UNIVERSITAT JAUME • I

HOW AIR POLLUTION IS RELATED TO GDP PER CAPITA OF THE OECD COUNTRIES

ABSTRACT

The main purpose of this project is to study whether air pollution is related to per capita GDP. The Environmental Kuznets Curve has been one of the most debated hypotheses in Environmental Economics in recent decades. According to this curve, the relationship between economic growth and environmental degradation follows an inverted U-shaped curve. This implies that environmental degradation is a function of economic growth, increasing until a certain income level is reached, after which further economic growth is associated with progressively lower levels of environmental degradation. This thesis briefly reviews some of the research conducted on the topic, and later performs an econometric analysis of panel data for OECD member countries.

AUTHOR: Jaime Tormo Vernia

Bachelor's Degree in Economics

Course 2022-2023

TUTHOR: Arne Hole Risa

Key words: Particle matters, Kuznets Curve, economic growth, inverted U-shape.

JEL code: C23, C33, F64, Q5.

INDEX

LIST OF FIGURES AND TABLES

FIGURES

TABLES

HOW AIR POLLUTION IS RELATED TO GDP PER CAPITA OF THE OCDE COUNTRIES

1. INTRODUCTION

Concerns about the global decline in environmental quality have given rise to a significant amount of literature on the relationship between pollution and economic growth. The World Development Report (1992) provides evidence that there is a relationship between indicators of environmental quality and per capita national income in all countries. Other studies have found an inverted U-shaped relationship between environmental degradation and income. This means that environmental quality initially deteriorates and then improves as the economy develops. This relationship has been dubbed the Environmental Kuznets Curve (EKC).

There are two main explanations for the EKC phenomenon. The first explanation is that the environment is used as an important source of inputs and waste assimilation, which increases in the early stage of economic growth. As a country becomes richer, structural changes occur, resulting in greater environmental protection. The second explanation is that the state of environmental quality changes from a luxury to a necessary good as the economy develops.

Several factors determine the relationship between economic growth and environmental quality. Structural economic change and transition, technological improvements, and increased public spending on environmental research and development with rising per capita income are significant factors. Grossman and Krueger (1995) found support for the EKC hypothesis with peaks at an early stage of development, using city-level data nationwide on environmental quality. However, no such peak was observed for heavier particles.

Selden and Song (1994) used aggregate emissions data and estimated peaks of air pollutants at per capita GDP levels above $8000. Cole et al. (1997) suggested that significant EKCs exist only for local air pollutants, while Vincent (1997) analyzed the relationship between pollution and income level using time series data for Malaysia. Their findings contradict those obtained from cross-country panel data and are believed to reflect the consequences of non-environmental policy decisions. Carson et al. (1997) also found an inverse relationship between per capita income and emissions for seven major types of air pollutants in 50 US states. They also observed greater variability of per capita emissions for low-income states.

Kaufmann et al. (1998) found an inverted U-shaped relationship between income and atmospheric concentration of SO_2, and an inverted U-shaped relationship between spatial intensity of economic activity and SO_2 concentration. It has also been found that sociopolitical conditions have significant effects on environmental quality. A better institutional setup characterized by good governance, credible property rights, defined political rights, literacy, regulations, etc., can create strong public awareness against environmental degradation and help protect the environment.

Rothman (1998) and Suri and Chapman (1998) aimed to clarify the EKC trend by analyzing the varying trade and consumption habits of developing and developed countries. Less developed countries tend to have a greater concentration of polluting manufacturing industries, while high-tech industries that are less polluting are typically situated in already industrialized and wealthier countries, reflecting established international trade patterns. Therefore, it is possible that the increasing section of the EKC trend may be caused by the heightened level of polluting manufacturing activities in developing countries, whereas the decreasing portion could be attributed to a higher concentration of less polluting high-tech industries in the developed world.

In addition, household preferences and demand for environmental quality are also being considered as possible explanations for the EKC trend. As the demand for environmental quality is influenced by income levels, there is a strong private and social need for a high quality environment in developed countries, leading to significant private and public spending
on environmental protection. Consequently, while the increasing part of the EKC may indicate the trade-off between material consumption demands and environmental quality, the declining portion may be due to a stronger inclination towards environmental quality over material consumption.

Therefore, the thesis will try to find a relationship between air pollution and GDP per capita. In order to make the quality of the work more precise, this relationship will be made by using the statistical software Gretl. Through an extensive literature review, we will learn which variables are useful to carry out such a study and we will acquire a great source of information on completed thesis.Four independent variables and one dependent variable will be used to dtermine our econometric model. Panel data will be used, with the 38 oecd member countries over an interval period of 10 years, from 2010 to 2019. A hypothesis will be formulated which will be contrasted according to the results obtained and a series of conclusions will be drawn which will lead us to determine whether these countries in this time interval follow the same pattern of the Kuznets Curve or not.

2. REVIEW LITERATURE

In order to carry out the project with greater precision, a study is made of various articles which are related to the work in question. The first articles on the Kuznets Curve are presented below.. Compiles empirical literature on EKC, including the most important pioneers who provided empirical evidence and a selection of representative and more current articles. The first studies to present evidence on the inverted U-shaped pollution-income relationship were Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992), Panayotou (1993) and Selden and Song (1994). In their working paper on the environmental impacts of NAFTA, Grossman and Krueger (1991) examined 52 cities during the years 1977, 1982 and 1988 and obtained evidence that validated the inverted U-shape hypothesis. Shafik and Bandyopadhyay (1992) explored the relationship by analysing patterns of environmental change, such as CO_2 emissions per capita, SO_2 emissions, among others. Pargal and Wheeler (1996) examined the effects of regulation on pollution and property rights, which set the maximum amount that can be exploited of a natural resource, determined economic progress (Lopez, 1994).

Other studies, such as Halicioglu (2009), analysed 149 countries in the period 1960-1990 and obtained different results depending on the environmental pattern analysed. The most notable results confirmed the EKC hypothesis for deforestation, suspended particulate matter, SO_2 and CO_2, while for faecal coliforms in rivers they obtained an N-shaped curve in this sample.

Finally, the importance of informal regulation in finding the right way to compensate for the double effect on the environment is highlighted. This informal regulation can affect countries with different income levels and can have a positive impact on pollution abatement in developing countries. Thirdly, there is a need to find appropriate regulation to compensate for negative environmental effects, known as informal regulation. Pioneers who provided evidence in this field include Panayotou (1993), who empirically demonstrated the hypothesis of the inverted U-shaped environmental Kuznets curve (EKC). Shafik and Bandyopadhyay (1992) and Selden and Song (1994) also conducted important studies on the relationship between pollution and income. In addition, foreign direct investment can provide technology to developing countries and promote technology diffusion globally (Dasgupta et al., 2001).

