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# An Analysis of the Relationship between Carbon-Dioxide Emissions and Gross Domestic Product for 139 Countries within the Time Period 1985-2004

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**Abstract**

The purpose of this dissertation would be to find the relationship between $CO_2$ emission and GDP. We found that in case of the majority of countries the $CO_2$ emission is related to national income and follows an inverted-U shaped curve. In our analysis we used the regression technique on 139 countries within the time period 1985-2004 to model and analyze the mentioned relationship and define the variables, that describe it. As it will be proved, Environmental Kuznets Curve validate the model and our hypothesis confirm other researches, therefore the inverse-u relationship proves to be correct.

**Key words and phrases**: $CO_2$ emission, economic development, environment, Environmental Kuznets Curve, GDP, national income, pollution.

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# 1.Introduction

## Problem

During the last decades growing environmental awareness led to many studies of the relationship between pollution and economic growth. It is obvious that the expansion of the world economy causes significant changes in the earth climate. There is an enormous increase in world population, and therefore need for the increase of energy input. This leads directly to growing emission of pollutants. In this paper particular attention is paid to Environmental Kuznets Curve (EKC) as our curiosity in the topic was lead by finding, that according to the EKC theory the emission of a country only grows with the GDP level until a certain point, and after that the pollution level decreases along with further GDP growth.

## Purpose

The objective of this paper is to examine Environmental Kuznets Curve for a 19 years period of time for 139 countries. The assumption of our research was that the EKC holds and the relationship between development of the economies and their $CO_2$ emission resemble the shape of the inverse-U. Our results became coherent with most of the presented further studies

## Sources/Method

In our research we used regression technique and show both data studying and article discussion concerning the aforementioned relationship. The main source of the data for this paper is World Resource Institute (2009) for accumulated GDP and $CO_2$ emission within the time period of 19 years. Since we used the data only for 139 countries, the study is limited in the case of data contribution. Also the described relationship will be defined without any additional factors (except the $CO_2$ and GDP input), and is bounded to only pure relationship between GDP and $CO_2$ emission.

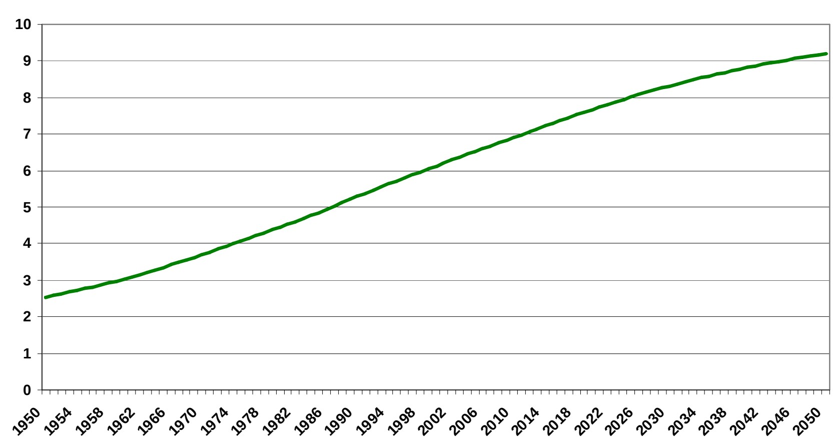
## Structure

The structure of this paper is as following: In second chapter there will present an overall view of the theories related to the relationship between $CO_2$ emission and GDP, in third chapter we will present the model we used to analyze the relationship by the use of the regression technique, in the fourth chapter will show the data and the sources for our analysis, the results of the analysis will be described in the fifth chapter and finally conclusions will be presented in the last chapter.

## 2. Theory

According to the IPCC's Fourth Assessment Report (2007), $CO_2$ emission has led to a 0.15ºC increase of the average global temperature per decade since 1990, and is estimated to rise 0.2ºC during the next two decades. The overview of the last century's climate warming shows an even more dramatic scenario: the earth surface has been heated by 0.6 ºC since the 19$^{th}$ century and with such high pace of growth, it is predicted to increase up to almost 6 ºC in 2100 (Kovats and Haines, 2005). Such strong climate warming may lead to serious negative effects on economies and ecosystems around the world. One of the most important factors, that causes global warming, is the emission of greenhouse gases. The most important greenhouse gas that effects global warming is $CO_2$, which in a major part comes from the burning of fossil fuels. Global warming has effects, which are predictable, and also numerous ones, which are not thought of yet. Some of these are mentioned by Kågeson (1998). Among the most important ones, is the change of natural ecosystems. Species loss is a significant problem and it is very difficult to predict the exact quantity of it. Difficulties in food production and shortage of drinking water are also a big threat. One of the other effects caused by the climate change - besides the rising of temperature and the changing of climate - is the rising of sea level. And of course many of these effects are interrelated. The shortage of food is only one serious consequence, that the rising of sea level causes, among other significant ones are also the decrease of space of living, and consequently the need for migration.

