increased education leads to higher CO_2 emissions. It may reflect in the high urbanization and consumerism in this region.

Group 4: APAC & OCE	Model 1 coef (FE)	Robust std. rrors	P-value
cons_	-18.50773	7.073672	0.079*
ln_gdp	4.11366	1.334457	0.054*
ln_gdp_sq	-0.2017907	0.0628587	0.049**
R-squared	0.2748		
	Model 2 coef (FE)	Robust std. Errors	P-value
cons_	-17.20393	5.795753	0.059*
ln_gdp	3.513748	1.032304	0.042**
ln_gdp_sq	-0.1764975	0.0484907	0.036**
ln_mean_schooling	0.8775218	0.7336034	0.318
R-squared	0.3581		

Table 9: FE-regression results for APAC & OCE

Group 5: Eastern Europe

The results from Eastern Europe (see table 10) do not support the EKC in either model. In model 1, the coefficients for GDP (1.2235) & GDP squared (-0.0730) are the right signs for EKC, however neither of these are statistically significant (0.162 & 0.137). This means that the inverted U-shaped relationship can't be confirmed in this region. Model 2 shows similar results, rejecting the EKC with right signs on the coefficients and insignificant p-values for the GDP and GDP squared variables. The education variable also fails to reach significance (0.296), but has a negative coefficient (-0.3127). These results suggest a potential but weak effect in reducing CO_2 emissions, because of statistical insignificance. Both models seem to catch effects on CO_2 emissions well, with R-squared being 0.4784 for model 1 and 0.4963 for model 2.

Group 5: Eastern Europe	Model 1 coef (FE)	Robust std. rrors	P-value
cons_	-2.961409	0.7137791	0.41
ln_gdp	1.223591	0.039366	0.162
ln_gdp_sq	-0.073072	3.221167	0.137
R-squared	0.4784		
	Model 2 coef (FE)	Robust std. Errors	P-value
cons_	-1.979931	3.59756	0.611
ln_gdp	1.121566	0.8376217	0.252
ln_gdp_sq	-0.0646713	0.0454107	0.228
ln_mean_schooling	-0.3127567	0.2607224	0.296
R-squared	0.4963		

Table 10: FE-regression results for Eastern Europe

Group 6: Americas

In Americas the results offer support for the EKC at a 10% risk level (see table 11). In model 1 both GDP (0.070) and GDP squared (0.080) are statistically significant at a 10% risk level. Both also follow the expected sign pattern for EKC, GDP coefficient (1.9778) and GDP squared (-0.1007). This suggests a weak but significant inverted U-shaped pattern between economic growth and CO_2 emissions. In model 2 the results for EKC are extremely similar, with significance at 10% risk level and consistent in signs. However, the education variable isn't statistically significant (0.19), but shows a negative coefficient (-0.347). This suggests a potential, however inconclusive emission-reducing relationship. R-squared values also suggest reasonable explanatory power at (0.3806 & 0.4066) for both models respectively.

Group 6: Americas	Model 1 coef (FE)	Robust std. rrors	P-value
cons_	-7.125571	3.620778	0.106
ln_gdp	1.831851	0.796536	0.07*
ln_gdp_sq	-0.0956662	0.0436335	0.08*
R-squared	0.3806		
	Model 2 coef (FE)	Robust std. Errors	P-value
cons_	-7.257417	3.85905	0.119
ln_gdp	1.977838	0.8696754	0.072*
ln_gdp_sq	-0.1007873	0.047117	0.085*
ln_mean_schooling	-0.3474985	0.2290783	0.19
R-squared	0.4066		

Table 11: FE-regression results for Americas

The EKC is supported in 4 out of 6 researched regions, with Western and Eastern Europe showing no support for EKC. 2 out of 6 countries show support for increased education time decreasing CO_2 emissions. Western Europe shows clear support, while Nordics and Baltics is borderline significant. Southern Europe, Western Europe and Americas also show negative coefficients, but aren't statistically significant. This means they could have a emissions reducing effect, but it isn't significant in this dataset. These results highlight regional differences in how economic and educational factors influence emissions.