There have been many subsequent studies that have expanded the sample of previous studies and validated the EKC hypothesis. For example, Dinda et al. (2000) and Stern and Common (2001) have also demonstrated the relationship between environmental degradation and income in developed and developing countries. Dinda et al. (2000) studied 39 cities in the 1970s and 1980s and found that environmental degradation followed a similar trend to Kuznets' inequality. Stern and Common (2001) looked at 73 countries iin the period 1960-1990 and extended the sample of previous studies. They observed that the relationship between environmental degradation and income depended on the pollutant studied and obtained evidence of inverted U-shape for SO_2 and U-shape for particulate matter.

Table 1 summarises some of the most old relevant studies research on EKC.

In the article made in 2020 by Zhang, X., & Cheng, X. we can see how China's economy has undergone significant changes and improved people's living standards. However, the rapid economic development has led to environmental problems, such as an increase in the amount of industrial waste gas emissions. Environmental pollution can cause serious health damage and social losses. The relationship between environmental pollution, economic development and public health is crucial to improving people's health. The Chinese government has complied with the Healthy China 2030 Plan to improve people's health and health equity, but the impact of economic development and environmental pollution on public health in China needs to be further understood..

This paper establishes a regression model based on Grossman's health production function and conducts an empirical analysis on the relationship between China's economic development, environmental pollution and public health This study analyses the impact of economic growth and environmental pollution on public health in China through a regression analysis using panel data from 30 provinces between 2007 and 2018. The results show that public health is affected by factors other than pollution and economic growth, such as per capita income and urbanisation rate.

A stable and long-term equilibrium relationship between these factors and public health was also found. Air pollution is significantly related to perinatal mortality and GDP per capita has a positive effect on mortality reduction. Government should focus on pollution, sustainable economic development and health care. Businesses should assume their environmental responsibility and adopt energy-saving technologies. Regions should adopt policies according to their local conditions to improve public health.

The article by Kim, H. S., & Lee, S. J. (2018), discusses the relationship between economic growth and environmental conditions. There is a debate in the scientific community as to whether economic growth worsens or improves the environment. Some studies have suggested that there is an inverted U-shaped relationship between environmental degradation and economic growth, meaning that degradation initially worsens with economic growth, but then begins to improve once a certain level of growth is reached.

The Environmental Kuznets Curve hypothesis has been tested for several environmental indicators, such as deforestation, carbon emissions and municipal waste. This hypothesis has been shown to be valid mainly for sulphur dioxide emissions, but an inverted U-shaped function has also been reported for CO_2 emissions.

Energy consumption is another important contributor to CO_2 emissions, along with economic growth. Several studies have analysed the relationship between energy consumption and economic growth using different techniques and country panels.

Recent studies combine the growth-environment and growth-energy nexus in a single multivariate model to study its validity in the same framework.

Most studies on this topic have used pooled panel data for a group of countries to establish a relationship between economic growth and environmental degradation. This approach allows the impact of environmental policies, the development of trade relations and other exogenous factors to be examined over time, so we will use a panel data in our analysis.

This study focuses on estimating the EKC for CO2 emissions in China, one of the most important emerging markets and one of the largest CO2 emitters with the highest energy consumption.

There are some articles and studies that are briefly summarized:

In the article by Ang, B. W., & Xu, X.(2011),the study examines the relationship between GDP and CO2 emissions in several countries in the Asia-Pacific region, including some OECD members.

This article by La Rovere, E. L., & Andrade, M. F.(2014), examines the relationship between economic growth and air pollution in several Latin American and Caribbean countries, some of which are members of the OECD.

The article by Carmona, M., & de Witte, K.(2018), analyses the relationship between economic growth and air pollution in OECD countries over three decades.

The study by Gómez-Álvarez, P., García-Alonso, C. R., & Martínez-Paz, J. M(2018), uses non parametric techniques to analyse the relationship between economic growth and CO2 emissions in OECD countries.

This study by Lee, C. C., & Chang, C. P.(2018), examines the relationship between energy consumption and GDP in developed and developing countries, including some OECD members. Although it does not focus specifically on air pollution, it can provide relevant information on the relationship between economic growth and energy resources.

Old studies research

Source: Own elaboration

Authors	Year	Period	Place	Dependent Variables	Independent variables	Conclusions
Grossman and Krueger	1991	1977-1988	53 cities	Suspended particles and SO2	GDP per capita, (in levels, square and cubic terms)	Inverted U shape
Shafik and Bandyopadhyay	1992	1960-1990	149 countries	Suspended particles, SO2, CO2 emissions, deforestation and other variables	GDP per capita income (in levels, square and cubic terms), investment GDP and other variables	Inverted U shape
Panayotou	1993	1987-1988	55 countries	SO2 and deforestation	Income(in levels and in square terms) and pouplation	Inverted U shape
Selden and Song	1994	1979-1987	22 OECD countries and 8 countries more	SO2, CO2, suspended particles matters	Gdp per capita	Inverted U shape
Stern and Common	2001	1960-1990	73 countries	SO2 emissions per capita	Gdp per capita(in levels and in square terms)	Inverted U shape

Table 1. Old research stduies

<u>Recent studies research</u>

Source: Own elaboration

Authors	Year	Period	Place	Dependent Variables	Independent variables	Conclusions
Lee, C. C., & Chang, C. P.	2008	2007-2011	European countries, Asian countries, India, USA, Brazil and south Africa.	Air pollution	GDP per capita and energy sources	Inverted U shape
Ang, B. W., & Xu, X.	2011	2008-2010	Asian-Pacific region and some OECD members	Air pollution	GDP per capita	Inverted U shape
Gómez Álvarez, P., García Alonso, C. R., & Martínez Paz, J. M	2018	2005-2015	OECD countries	CO_2 emissions	GDP	Inverted U-shaped
Kim, H. S., & Lee, S. J.	2018	2013-2016	China	Air pollution	GDP per capita	Inverted U-shaped
Zhang, X., & Cheng, X	2020	2007-2018	China (30 provinces)	Air pollution	PM2.5, SO_2, NO.	Inverted U-shaped

Table 2. Recent research studies

3.KUZNETS CURVE

The Kuznets Curve illustrates the correlation between income per capita and inequality. According to this theory, inequality tends to increase at the beginning stages of development, reaching a peak before gradually declining. Simon Kuznets first proposed this idea in 1955 and presented it in the form of an inverted-U-shaped curve. As a country's income per capita rises, so does the level of inequality, until it eventually reaches a turning point where it starts to decrease. This concept is represented by a bell shaped curve, commonly referred to as The Kuznets Curve.