**Figure 1 World population (millions) and forecast 1950 – 2050**




*(Source*: World Resource Institute, 2009*)*

Certainly each economy has a different impact on natural environment and according to Galeotti and Lanza (1999) it depends on many interrelated factors: the size of the economy, its structure and energy demand, expenditures etc. Many countries had already implemented pro-ecological policies and therefore limited the environmental damage (European Commission, 2005), however their market share is still not sufficient for the significant decrease in the global emission of pollutants. Another important point, presented by Padilla and Serrano (2006), leads to a discussion whether the decrease in emission of greenhouse gases may influence the development of the economies. As proved by many authors, the relationship between $CO_2$ emission and GDP exists, and its examination can be based on Kuznets (1955) theory.

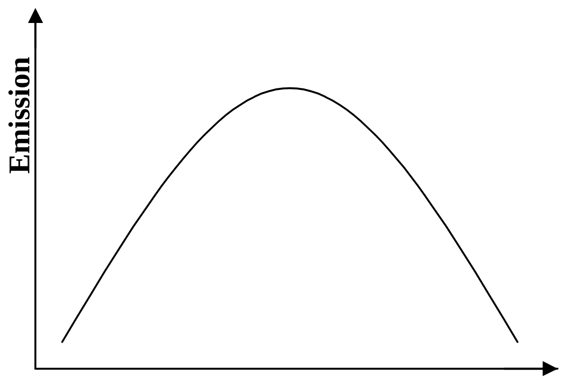
Kuznets examined the relationship between economic growth and income distribution inequalities in the mid 50s and he found that the relationship has an inverted-U shape. He was hoping that others would continue to explore this area (Kuznets, 1955). Many after him became interested and inspired by his article, and began to use the theory in different fields as well. One of these was environmental pollution.

## 2.1 Definition of the Environmental Kuznets Curve

With regard to many studies (Grossman and Krueger, 1995; Holtz-Eakin and Selden, 1995; Hilton and Levinson, 1998; Galeotti and Lanza, 1999) pollution is in inverse-U relation to the countries income. At the beginning, it was proved that the inverted-U relationship exists between pollution with local, short-term costs, like sulfur dioxide and income. Later the question evolved whether the same thing can be proved for other pollutants as well, like carbon-dioxide, which have long-term, more dispersed costs (Arrow et al, 1995).

The theory is presented on Figure 2. It is observable that countries with low per capita income, usually report lower level of $CO_2$ emission.

**Figure 2 Kuznets Curve**




*(Source: American Enterprise Institute for public policy research)*

The theory states, that during the economic development the income level increases, along with the pollutants emission, however the pace of the pollution growth is decreasing in time. After achieving a certain level of income the greenhouse gas emission begins to decline. It is following the model of the Kuznets Curve, that describes the inverted-U relationship between income distribution and income growth, this is why curve describing the relationship was named Environmental Kuznets Curve (EKC).