Summary of region-specific results	Supports EKC	Education reduces CO2 Emissions	Notable insights
Group 1: Western Europe	No	Yes	Education is an important factor compared to economic growth in this region
Group 2: Nordics and Baltics:	Yes	Yes, borderline	EKC is valid, education could have an impact
Group 3: Southern Europe	Yes	No	Strong EKC, education's effect inconclusive
Group 4: APAC & OCE	Yes	No	EKC holds, education linked to higher emissions
Group 5: Eastern Europe	No	No	No EKC, no statistical support for Education
Group 6: Americas	Yes, at a 10% risk level	No	EKC supported at 10%, education inconclusive

Table 12: Summary of region-specific results

4.2 Limitations

While this research provides valuable insight into the EKC and the role of education across the regions of OECD, there are a few limitations that need to be acknowledged. Due to using a log-log functional norms, deriving meaningful and interpretable turning points becomes challenging, as the results no longer reflect straight monetary thresholds (Dinda 2004; Stern 2004). For this reason, some EKC studies specific turning point estimation, when using a log-log-model. That has also been done in this paper.

The estimation method also brings limitations. Cluster robust standard errors were employed to correct for heteroskedasticity and correlation within countries, but they can be problematic in small sample sizes. This research has regions with 4-9 countries, so sample sizes could be a little small, this could affect the accuracy of cluster robust standard errors. Using only OECD countries (38) isn't generalizable for global research and education's effect globally.

Multicollinearity and endogeneity are also potential limitations in the thesis. Multicollinearity is expected between GDP and its square and was also observed earlier in the thesis (see table 3). This is very common in EKC studies. While this may reduce the accuracy of individual coefficient estimates, which is also one reason for not being able to compute accurate turning points. However, this doesn't invalidate the overall interpretation of the EKC relationship (Stern 2004). Endogeneity can also pose a threat, in formulating reliable estimates. To address this, the model uses lagged explanatory variables and control variables, which help mitigate endogeneity, autocorrelation and simultaneity bias, ensuring a more credible structure.

These limitations should be kept in mind when interpreting the results, but by no means do they invalidate the findings.

5 Conclusions

This study set out to analyse how education impacts the EKC hypothesis in OECD countries in 1995 to 2021. Education was included in the EKC analysis as an explanatory variable. Two models were used to examine this relationship, one without education as a control variable and one with education as the control variable. The main research question was: How does education impact the EKC hypothesis in OECD countries in 1995-2021? This question is answered with the help of two sub questions:

SQ1. Are OECD countries with higher educational attainment more likely to support the EKC hypothesis?

SQ2. Does the impact of education on environmental degradation differ based on economic or geographical factors within the OECD countries?

As seen from the results section (see table 13), education appears to play a role reducing CO_2 emissions on an OECD-wide level. The inclusion of mean years of schooling to the EKC model led to improved explanatory power with negative and significant coefficients for education, suggesting that education may be associated with lower emissions. This result was statistically relationship was statistically significant at a 10% risk level in the OECD-wide model, while regional variation was observed. This indicates that educations effect on environmental outcomes are context-dependent and shaped by other factors. This highlights the importance of country-and region-specific research. While education alone doesn't determine whether a country supports the EKC hypothesis, it appears to be an important factor in shaping long-term reductions in emissions and should be a factor to be considered in future EKC research.

The results don't reveal a consistent pattern linking educational attainment and the validation of the EKC hypothesis. Some historically strong regions in educational attainment like Nordics and Baltics exhibit EKC dynamics. Meanwhile, Western Europe, which includes countries like France, UK and Germany, known for their solid educational

systems don't support the EKC. This indicates that even though education can contribute to lower emissions, it doesn't guarantee an EKC relationship. Education seems to play more of a complementary role alongside factors like institutional quality, energy policy and economic structure.