In the 1990s, researchers extended the Kuznets Curve theory to explore its relationship with environmental degradation, coining it the Environmental Kuznets Curve (EKC). Panayotou (1993) was the first to use the term EKC to describe the correlation between development and the environment.

The correlation between environmental degradation and per capita income follows the same pattern as the Kuznets curve, which is shaped like an inverted U, as depicted in Figure 1. The Environmental Kuznets Curve has been used to describe the relationship between environmental quality and income since these years. Grossman and Krueger (1993) were the first to notice that the relationship between environmental quality (SO2 and smoke) and income follows an inverted-U-shaped curve. In the early stages of development, environmental deterioration is caused by intensifying agriculture and exploiting natural resources, while countries lack clean and efficient technologies. This is typical of underdeveloped economies or those in the initial stages of development. However, as income continues to grow, environmental degradation begins to decline. Pollution tends to increase more rapidly in countries in the early stages of development, but as time passes, this situation improves, and degradation decreases.

During the initial stages of development, pollution tends to increase at a faster rate than income, but as income levels rise, the rate of pollution slows down. This creates a dilemma for countries in terms of what policies they should implement. The Environmental Kuznets Curve (EKC) is a long-term phenomenon, which is influenced by the technological lifecycles of countries. Panatoyou (1993) observed that countries shift from being primarily agrarian to service-based economies. This transition results in an initial increase in pollution until a tipping point is reached, after which pollution levels decline. This is because economies that are industrialized or based on agriculture tend to be more polluting than service-based economies. Therefore, the EKC model can be used to describe the shift from a clean rural economy to a polluted industrialized economy and ultimately to a cleaner service based economy (Arrow et al., 1995).

There are various reasons why the Environmental Kuznets Curve (EKC) phenomenon occurs. Firstly, the level of income elasticity plays a significant role in environmental pollution. Researchers such as Carson et al. (1997) and McConnell (1997) have demonstrated this influence. As people's income increases, their standard of living improves, and they tend to take better care of the environment by making changes that reduce environmental pollution. When a country reaches a high enough standard of living, people start to value the quality of the environment more (Pezzey, 1989; Selden and Song, 1994; Baldwin, 1995). After a certain level of income, the willingness to pay for a clean environment increases at a higher rate than income (Roca, 2003). This is also evident in the level of donations to organizations, the election of less contaminant products, and expenditures on pollution defense. Rich people put pressure on the government to regulate and protect the environment, and in most cases, the government's intervention is the most important factor in reducing pollution (Dinda, 2004).

Secondly, another reason was published by Grossman and Krueger (1991), who suggested that economic growth affects the environment in three ways: scale, composition, and technology. The scale effect means that as output increases, resource and energy consumption during the production process also increases, along with emissions that worsen the environment. This effect has a negative impact on the environment. However, the composition effect has a positive impact because as income grows, the economy tends to favor cleaner activities over polluting ones. The composition effect facilitates the transition from a rural to a service-based economy. Moreover, technological progress advances with economic growth, making it possible to replace obsolete machines and technologies with cleaner ones. Wealthy nations can invest more in research and development (Komen et al., 1997). The EKC shows that the environment is negatively impacted in the early stages of growth due to the scale effect, but this effect changes positively due to the composition and technology effects (Vukina et al., 1999).

The third explanation for the environmental Kuznets curve concerns international trade, which has a two-fold impact. On the one hand, trade can lead to an expansion of a country's economy, but also an increase in pollution due to the scale effect - as exports increase, so does pollution. However, free trade can also have a positive impact on the environment through the composition and technology effect. Certain goods are highly polluting, and if pollution decreases in one country, it may increase in another via international trade. Furthermore, international trade can improve the diffusion of clean technology. Developed countries often have more stringent environmental standards, which can lead to high regulatory costs, causing some polluting industries to relocate. Fourth, foreign direct investment has a dual effect on the environment. Developing countries may receive pollution-intensive foreign direct investment, worsening the quality of the environment, but they may also benefit from technology transfer. Developed countries are often innovative, and this technology can be shared with other countries, leading to cleaner technologies worldwide. Finally, regulations play a critical role in reducing pollution. Developed countries have measures to improve the environment, such as sanctions for polluters and rewards for clean firms, while regulation is often weaker in poor countries, with a focus on sources of pollution. In such cases, informal regulation may be used. Property rights also play a role in determining economic progress and environmental protection.

Source: Panayotou(1993)

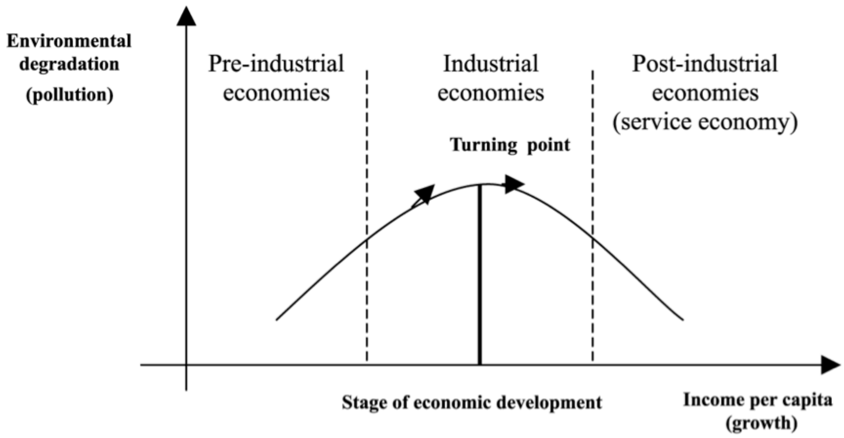

Figure 1. Kuznets Curve

4.GDP PER CAPITA IN OECD COUNTRIES

GDP per capita can be defined as an economic indicator which measures the relationship between two variables such as the income of a country in a given period, in our case one year (GDP) and the population existing in that year in that country. It is a very simple calculation, as it is obtained by dividing GDP by population. It is illustrated below in a text box.