Since 1991 when EKC was defined (Yandle, Vijayaraghavan, Bhattarai, 2000) many economists tried to explain the source of the relationship between pollution and degradation of natural environment. As mentioned by many authors (Arrow et al, 1995; Galeotti and Lanza, 1999) the first reason is due to environment being viewed as a luxury good. In early stages of economic development, countries are not easily trading energy consumption for environmental protection, however with the increase in the standard of living, the demand for improvements in the environment is growing. Another reason, described by Galeotti and Lanza (1999), is related to economical cycle. Through the change from clean agrarian economies into heavy industrial, every country begins to emit more pollutants. With economic growth the transition into cleaner service based economy is obvious, and the negative impact on environment is therefore reduced. Another explanation for the inverse-U shape relationship between $CO_2$ emission and country income is explained by Suri and Chapman (1998). Growing environmental awareness, especially in the countries that report higher income, often leads to implementation of pro-environmental programs including high rate of carbon taxes.  Holtz and Selden (1995) also states that the reason for the relationship is that when income increases, the demand for health is also increasing, such as the demand for environmental quality (which is closely affected by health awareness). Another alternative reason for EKC considers externalities, which represent all additional costs caused by the degradation of the environment (air pollution, human health, ecosystems destruction, the costs of global warming and climate change) (ExternE, 2005). They are external economic impacts on all actors who are not involved directly in an economic transaction. For example when producing a certain good it decreases the quality of air for people not involved in the production or consumption of the given good. It creates a cost for the society, that the producer doesn't pay for and other people have to bear consequently. According to Andreoni and Levinson (2001) "*appropriately internalizing those externalities requires relatively advanced institutions for collective decision-making, that may only be implementable in developed economies." (Andreoni, Levinson, 2001: 270.)* As mentioned by Arrow et al (1995) along with economic development environmental issues get greater attention, and so the legislation and institutions related to environment improve as well. The aforementioned reasons are all interrelated with each other. During the economical cycle, where the society is becoming richer and as a result enlarges the expenses on health and insurance, environment is becoming to be important. The wealth and health of future generations starts to be taken under consideration and consequently the society create a demand for a better quality of environment. In response the governments join international, pro-environmental programs, launch special environmental friendly tariffs, and try to discourage the heavy industries by implementing carbon tax tariffs. According to Suri and Chapman (1998) the introduction of pro- environmental programs and higher tax rates to protect environment discourages the energy intensive industries to invest. Since environmental policy may reduce the competitiveness of many companies, they may be forced to reduce their production or even relocate to the country with less rigorous policy. The latter case obviously would reduce the country's pollution ratings, however in general the emission will be transferred into another economy and total world environmental balance would not change. Many literature cases prove however, that this is a case in many countries, especially with taking under consideration many poorer economies, that tend to lighten their environmental regulations only to attract foreign direct investments. The existence of those pollution havens undermines the effectiveness of worldwide environmental policies as they unfortunately compensate emission reductions of the economies that implemented stricter law. As mentioned by

Verbeke and Clercq (2002) if the country did not implement any environmental policy, all industries usually locate in low cost country. If the countries increase environmental taxes it may made firms to relocate as it is becoming a cheaper alternative to decrease in production. According to De Groot, Manders and Tang economies face a trade off with compromising implementation of environmental policy with minimum amount of relocation. One solution for diminishing the transfer effect is to exclude heavy industries from the policy – that would certainly decrease the relocation effect, but unfortunately would not improve the quality of the environment, even if the burden of policy is shifted into other sectors. Since the only relevant measurement for the whole environment improvement is the total $CO_2$ emission, the relocation effect makes the problem serious for the country's policy makers to create efficient climate change policy.

## 2.2 Alternate theories

*Depending on the decision-making institution, the pollution-income relationship can be an inverted-U, monotonically increasing, or even a 'sideways-mirrored-S'" (Andreoni, Levinson, 2001: 270.)* Apart from Andreoni and Levinson's observation others also found that the relationship between pollutants emission and income does not necessarily reflect an inverted-U shape curve (see Appendix 3)

Some authors (Arrow et al, 1995) came to the same conclusion, saying that the inverted-U shape is only valid, if we examine the $CO_2$ emission by countries, but not valid for the whole environment, as the emission of different pollutants can be interconnected. This means that, if the emission of a polluting substance decreases in a country, another one might increase at the same time. Another reason, is that the emission in different countries is also connected, so the emission reduction of an environmentally harmful substance in one country can cause the increase of the same substance in another country. It is a general phenomenon, that companies of more developed countries intend to move their greatly polluting subsidiaries to poorer countries, where the tax costs connected with pollution are lower. As reported by Andreoni and Levinson (2001), it is not possible to transfer the pollution permanently into poorer countries, since once it reaches the poorest ones there will be no further way. This finding is in contradiction to the theory, that economic growth, by itself, leads to improvement in the natural environment (Beckerman, 1992). According to Panayotou (2003) the pollution relocation is obvious, however its impact is not significant enough to explain the emission reductions in the rich economies, therefore according to the author it is still not certain whether the past may the best indicator of the future shape of the world's total emission. Additionally as mentioned by the same author, poor economies may improve their environmental standards, by the more efficient use of their economic growth. Either the structural, technological or even political transformations may reduce future emission of pollutants even if the country represent small amount of national income.