The effect of education seems to clearly vary between different economic and geographical contexts. In Western Europe, Nordics and Baltics education seems to have a stronger negative relationship with emissions. However, in other regions like Americas or Eastern Europe, it seems to have no significant impact. In APAC & Oceania it seems to have an increasing effect on emissions which is interesting. These findings indicate that education is shaped by regional and economic contexts.

Questions and hypotheses:	Result
How does education impact the EKC hypothesis in the OECD?	Education often supports lower emissions, inconsistantly across regions
SQ1: Are countries with higher education more likely to support EKC?	No consistent pattern across countries or regions.
SQ2: Does education's impact differ by economic/geographic factors?	Yes, the impact varies clearly across regions.
H1: The EKC hypothesis holds for most of the countries.	Partially supported; valid in several, not all regions.
H2: Education has a negative effect on CO_2 emissions.	Some support; effect varies in strength and direction.
H3: The education-emissions relationship differs across regions	Supported; clear regional differences in outcomes.

Table 13: Summary of research questions and hypotheses with their respective answers.

The findings from this research shows partial support for EKC across OECD regions, aligning with a lot of the EKC literature, studies like Stern (2004) show that EKC isn't universal and that its validity depends on country-specific contexts a lot. The result that education may reduce emissions aligns with Tunali (2022), who found support for the EKC, when tertiary education was included. Similarly, Ng, Choong & Lao (2020) found that EKC only holds for only a certain part of the countries, which is a similar result to this

research. The main takeaway is that economic growth alone may not be sufficient to reduce emissions, and education can play a role in achieving better environmental outcomes.

In conclusion this research contributes to the EKC literature with evidence that education could be an important factor in reducing emissions in the long-term. While the EKC holds in some parts of the OECD, it doesn't appear universally and is highly context-dependent. These findings reinforce the view that addressing environmental challenges requires a multidimensional approach where education, policy and structural conditions work in unison. Future research could benefit from researching this in a country-specific context or incorporating several control variables including education.

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6 Appendices

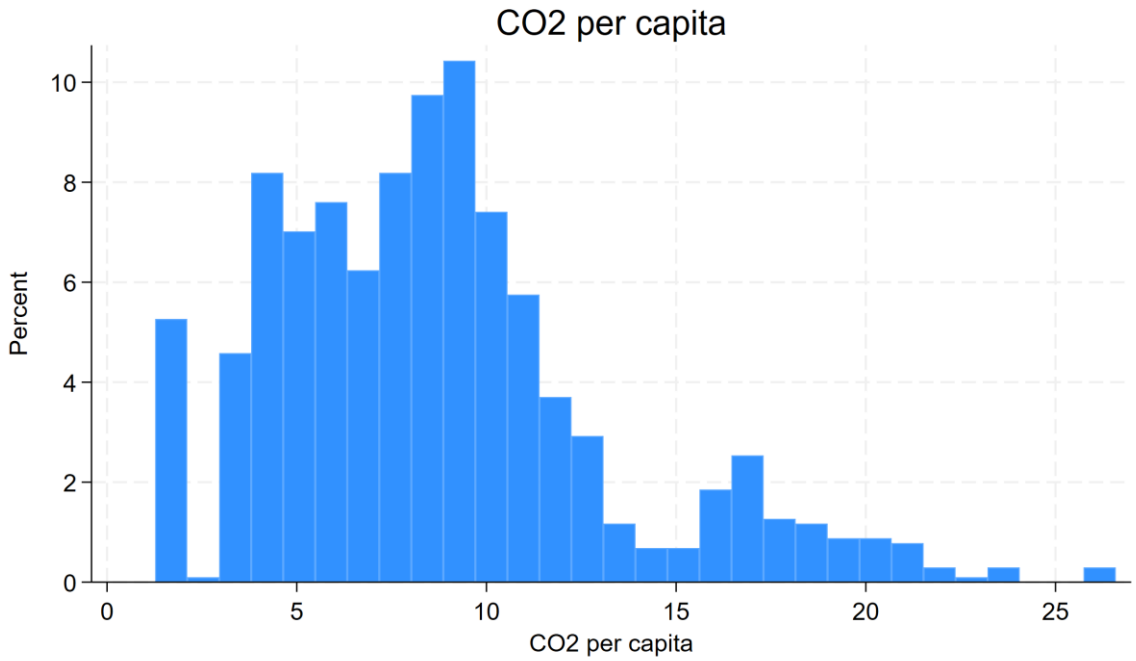
Appendix 1: Used significance levels in this thesis