GDP Per Capita = GDP of the Country / Population on that Country

Gross Domestic Product per capita, also known as GDP per capita, is an economic indicator used to measure the average level of wealth or well-being of a population in a specific country. It is calculated by dividing the total value of a country's Gross Domestic Product (GDP) by its total population.GDP represents the monetary value of all final goods and services produced within a country's borders during a given period of time, usually a year. It includes a wide range of economic activities, such as the production of manufactured goods, services, investment, government spending and net exports.By dividing GDP by the total population of a country, we get GDP per capita, which is a measure of how much economic output, on average, is available to each individual. This indicator provides an idea of the average wealth of a nation and is commonly used to compare the economic level between different countries.GDP per capita is useful because it allows more meaningful comparisons to be made between countries with different population sizes. For example, a country with a high total GDP could have a very large population, which would dilute the average level of wealth. However, when calculating GDP per capita, the population is taken into account, which allows for a more accurate assessment of the economic well-being of citizens.

OECD countries

Firstly, the Organisation for Economic Co-operation and Development (OECD) is an international organisation whose purpose is to develop a series of policies to improve the quality of life in countries. Basically, to promote and encourage policies that help countries to prosper.

There are currently 38 OECD member countries: Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

Therefore, these will be the countries used for the realisation of this project.The average GDP per capita for OECD countries is $37,881. The same countries are found above and below this figure. Luxembourg stands out with a value of $107.792, followed by Switzerland and Norway with figures of $87.339 and $77.513, respectively. These three countries are part of the European Union. One step below is the United States, followed by Australia and Iceland. The OECD country with the lowest GDP per capita is Colombia with $6.418, followed by Mexico and costa Rica with $9.525 and $12.894 respectively.

Source: World Bank (own elaboration)

OECD COUNTRIES GDP PER CAPITA($)	OECD COUNTRIES PIB PER CAPITA($)
Luxemburg 107.792,2	Corean Republic 32.730,7
Switzerland 87.339,8	Italy 31.505,9
Norway 77.512,9	Spain 26.125,9
USA 61.855,5	Slovenia 24.744,8
Australia 59.341,2	Estonia 21.707,2
Denmark 58.359,6	Portugal 20.831,1
Iceland 54.417,3	Chec Republic 20.083,8
Sweden 54.262,4	Greece 18.907,8
The Netherlands 48.301,5	Latvia 18.233,7
Finland 46.297,2	Eslovaquian republic 18.181,2
Austria 45.238,4	Letonia 16.609,7
United Kingdom 45.101,5	Poland 15.850,3
Canadá 43.936,3	Hungary 15.518,8
Belgium 42.901,4	Chile 14.116
Germany 42.726,5	Turkey 13.341,6
Israel 40.805,2	Costa Rica 12.894,3
New Zeland 40.415,5	Mexico 9.525,4
France 8.045,9	Colombia 6.418,1
Japan 35.291	**OECD members** 37.881

Table 3. GDP per capita OECD

Graphic

In figure 2, we can see a heat map of GDP per capita in OECD countries.

Source: World Bank

Figure 2. GDP per capita in OECD countries

In this heat map it can be seen how the member countries have been selected and delimited by a red line, which makes it easier to locate the countries.

The table below shows the OECD member countries in descending order, i.e. from the first In tcountry with the highest GDP per capita to the country with the lowest value. The OECD includes 26 countries from the European continent, 4 from Asia, 3 from North America, 2 from South America, 2 from Oceania and one from Central America.

5. AIR POLLUTION IN OECD COUNTRIES

Air pollution is the presence in the air of substances that can affect human health, the environment and the climate. Among the most common pollutants is particulate matter PM 2.5, which is the pollutant that will be used for the analysis of the project. It can be defined as a series of fine particles with a diameter less than or equal to 2.5 micrometres.

Depending on the concentration of these particles per cubic metre, we can measure the atmospheric pollution in the territory we are interested in. In our case, as previously mentioned, in the OECD countries. Looking more closely at the particulate matter in question, PM 2.5 is produced by a variety of sources, such as the burning of fossil fuels in vehicles and power plants, industrial activity and the burning of biomass. These particles can travel long distances in the air and can remain suspended for long periods of time. Heat maps will be presented below, in which we will be able to observe these particles far from the earth's surface.

Exposure to PM 2.5 can have serious effects on human health, especially for people suffering from respiratory and cardiovascular diseases. Particulate matter can penetrate deep into the lungs and bloodstream, causing inflammation, cell damage and oxidative stress.In addition to human health effects, PM 2.5 can also have environmental and climate impacts. It can reduce visibility, damage vegetation and ecosystems and contribute to climate change.

To reduce exposure to PM 2.5, it is necessary to take measures to reduce the emission of pollutants into the atmosphere, such as promoting cleaner technology measures and regulating emissions from industrial and vehicular sources. It is also important to monitor air quality and educate the public about the risks of air pollution and ways to protect themselves.From this set of assumptions and the information available, it can be determined that this is the right pollutant to carry out such a project.

The amount of PM2.5 (fine particles less than 2.5 micrometres in diameter) emitted by a country depends on several factors, such as the amount and type of industry, the use of fossil fuels for energy generation, transport and consumption patterns.

Some of the main factors that may influence PM2.5 emissions in OECD countries are:

- **Industrialisation**: More industrialised countries have higher energy production, higher manufacturing activity and higher transport use, which often leads to higher PM2.5 emission.

- **Energy composition:** Dependence on fossil fuels for energy production affects PM2.5 emission. Countries that use a higher proportion of renewable energy have lower emissions of fine particulate matter.

- **Environmental policies**: Countries that have adopted stricter environmental policies to reduce the emission of pollutants such as PM2.5 have lower emissions.

- **Climate**: Weather conditions can influence the concentration of PM2.5 in the air. For example, thermal inversions in urban areas can trap polluted air and increase its concentration.

In general, the most PM2.5 polluting countries in the OECD are those with high industrial activity, high dependence on fossil fuels and less stringent environmental policies. On the other hand, the least polluting countries are those that have adopted more proactive policies to reduce PM2.5 emissions and have achieved greater diversification of the energy mix, including renewable energy sources.

PM 2.5 (fine particulate matter) pollution is a major problem in many OECD countries. In OECD reports. According to OECD reports, some of the countries most affected by PM 2.5 pollution include Mexico, Turkey, Poland, South Korea and Chile.

In Mexico, air pollution is a chronic problem, especially in Mexico City. The burning of fossil fuels and the lack of adequate measures to control emissions are among the main causes of PM 2.5 pollution in Mexico. In Turkey, air pollution is a growing problem, especially in cities. The use of fossil fuels for power generation and transport are the main sources of PM 2.5 emissions in the country. In Poland, coal burning for power generation is one of the main causes of PM 2.5 pollution. Heavy industry and transport also contribute significantly to the emission of fine particulate matter into the air. In South Korea, air pollution is a serious problem, especially in large cities such as Seoul. Coal and oil combustion, as well as vehicular traffic, are the main causes of PM 2.5 pollution in the country. In Chile, air pollution is a growing problem, especially in Santiago and other major cities. The burning of firewood and the use of fossil fuels for power generation are some of the main causes of fine particulate matter emissions in the air.