Holtz and Selden (1995) mention also the free rider problem, but states that, in spite of its existence, the $CO_2$ emission may still be lower, as economy is getting more developed, because other impacts may be stronger. These mentioned previously reasons may be pro-environmental acts, environment being viewed as a luxury the simply economic cycles.

According to Ekins (1997) majority of world's population still represents poor economies, situated at the beginning of the Environmental Kuznets' Curve, where the pollution is still raising, therefore along with the poor countries development the pollution will increase within next decades, leading to even bigger environmental destruction until they reach the certain level, when finally it starts to decline. This significant growth in environmental destruction may not be however efficiently utilized by the decrease of the pollution in the richer economies – as their number is considerably lower.

Finally as described by Dasgupta et al.(2002) the Environmental Kuznets Curve may not reflect the actual relationship between pollution and economic growth, due to the scarcity of the data and their incompleteness.

## 3. Model

In this part we intend to model the relationship between GDP (y) and $CO_2$ emission (E). In order to prove the inverse U-shape of the curve, in our equation we need to include the quadratic term shown in Equation 1 by $\varphi$.

**Equation 1.** $E = \alpha + \beta y + \varphi y^2 + \varepsilon$

Following the assumption of EKC the model concentrate on defining the stable linear growth of $CO_2$ emission for poor economies and reflect the quadratic shift of the curve along with the growing GDP. The sample division has lead our further research (see appendix 2), that proved that poor economies are in fact characterized by the linear relationship between GDP and $CO_2$ emission, whereas rich economies develop the quadratic relationship, with the turning point of the inverted-u Kuznets curve at approximate level of 390 GDP value.

This fact convinced us, that the application of dummy variables, in the whole sample, could be suitable to estimate parameters of the relationship within only one model equation. We submitted indicator variables of the value 0 - for poor economies characterized by the linear trend, and 1 – for the rich economies, for which the quadratic trend was observable. Dummy 0 specified the absence of the quadratic shift, whereas the dummy 1 indicated the presence of the inverse-u shape trend. The model with applied dummies would look as following:

**Equation 2**. $E = \alpha + \beta y + \gamma D + \delta D y + \varphi D y^2 + \varepsilon$

The parameters in equation 2: $\alpha$ , $\beta$ , $\gamma$ , $\delta$ , $\varphi$ were to be estimated. D is a dummy implemented for the richer economies.

The model with applied dummies, although still explained the relationship effectively, was unfortunately characterized by the non-significant values of t-statistics for the dummy coefficients (Table 1) therefore as a result we decided to follow our basic simple model equation, as that one allow us to receive the parsimonious model.

**Table 1. Regression results for the model with applied dummies**

| **R Square** | 0,613 | | |
|---|---|---|---|
| **Operative variables** | **Coefficients** | **t Stat** | **P-value** |
| $\alpha$ | 1,635 | 0,128 | 0,898 |
| $\beta$ | 1,011 | 2,152 | 0,033 |
| $\gamma$ | -20,547 | -0,591 | 0,555 |
| $\delta$ | 0,528 | 0,996 | 0,321 |
| $\varphi$ | -0,002 | -5,363 | 3,489E-07 |

## 3.1 Hypothesis

Our assumption was that the relationship between $CO_2$ emission and GDP has an inverted-U shape as suggested by the environmental Kuznets Curve. Assuming the relationship stands, the Equation 1 should therefore explain the model effectively.

**Equation 1.** $E = \alpha + \beta y + \varphi y^2 + \varepsilon$

The parameters $\alpha$ , $\beta$ , $\varphi$ are to be estimated. $\alpha$ , $\varepsilon$ represent the intercept of the relationship and error term respectively, while $\varphi$ define the quadratic shift and the turning point of the inverse-u shape of the curve. .

Our hypothesis stands therefore:

$H_{0:}$ due to the inverse-U shape of the relationship between $CO_2$ emission and GDP, the value of $\varphi$ is negative.

# 4. Data

The source of our data is the World Resource Institute (WRI, 2009).