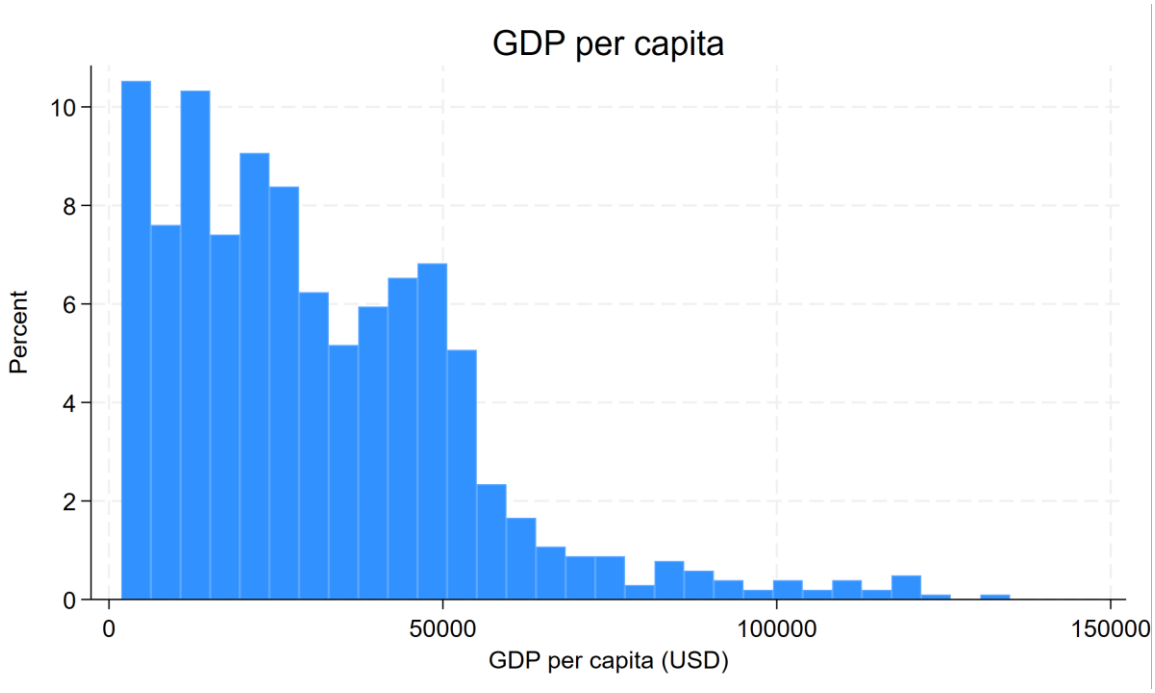
Significance level	Symbol	Meaning
1 %	***	Statistically highly significant
5 %	**	Statistically significant
10 %	*	Statistically suggestive