To reduce PM 2.5 pollution, effective measures are needed such as promoting renewable energy sources, improving energy efficiency measures, regulating emissions from industry and transport, and promoting cleaner and more sustainable modes of transport.

The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental organisation composed of 38 member countries that work together to promote policies that improve the economic and social well-being of people around the world. In terms of PM 2.5 pollution, there are some OECD countries that have relatively low levels of pollution.

According to the OECD Air Quality Report, the OECD countries with the lowest PM 2.5 levels in 2019 were:

Source: Own elaboration

COUNTRIES	AIR POLLUTION (µg/m³)
Iceland	5,79
Finland	5,47
Estonia	6,35
Sweden	5,96
Canada	6,39
Norway	6,3
New Zeland	8,61
Australia	8,93
Ireland	8,2

Denmark	9,66

Table 4. Lowest levels of air pollution

It is important to note that these are only the levels of PM 2.5 in ambient air and may vary depending on geographical location and other factors. In addition, these countries may have other environmental problems that need to be addressed.

Graphics

First of all, it is worth noting that the green areas have the lowest amount of air pollutants, while the yellow areas have moderate levels. The reddish area is the most polluting. In this graph, extracted from the iqair portal website , we can see how the countries indicated in the previous section are graphically valid, as they are the areas with the highest intensity. This figure shows a heat map of all the earth.

Source: https://www.iqair.com

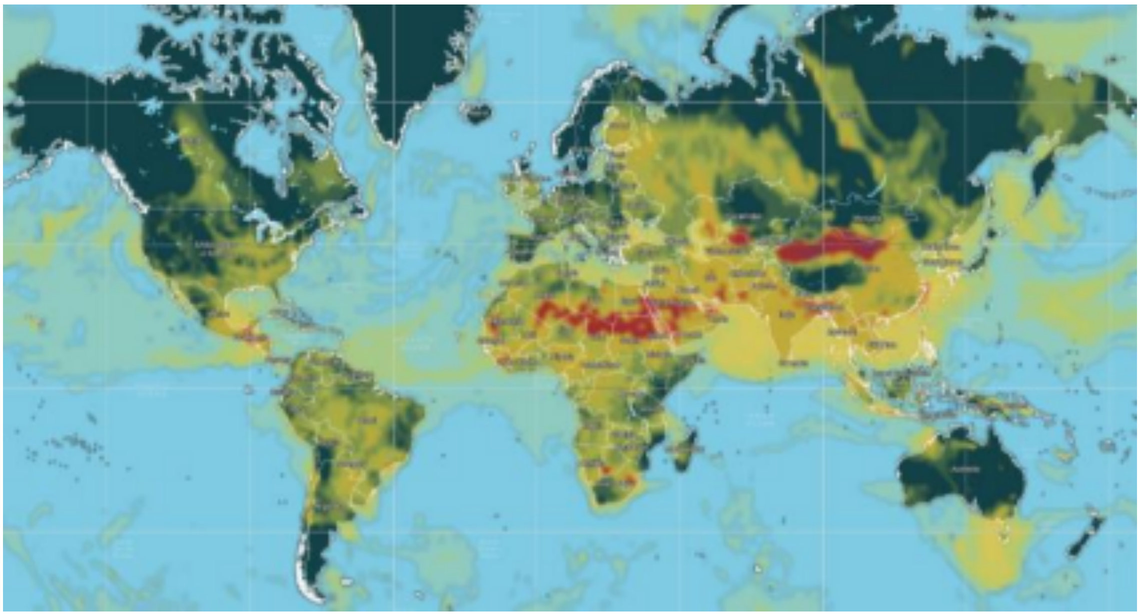

Figure 3. Heat map of the earth

6. DATA AND ECONOMETRIC MODEL

1.Data

As for the data we are going to use to be able to contrast our analysis of how air pollution is related to GDP per capita, we have used data from all 38 OECD member countries. Over a ten year interval, from 2010 to 2019. Data prior to covid-19, in order to provide a more reliable model.

In this way, we have constructed a panel from the data extracted from the World Bank, where we can distinguish between the dependent variable and the various independent variables that make up our model.

Dependent Variable:

- ***Air pollution*** Air pollution in each country is expressed in (U/m^3). These are fine PM2.5 particles that remain suspended in the air. They are considered a good indicator of air pollution.

Independent Variables:

- ***GDP per capita*****:** It is defined as the real GDP of that country divided by its population. It is expressed in thousands of dollars.

- **GDP per capita square**: It is a very useful variable for the model, as it allows us to get closer to a more accurate kuznets curve.

- **Renewable energy consumption:** It is defined as the percentage of renewable energy used in a country out of the total energy used. It will provide information on the environmental awareness of that country. Expressed as a percentage (%).

- **Industralization:** Provides information on the level of industrialisation of each country. Expressed as a percentage (%).

For a correct specification of the model, we have considered four independent variables that directly affect air pollution, the dependent variable in our model. This would therefore be the specification of our econometric model:

Source: Own elaboration

$$air\_pollution_{it} = \beta 0 + \beta 1\, gdppc_{it} + \beta 2\, (gdppc)^{2}_{it} + \beta 3 industry_{it} + \beta 4 ren\_energy_{it} + \varepsilon_{it}$$

$$i = 1,2,\ldots,10 \qquad t = 2010,2011,\ldots,2019$$

Figure 4. Econometric model

In our model, we analyse the air pollution of the 38 OECD member countries. This rate is affected by a myriad of variables, of which we have chosen to emphasise GDP per capita, GDP per capita square, renewable energy and industrialisation of the countries.

In the following, we will detail the expected signs of the coefficients that accompany our independent variables, as well as their interpretation.

The univariate and multivariate statistics for these variables are then expressed:Within this section, we present the primary statistical data of the dataset. Following that, we will analyze the primary univariate statistics, the correlation matrix of all variables, and the specific correlation between the growth of GDP per capita and other variables.