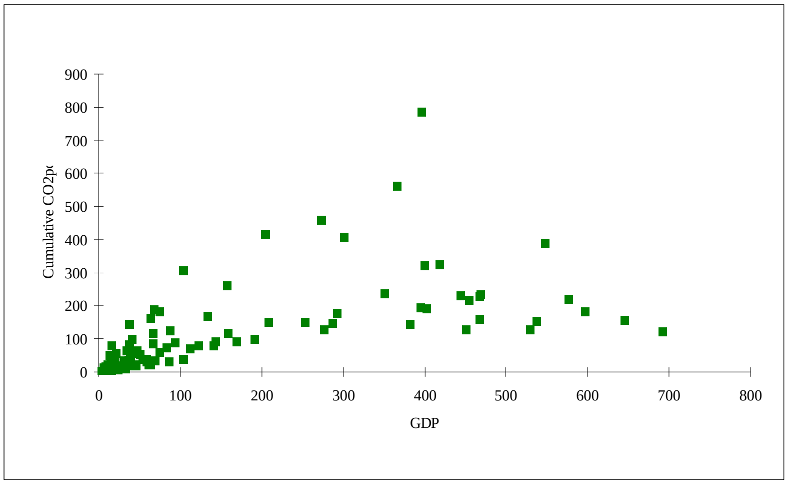
For our research we chose the accumulated values of GDP and $CO_2$. Most scholars used the GDP data to express income for a specific country in the regression. As our main purpose was to examine the results other scholars obtained, we also decided to use GDP data for all countries. Another reason for using GDP was that this data can be easily accessed for most of the countries for a relatively wide and recent period, in contrast with data for other measurements of income. The relationship could be described effectively by the use of national values (GNP and $CO_2$), as they disclose the effect of the pollution transfer, however obtaining such data may be complicated. There is not significant amount of data that describe the GNP – therefore, if we decide to use this variable our sample would be considerably reduced. Additionally it is very difficult to obtain valid data for national $CO_2$ emission, as not every country report the amount of $CO_2$ it emits abroad.

The GDP data is the total annual output of the different countries, the market value of the final services and goods manufactured during a year in the economy. World Bank uses US dollars to measure income; therefore in our model we also chose this currency. Specifically we decided to use current US dollars, which exclude the yearly inflation from the data. This way we can examine the GDP data without having to consider inflation effects. $CO_2$ emission is measured in metric tons. The data is used by WRI and it includes emission from burning fuel, which is the major source of emission, and also includes emission from producing cement. We use the per capita data to exclude the effect of population differences between countries and examine the years between 1985 and 2004. We use accumulated GDP and $CO_2$ per capita in order to achieve the total value of the GDP and $CO_2$ produced by each economy within 19 years. In other words, our collected data for each country were summed within time period 1985 – 2004 and result in cumulative value for every economy. We used this method instead of adjusting the data for each year for annual effects. This way the year-specific fluctuations are negligible. In order to make the calculation simpler and smaller, we divided the GDP accumulated value by 1000, and consequently $GDP^2$ by 1000000.

## Sample choice

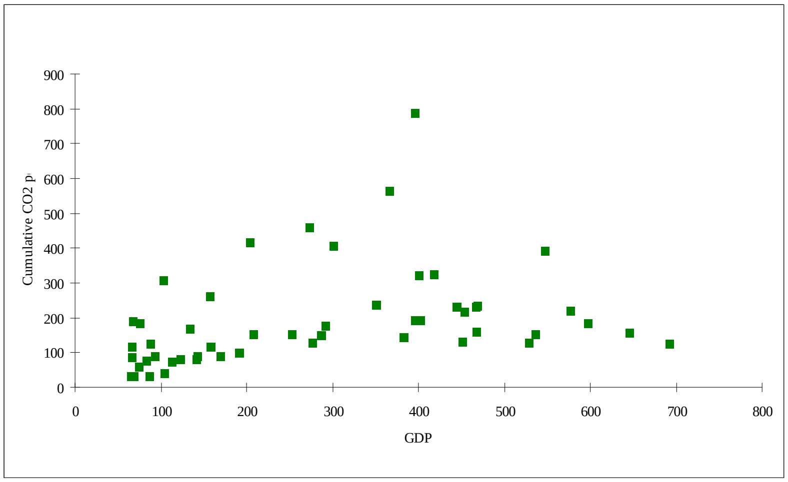
We have the 139 countries in our sample and realized, that the values of $CO_2$ emission of the countries with the lowest GDP are accumulated almost on one spot – as can be seen on Figure 3. This suggests that their emission values are similar. Also it is noticeable that they are centered on a low level of $CO_2$ emission. The phenomenon is apparent for the countries that report cumulative GDP per capita at the approximate level of USD 6,500 or below.