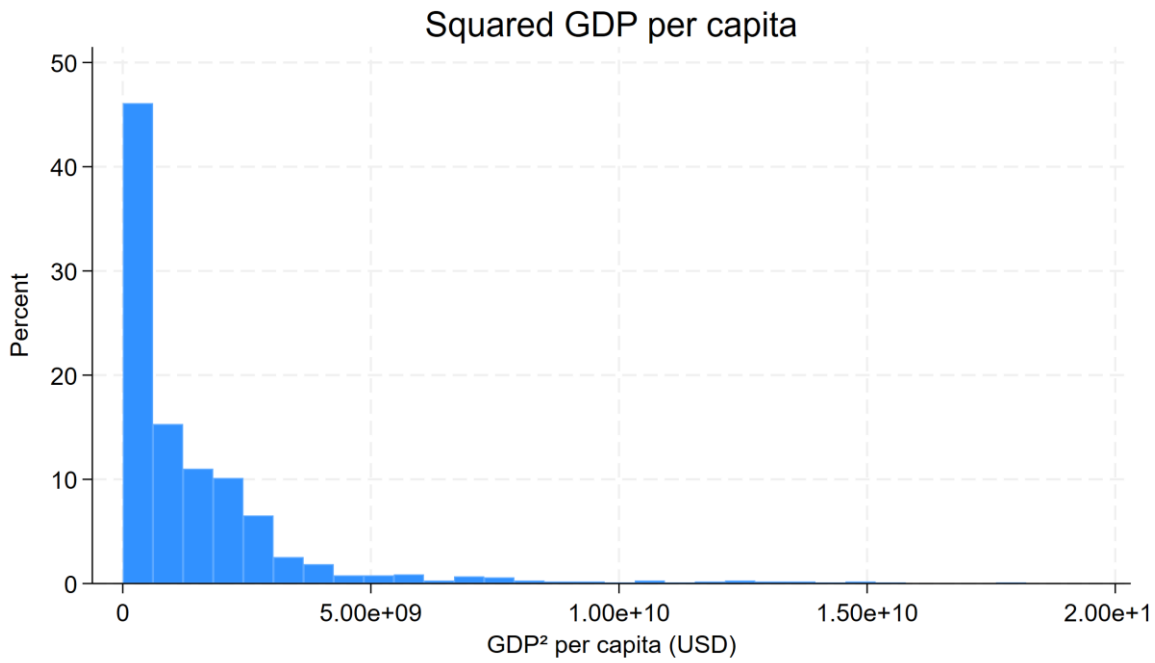
Appendix 2: Correlation matrix of the logarithmic variables

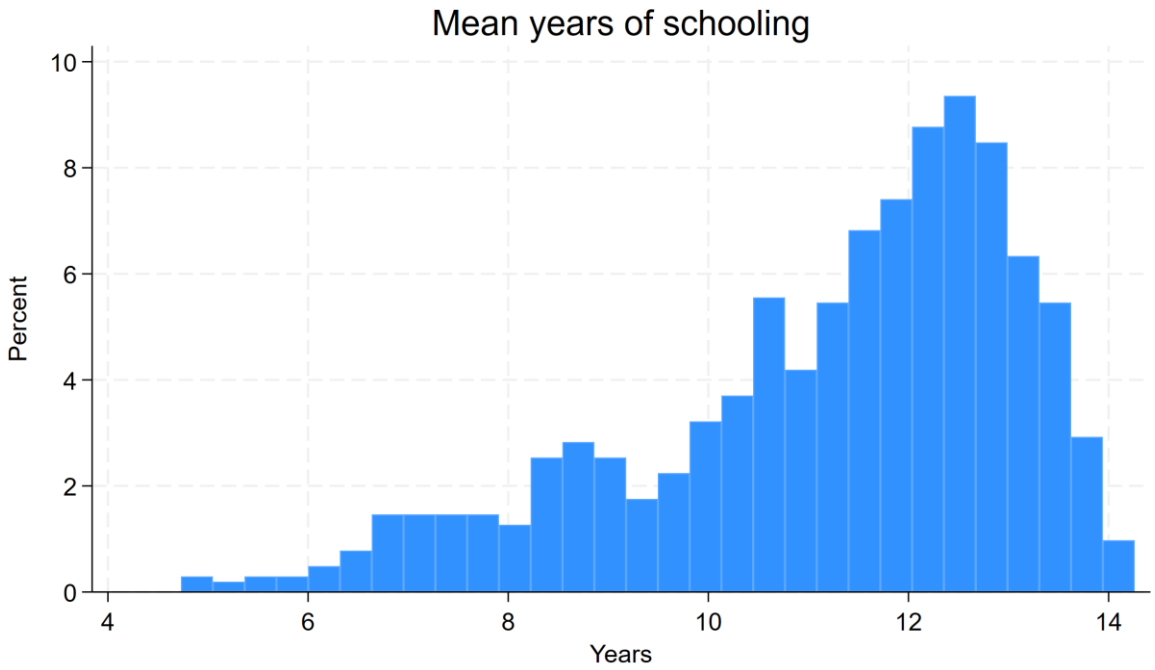
	ln_co2	ln_gdp	ln_gdp^2	ln_schooling
ln_co2	1			
ln_gdp	0.5568	1		
ln_gdp^2	0.5494	0.9987	1	
ln_schooling	0.569	0.5971	0.5953	1