The primary univariate statistics for this dataset consist of:

Source:Gretl(own elaboration)

Variable	**Mean**	**Median**	**Standart Deviation**	**Min.**	**Max.**
Air pollution	13,7	12,6	5,72	5,37	29,8
GDP per capita	38,1	38,3	24,1	5,94	124
Renewable energies	21,8	16,4	16,2	1,32	81,1
Industry	24,1	24,0	5,57	10,4	38,2

Table 5.Univariate statics

The correlation between the main variables are:

Source: Gretl(own elaboration)

Variable	Air pollution	GDP per capita	GDPpercapita square	Renewable energies	Industry
Air pollution	1,000				
GDP per capita	-0,3003	1,000			
GDP per capita square	0,0015	0,9341	1,000		
Renewable energies	-0,1368	0,1275	0,0834	1,000	
Industry	0,2242	-0,2810	-0,3149	-0,0133	1,000

Table 6. Correlation between variables

2. Hypothesis

When carrying out the test to determine whether the null or alternative hypothesis is statistically valid, the concept of both hypotheses will be defined.

On the one hand, we have the null hypothesis (H0) which is a statement or assumption that is made about a population or a phenomenon that is being studied, and which is to be refuted or rejected by means of a statistical analysis. In general, the null hypothesis states that there is no difference or effect between two groups or conditions, or that any observed differences are simply the result of chance or the natural variability of the phenomenon.

On the other hand, the alternative hypothesis (H1) is the opposite statement to the null hypothesis. That is, it states that there is a real difference or effect between the groups or conditions being compared.

The null hypothesis stated for this project is:

➢ H0: OECD member countries establish a positive(increasing) relationship between their air pollution and GDP per capita up to a point, at which point that relationship becomes negative(decreasing).

➢ H1: H0 is not true.

The p-value indicates the probability of obtaining the observed results, or more extreme results, if the null hypothesis were true. If the p-value is less than the previously established significance level (usually α = 0.05), the evidence is considered sufficient to reject the null hypothesis and accept the alternative hypothesis.

To perform the test, we go back to the table produced using the Gretl statistical software and look at the p-value of the independent variable GDP per capita, which is

5.86e-040. Being a very small number and not being above 0.05 we have evidence to reject the null hypothesis and accept the alternative.

P-valor < α → **Reject H0** 5,86e-040 < 0,05

Therefore, we conclude that there is no expected relationship that as countries have a lower GDP per capita, pollution remains at low levels and as GDP per capita increases, air pollution increases progressively until it reaches a peak at which the relationship decreases and behaves inversely, with the curve adopting an inverted U-shape.

This means that the model with the 38 OECD member countries does not behave according to the Kuznets Curve pattern. It will adopt another shape which we will now analyse on the basis of the results obtained and with the help of a graph obtained from the Gretl statistical software.

3 .Expected interpretation of the coefficients

In the following, a prior interpretation of the coefficients that will accompany the aforementioned independent variables will be made.

Source: Own elaboration

DEPENDENT VARIABLE	INDEPENDENT VARIABLE	INTERPRETATION
Air pollution (air_pollution)	**GDP per capita** (gdppc)	**<0>** **Positive and negative expected relationship** We expect a negative relationship between the 2 variables until a certain point where the relationship converges to positive level.
	GDP per capita square (gdppc)^2	**<0>** **Positive and negative expected relationship** We expect a negative relationship between the two variables until a certain point at which the relationship converges to positive levels
	Renewable enegergies (ren_energy)	**<0** **Negative expected relationship** The use of renewable energies contributes to the reduction of air pollution. Therefore, we expect that the increased use of renewable energies will reduce air pollution.
	Industralization (industry)	**>0** **Positive expected relationship** An industrialised country tends to generate more pollution than a non-industrialised country. Therefore, we expect a positive relationship between the dependent and independent variables.

Table 7. Expected coefficients

7. RESULTS

1.Results

Following the completion of the study in the statistical software gretl, the estimation of the regression "how is air pollution related to GDP per capita" of the 38 OECD member countries has been carried out. In the following model, it can be seen how the four explanatory variables used in the model are valid.

In the following, an image will be presented, which was obtained by carrying out the study in Gretl. It will present the data obtained, which will be interpreted later.

Model 1: MCO observations 1-380
Dependent Variable: AIRPOLLUTION
Timbre deviations robust to heteroscedasticity, HC1 variant.

Source: Gretl(own elaboration)

	Coeficient	**Standart deviation**	**t-ratio**	**Valor p**	
const	18,8430	1,04176	18,09	<0,0001	***
GDPpercapita	−0,300361	0,0200945	−14,95	<0,0001	***
GDPpercapitasquare	0,00189537	0,000152464	12,43	<0,0001	***
Renewable energies	−0,136841	0,0121289	−11,28	<0,0001	***
Industry	0,224267	0,0367458	6,103	<0,0001	***

Mitj. de la vble. dep.	13,65958	D.T. de la vble. dep.	5,718924
Sume de quad. residus	5115,890	D.T. de la regressió	3,693558
R-quadrat	0,587282	R-quadrat ajustat	0,582880
F(4, 375)	159,3791	Valor p (de F)	1,56e-79
Log-versemblança	−1033,184	Crit. d'Akaike	2076,369
Criteri de Schwarz	2096,070	Crit. de Hannan-Quinn	2084,186

Table 8. Results model

In this figure, information on the regression can be observed. The R-squared has a value of 0.587 (value between 0 and 1), therefore this model is explained by 58.7%, which gives us a model where the explanatory variables explain around 60% of the explained variable. The interpretation of the 4 explanatory variables on the dependent variable atmospheric pollution is as follows:

The consumption of renewable energies has a negative impact, keeping the other explanatory variables constant (ceteribus paribus). This negative impact is due to the fact that the value of its coefficient is -0.1368. By increasing the consumption of renewable energies by one porcentage point, air pollution is reduced by 0.1368 units (u/m3). The implementation of renewable energies favours the reduction of air pollution.

Subsequently, industrialisation in the country has a positive impact on air pollution, keeping all other explanatory variables constant (ceteris paribus). The value of its coefficient is 0.2242. Increasing the country's industrialisation by one unit will generate 0.2242 units of air pollution.

While GDP per capita has a negative relationship with air pollution. The value of the coefficient is -0.3003. It has a negative interpretation with respect to air pollution because increasing GDP per capita by one unit decreases pollution by 0.3003.

2. Graphic interpretation of the model

The results obtained in the model give us a direct interpretation of how our explanatory variable GDP per capita has a relationship with respect to air pollution, and this relationship is somewhat unexpected when contrasted with the kuznets curve. It is U-shaped, whereas the Kuznets curve is inverted U-shaped.