**Figure 3 GDP/1000 plot, sample size 139 countries**



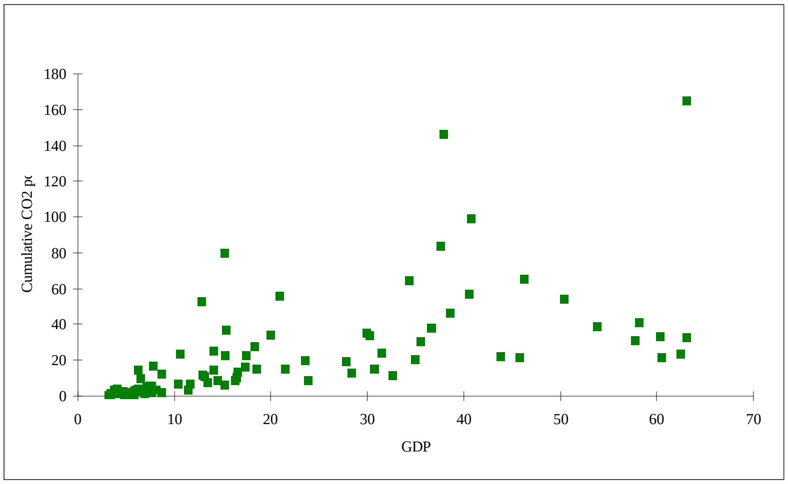

As a consequence we decided to make a more thorough examination of the two groups of countries: low income countries with cumulative GDP per capita below USD 6,500, and high income economies - cumulative GDP per capita above USD $6,500. The distinction of the series into two parts, resulted in clarification of the data and assumption, that there are two different trends characterizing both divisions. As it is observable on the Figure 4, for high income economies, the values of $CO_2$ emission are spread along the time and resemble a quadratic trend. In our sample the country with the biggest GDP is Switzerland (USD 691.474). The following are Norway (USD 644.776), Japan (USD 596.743) and Denmark (USD 576.723) and United States (547.410 USD). Qatar is the most outstanding in regards of the $CO_2$ emission with its 787,94 tons– and it only has a GDP of 395,554. It is followed by the United Arab Emirates (564.16 t.), Kuwait (459.6 t.) and Bahrain (418.33 t.). Aforementioned countries are characterized by intensive $CO_2$ emission connected with the oil production and this may be the reason for the turning point for the Kuznets' inverted U-curve in our sample.

**Figure 4 High income economies GDP/1000 Plot**




Similarly we examined the part of the sample, that includes only the countries that report low amount of GDP per capita. As shown in Figure 5 all of them report relatively small amount of $CO_2$ emission (<65 t.), however the linear growth tendency in time is noticeable.

**Figure 5 Low income economies GDP/1000 Plot**



## 5. Results

After regressing $CO_2$ emission on the GDP and GDP squared data we got the results, that satisfy our hypothesis. Vast interest of the research was put on the variable, that describe the $GDP^2$ as this coefficient explain the inverse U- shape of the relationship. The estimated parameters and the t-values are shown in the Table 2. The significant values of the t-statistics for GDP/1000 and $GDP^2$ prove that both coefficients represent the model effectively. The value of R square is comparable to those achieved by the other similar studies, that examined the relationship between country's economic growth and its pollution.

**Table 2 Regression Results for the whole sample**

| **R Square** | | 0,611 | |
|---|---|---|---|
| **Operative variables** | **Coefficients** | **t Stat** | **P value** |
| $\alpha$ | -6,168 | -0,674 | 0,502 |
| $\beta$ | 1,438 | 10,644 | 1,27E-19 |
| $\varphi$ | -0,002 | -7,344 | 1,72E-11 |