Appendix 3: The distribution of variables

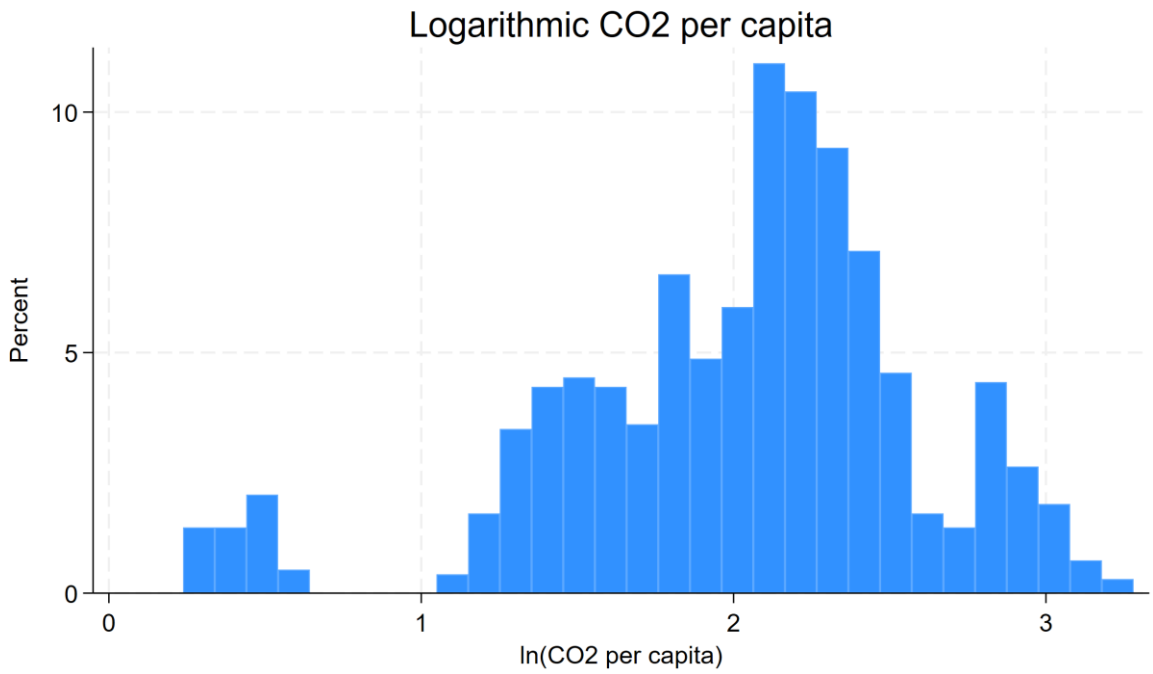

CO2 per capita
Percent
0
2
4
6
8
10
0
5
10
15
20
25
CO2 per capita

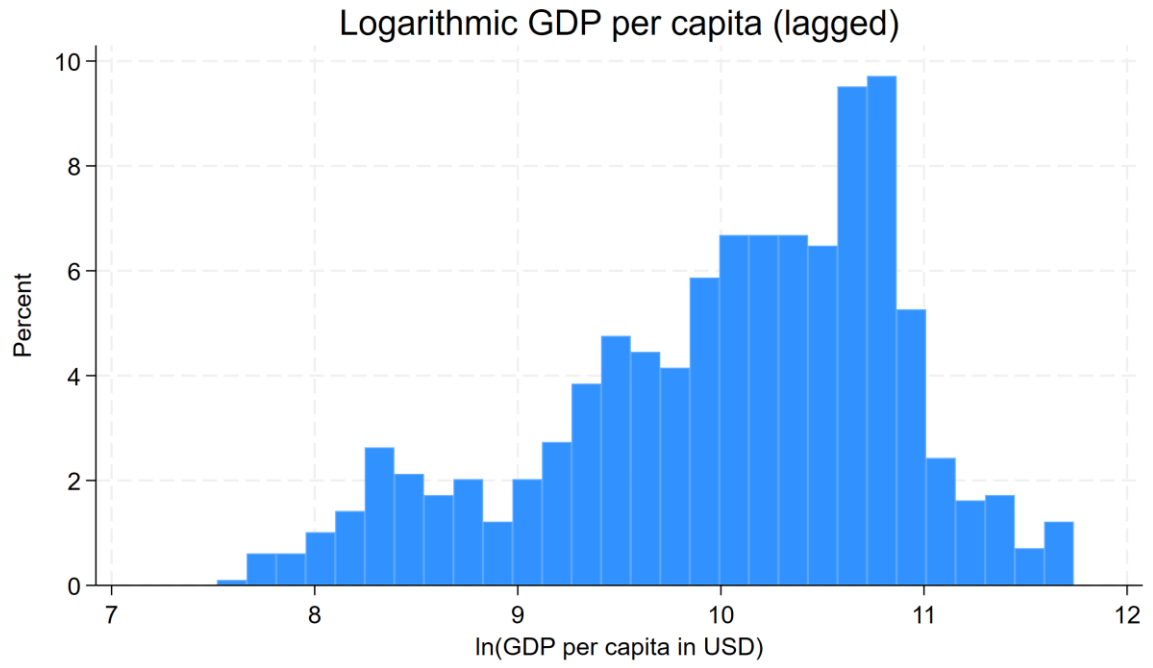

GDP per capita
Percent
0
2
4
6
8
10
0
50000
100000
150000
GDP per capita (USD)