In our study of the Kuznets Curve, we could see that countries with lower GDP per capita had lower pollution values. As per capita GDP increased, countries increased their pollution levels, until they reached a peak point at which, above a certain per capita GDP, pollution progressively decreased. As countries increased their purchasing power, they implemented certain improvements in technology in order to lower their pollution levels. In our case it has been different.

We have analysed 38 countries, the member countries of the OECD. Our study shows that it does not follow the pattern of the Kuznets curve. It graphically presents data in which countries with lower GDP per capita have high pollution, while as GDP per capita increases, countries reduce their pollution until they reach a convergence point where they tend to increase their pollution levels again.

Source: Gretl

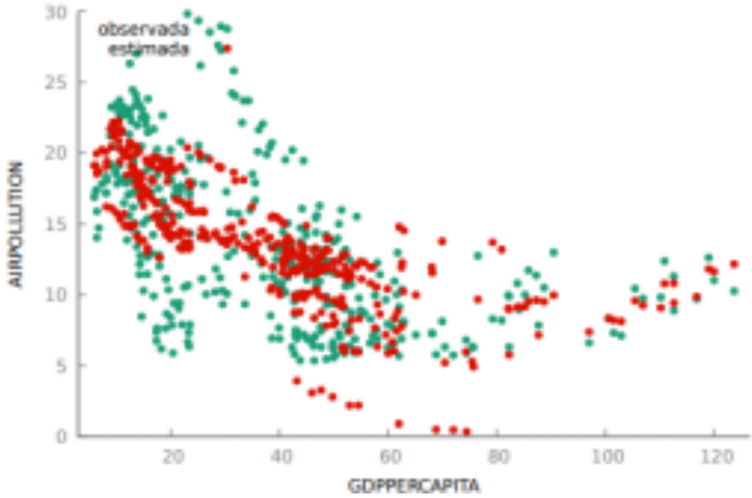

Figure 5. Relationship between GDP per capita and air pollution.

We can draw certain conclusions in this respect, such as that countries with less capital act in a less favourable way towards the environment. Countries with a high GDP per capita also act in an environmentally conscious way, with better policies and a use of factors that do not pollute as much as others. With a high level, countries tend to increase their pollution levels, not being high levels, but the change in the trend shown in the curve.

3. Possible factors determining the U-inverted shape

The Kuznets curve suggests that as countries experience higher economic growth, pollution may initially increase progressively, but then decrease as the economy develops further. However, it is important to note that the Kuznets curve hypothesis is just that, a hypothesis.

The sample of countries selected are the 38 members of the OECD, so it is possible that sufficient diversity of economies at the global level has not been captured. There may also be significant variation within the OECD in terms of inequality and economic growth. Another reason is the myriad of variables that may influence the relationship between economic growth and air pollution. In this case, four independent variables have been taken into account. Selection bias is another possible factor, as the countries selected for the study may differ in terms of social and economic structures that may influence the relationship between economic growth and income inequality.

The use of inappropriate economic policies could be another determinant. Inequality can also be influenced by inadequate economic policies, such as lack of investment in human capital and access to basic resources such as education and health.

In summary, there are multiple factors that may have affected the results of the Kuznets curve study. Based on the results obtained, it is open to question whether the Kuznets curve hypothesis holds true for the world population or whether it can only be tested for certain countries.

8. CONCLUSIONS

In this study using panel data from the 38 OECD member countries, we sought to establish a relationship between the Kuznets curve and the regression model used, however, the results obtained were not consistent with this relationship, but instead showed a U-shaped curve. The Kuznets curve is a theory that states that economic inequality increases during the early stages of economic development, but decreases as the economy develops further. This theory has been used to explain inequality trends in several countries and in the global context.

The results obtained in this study may have important implications for understanding air pollution in OECD countries. The study was motivated by seeing how the Kuznets Curve has an inverted U-shape which reveals that economic development worsens the environment in the early stages where income is lower. However, as income increases, pollution increases up to a point where pollution decreases. On the downward side of the curve, economic growth improves air quality, probably because countries have more efficient measures in place or because countries with higher incomes are more environmentally aware and sensitive. There are many factors that could have influenced these pollution levels, such as the policies implemented in that country, the lack of innovation in the consumption of renewable energies and the focus on immediate returns without taking into account the pollution levels that this generates. As the economy develops, there is greater economic and educational mobility, which can reduce air pollution.

However, in the later stages of economic development, economies tend to become more technological and service-oriented, which may cause air pollution to remain at more stable levels.

Furthermore, the fact that the results were not consistent with the Kuznets curve theory suggests that there are other factors that may influence air pollution in OECD countries, such as fiscal policy, the structure of the economy and global trends. These factors need to be studied further to gain a more complete understanding of economic inequality in these countries.

Importantly, this study used panel data, which means that data from several countries at different points in time were analysed. This may provide a more accurate picture of economic trends in OECD member countries than the analysis of single-country data. However, there may also be limitations in terms of data comparability and differences in political and economic contexts.

Another important aspect to take into account is that many articles related to the Kuznets curve have been read, suggesting that this theory has been widely studied in the academic literature. However, the results obtained in this study suggest that there may be limitations in the application of this theory in the specific context of OECD countries.

In conclusion, the results obtained in this study suggest that the Kuznets curve may not be an adequate theory to explain the relationship between air pollution and economic growth in OECD member countries, as a U-shaped curve was found instead of a bell-shaped curve. O although the results obtained do not show a clear and direct relationship following the Kuznets curve, they suggest that the relationship between these two variables is more complex than previously thought. This study can be used as a starting point for future research in this field and can help guide public policy and business decisions related to air pollution.

9. BIBLIOGRAPHY

Martínez-Zarzoso, I., & Maruotti, A. (2011). The impact of urbanization on CO2 emissions: Evidence from developing countries. Ecological Economics, 70(7), 1344-1353. https://doi.org/10.1016/j.ecolecon.2011.02.004

Jalil, A., & Mahmud, S. F. (2009). Environment Kuznets curve for CO2 emissions: A cointegration analysis for China. Energy Policy, 37(12), 5167-5172. https://doi.org/10.1016/j.enpol.2009.07.042

Chen, H., & Luo, S. (2016). Study on the relationship between economic growth and environmental pollution based on EKC theory. Journal of Cleaner Production, 112, 3426- 3435. https://doi.org/10.1016/j.jclepro.2015.10.029

Panayotou, T. (1993). Empirical tests and policy analysis of environmental degradation at different stages of economic development. Working Paper No. 238. Harvard Institute for International Development, Harvard University.

Ang, B. W., & Xu, X. (2011). The causal relationship between GDP and CO2 emissions in the Pacific Rim countries. Applied Energy, 88(11), 4874-4880.