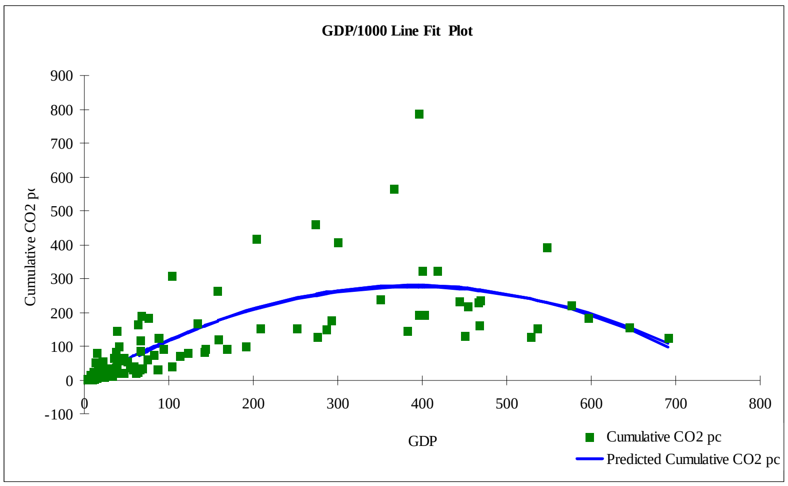
The examination of the residuals values prove the existence of the outliers, therefore we assume that the residuals exhibit a constant variance and heteroscedasticity does not complicate our analysis.

Figure 6 represent the result graphically. As proved numerically, the relationship between $CO_2$ emission and GDP resemble the inverse – U shape, as described by Kuznets. Countries that report small amount of the national income, usually are characterized by the small number of $CO_2$ emission. Along with the GDP growth, countries start to emit more, until the emission reaches a certain level. After the turning point of the inverse-u (which in our case is at approximate value of 390 GDP) , even if the GDP still grows the cumulative $CO_2$ emission begin to decline.

We can conclude from the above, that the equation of the regression expressing the relationship between $CO_2$ emission and GDP is the following:

**Equation 3.** $E = -6{,}186 + 1.438Y - 0.002Y^2$

**Figure 6 GDP/1000 Line fit plot for all countries**




The coefficient, that describes the quadratic variable dummy $GDP^2$, has a value of -0,002, therefore fully satisfies our hypothesis $H_0$ that stands: due to the inverse-U shape of the relationship between $CO_2$ emission and GDP, the value of $\varphi$ is negative.

As it may be seen in Appendix 3, our result is coherent with the results of the research made by De Bruyn et al.(1998) Authors used simple equation model, that describe the emission of many pollutants (including $CO_2$) of the individual country as the product of income and emission intensity of the country expressed in growth rates. De Bruyn et al. (1998) also predicted that $CO_2$ emission is likely to grow within next decades and therefore the environmental policy has to be stronger in order to decrease the negative impact on the environment. Additionally authors of *"Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves"* also explain why the emission in most developed countries have fallen after the 1970s and shifted the Environmental Kuznets Curve down.

The main mentioned reason is the slower pace of economic growth in 1970s than in 1960s. (De Bruyn et al,1998) It is worth mentioning that it may be caused by the 1973 oil crisis and its negative impact on the global economy. Because of the limited growth and due to the implementation of many technological and structural changes to improve countries competitiveness, the emission was significantly reduced; however that was not the effect of the countries development, but only more careful resources usage. The data presented by De Bruyn et al (1998) confirm the theory, as within next decade after the oil crisis, the $CO_2$ emission in OECD countries declined by 3,8%, but after 1985 begin to rise again by 1% annually. The increased emission may than be connected by the economical recovery of developed economies from the crisis, and explain the Environmental Kuznets Curve despite the economic growth.

Future shape of the Environmental Kuznets curve meet international discussion of whether rich economies should only limit their environmental policy and spending only to the borders of the country. Since the main problem is the global pollution, that unfortunately spread without any boundaries, it would be understandable to apply the ecological policies and investments in the countries, that are poorer- therefore cannot afford current environmental spending. This solution may significantly improve the quality of the global environment and also seems to be the cheapest alternative. Worth mentioning is also the fact, that since most of the countries included in our sample are only predicted to emit more pollutants, the shape of the environmental Kuznets curve may significantly change within next decade. Without any international support, this implies that the environmental destruction is about to be larger before we notice the positive influence of the economic growth on the pollutants emission.