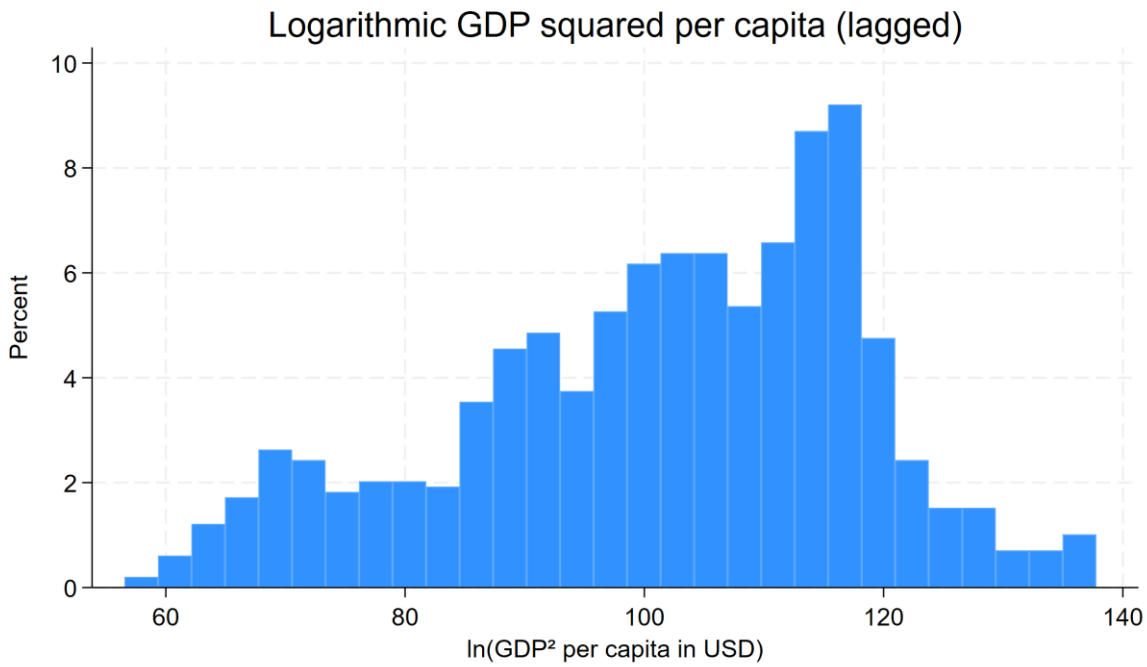


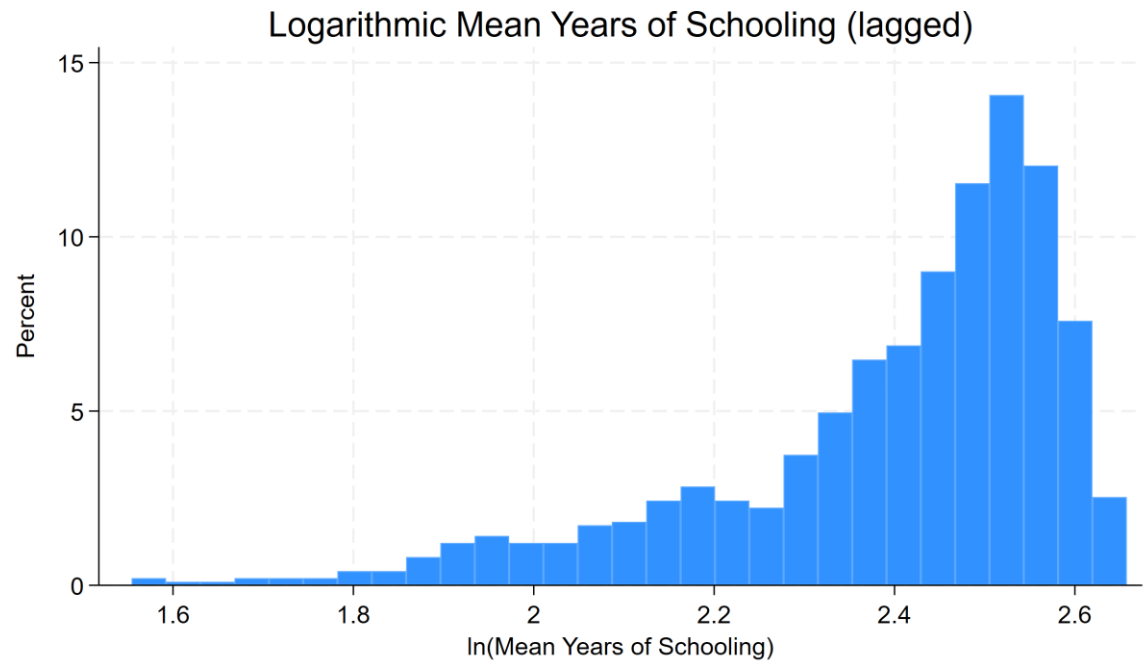


Appendix 4: Logarithmic distribution of variables:


Logarithmic CO2 per capita
Percent
10
5
0
0
1
2
3
ln(CO2 per capita)


Logarithmic GDP per capita (lagged)
Percent
10
8
6
4
2
0
7
8
9
10
11
12
ln(GDP per capita in USD)


Logarithmic GDP squared per capita (lagged)
Percent
0
2
4
6
8
10
60
80
100
120
140
ln(GDP² per capita in USD)


Logarithmic Mean Years of Schooling (lagged)
Percent
0
5
10
15
1.6
1.8
2
2.2
2.4
2.6
ln(Mean Years of Schooling)