Carmona, M., & de Witte, K. (2018). Economic growth and air pollution: Three decades of evidence in OECD countries. Journal of Environmental Management, 222, 384-394.

Gómez-Álvarez, P., García-Alonso, C. R., & Martínez-Paz, J. M. (2018). Economic growth and CO2 emissions: A non-parametric analysis for OECD countries. Journal of Cleaner Production, 174, 972-983.

Han, Q., Xu, H., Zhang, Y., & Wang, Y. (2020). Economic growth and air pollution: evidence from 31 provinces in China. Environmental Science and Pollution Research, 27(18), 22471-22482.

La Rovere, E. L., & Andrade, M. F. (2014). Economic growth and air pollution in Latin America and the Caribbean: a time-series analysis. Environment, Development and Sustainability, 16(5), 1063-1079.

Lee, C. C., & Chang, C. P. (2008). Energy consumption and GDP revisited: A panel analysis of developed and developing countries. Energy Economics, 30(5), 2382-2394.

McConnell, K. E., 1997. Income and the demand for environmentalquality. Environment and development Economics, 2(4), pp 383-399.

Narayan, P. K. and Smyth, R., 2008. Energy consumption and real GDP in G7countries: new evidence from panel cointegration with structural breaks. EnergyEconomics, 30(5), pp. 2331- 2341.

Özokcu, S., and Özdemir, Ö. 2017. Economic growth, energy, and environmentalKuznets curve. Renewable and Sustainable Energy Reviews, 72,pp. 639-647.

Panayotou, T., 1993. Empirical tests and policy analysis of environmental degradationat different stages of economic development. WP238. Technology and EmploymentProgramme.

Pargal, S., and Wheeler, D. 1996. Informal regulation of industrial pollution indeveloping countries: evidence from Indonesia. Journal of political economy, 104(6),pp.1314-1327.

Pesaran, M. H., and Smith, R. 1995. Estimating long-run relationships from dynamicheterogeneous panels. Journal of econometrics, 68(1),pp. 79-113.

Pezzey, J., 1989. Sustainability, Intergenerational Equity and Environmental Policy.University, Department of Economics.

Roca, J. and Padilla , R., 2003. Emisiones atmosféricas y crecimiento económico enEspaña. La curva de Kuznets ambiental y el protocolo de Kyoto. Economíaindustrial, 3(351),pp. 73-86.

Selden, T. M., and Song, D., 1994. Environmental quality and development: is there a Kuznets curve for air pollution emissions?. Journal of Environmental Economics andmanagement, 27(2), pp 147-162.

Stern, D. I., and Common, M. S. 2001. Is there an environmental Kuznets curve for sulfur?. Journal of Environmental Economics and Management, 41(2),pp. 162-178.

Vukina, T., Beghin, J. C., and Solakoglu, E. G. 1999. Transition to Markets and theEnvironment: Effects of the Change in the Composition of ManufacturingOutput. Environment and Development Economics, 4(4),pp. 582-598.

https://datos.bancomundial.org/indicator/NY.GDP.MKTP.CD?mo

st_recent_year_desc=true/

https://economipedia.com/definiciones/renta-pib-per-capita.html

https://www.wallstreetmojo.com/gdp-per-capita-formula/

https://www.oecd.org/acerca/

https://www.sciencedirect.com/science/article/pii/S09218009010019 51?casa_token=Shbii_dJ FjcAAAAA:Vx3oP2HWt85IdbSjqmx_gEg4fr5OPe0ml1cWonoBQfFdc aw0MU1H92BoFiGEu 8FCDrCObX_sw/

https://www.sciencedirect.com/science/article/pii

/S0921800997001808/

https://www.sciencedirect.com/science/article/pii

/S009506968471031X/

https://econweb.ucsd.edu/~rcarson/papers/USK

uznets.pdf/

https://www.sciencedirect.com/science/article/pii/S1470160X23002856/

https://www.iqair.com/es/air-quality-map/

https://www.who.int/data/gho/data/themes/world-health-statistics/

https://datos.bancomundial.org/indicator/NY.GDP.MKTP.CD?end=2021&start=2021&type=sha ded&view=map&year=2019/

https://repositori.uji.es/xmlui/bitstream/handle/10234/201316/TFG_2022_LlorensCorominas _Pasqual.pdf?sequence=1&isAllowed=y/

https://oehha.ca.gov/calenviroscreen/indicator/pm25/

https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health/

https://datos.bancomundial.org/indicator/NY.GDP.MKTP.CD?most_recent_year_desc=true/

https://economipedia.com/definiciones/renta-pib-per-capita.html

https://www.wallstreetmojo.com/gdp-per-capita-formula/

https://www.oecd.org/acerca/

https://www.sciencedirect.com/science/article/pii/S0921800997001778/

https://www.sciencedirect.com/science/article/pii /S092180099700180h/

https://www.sciencedirect.com/science/article/pii /S009506968471031X/

https://econweb.ucsd.edu/~rcarson/papers/USK uznets.pdf/

https://www.sciencedirect.com/science/article/pii /S1470160X23002856/

https://www.who.int/data/gho/data/themes/world-health-statistics/

https://datos.bancomundial.org/indicator/NY.GDP.MKTP.CD?end=2 021&start=2021&type=sha ded&view=map&year=2019/

https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health/

10. APPENDIX

Figure. Econometric model (Gretl)

```
Model 1: MQO, emprant les observacions 1-380
Variable dependent: AIRPOLLUTION
Desviacions típiques robustes front a heterocedasticitat, variant HC1

                      Coeficient   Desv. Típica  t-ràtio   Valor p
  ----------------------------------------------------------------
  const               18,8430      1,04176        18,09    5,05e-053 ***
  GDPPERCAPITA        -0,300361    0,0200945     -14,95    5,86e-040 ***
  GDPPERCAPITASQUA~    0,00189537  0,000152464    12,43    6,00e-030 ***
  Consumoenergiasr~   -0,136841    0,0121289     -11,28    1,29e-025 ***
  Industria            0,224267    0,0367458      6,103    2,60e-09  ***

Mitj. de la vble. dep.  13,65958   D.T. de la vble. dep.   5,718924
Suma de quad. residus   5115,890   D.T. de la regressió    3,693558
R-quadrat               0,587282   R-quadrat ajustat       0,582880
F(4, 375)               159,3791   Valor p (de F)          1,56e-79
Log-versemblança       -1033,184   Criteri d'Akaike        2076,369
Criteri de Schwarz      2096,070   Crit. de Hannan-Quinn   2084,186
```