## 6. Conclusion

Within last decades the significant negative change of the environment is observable. Strong climate warming already leads to the destruction of many ecosystems, and soon will also influence the prosperity of world economies. It is evident, that the number of people living on Earth is growing and that growth certainly creates a tremendous demand for energy, that straightly direct to the increase in the emission of polluting gases. During the last decades growing environmental awareness led to many studies of the relationship between pollution and economic growth, within others also Environmental Kuznets Curve was created. The purpose of this thesis was to find the connection between $CO_2$ and GDP based on the Kuznets' idea.

That relationship has been proved by the use of the regression technique to model, analyze, and define the variables and we achieved coherent results. $CO_2$ emission is growing in accordance with the growth in GDP until it reaches a certain income level. In time along with the growing development and increase in GDP, the emission of $CO_2$ begin to decline and as a result resemble the inverse U shape. This result is coherent with the result of other scholars who examined the mentioned relationship like De Bruyn et al.(1998). From many aspects using GNI instead of GDP could provide valuable information to compare with $CO_2$ emission, because it expresses the income made by the nationals of a country. However data may prove to be difficult to obtain- also for the national $CO_2$ emission which should be considered in this case-, we believe that an analysis based on it would provide a possible area for future research, and it would offer useful information about the country's real emission.

Our approach is limited only to the estimation of the relationship between $CO_2$ emission and GDP and the reasoning for this relationship within all 139 countries. Therefore it is suggested to broaden the study with evaluation of most direct results for the particular groups of countries. Additional study may be done in the area of the residuals. We assumed that the heteroscedasticity does not affect our results, however the careful research, that would include the use of OLS for log transformation of GDP and also Goldfeld-Quandt or White test, may prove our assumption incorrect.

Another future study may include the careful analysis of the pollution havens and the impact of their existence on the total environment destruction along with estimation of the influence of the countries, that are characterized by the higher and lower emission, that the expected one. Additional research may be made only for the economies, characterized by the significant $CO_2$ emission, connected with the intensive oil production.

In our research there were some countries, which were characterized by the lower $CO_2$ emission than the expected - these might be relatively more environmentally aware countries. In our list, the countries with the $6^{th}$ and $7^{th}$ highest GDPs, were Iceland (with cumulative GDP of (USD 536,449) and Sweden (USD 528,339). They emit $CO_2$ of 154 and 127.99 respectively, which are relatively low values, compared to the expected value of emission for countries with similar GDPs. Both economies have smaller GDPs than Denmark and Japan, which would predict a higher $CO_2$ emission, as we progress along with the curve towards the left, but instead they have lower $CO_2$ emissions. This makes them deflect from the curve in a downward direction, which is the characteristic for more environmentally cautious countries.

These numbers may be explained by the implementation of effective pro environmental policies and the obligation of the use of renewable energy, that significantly reduce the emission of $CO_2$. Careful study, that would include the reasoning of the lower values for aforementioned countries, combined with our research, may lead to the design of the useful tool for policy makers while creating the effective and cheap environmental policies, that would not necessarily lead to the relocation effects and allow future generations to live in a clean environment.

# Bibliography


American Enterprise Institute for public policy research https://www.aei.org/publications/filter.all,pubID.23617/pub_detail.asp

Andreoni, J., Levinson, A., 2001. The simple analytics of the environmental Kuznets curve, *Journal of Public Economics* 80 (2001) 269 –286.

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C., Jansson, B.O., Levin, S.,Maler, K.G., Perrings, C., Pimentel, D., 1995. Economic growth, carrying capacity, and the environment. *Science* 268, 520–521.

Beckerman, W., 1992. Economic growth and the environment: Whose growth? Whose environment? *World Development* 20, 481–496.

Dasgupta, S; Laplante, B.; Wang, H.; Wheeler, D., Confronting the Environmental Kuznets Curve, *Journal of economic perspectives*, 16(1),  147-168.

De Bruyn, S. M., Van den Bergh, J.C.J.M, Opschoor, J.B., 1998, Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves,  *Ecological Economics*, 25( 2), 161 – 175.

De Groot, H. L.F., Manders, T. and Tang, P. J.G.; 2002, *Relocation effects of climate change policies,* CPB Report 2002/4, access date 29.04.2009.
http://www.cpb.nl/nl/pub/cpbreeksen/cpbreport/2002_4/s2_1.pdf

Ekins P, 1997, "The Kuznets curve for the environment and economic growth: examining the evidence" *Environment and Planning A* 29(5), 805 – 830.

European Commission, 2005, *Communication from the Commission: the Support of Electricity from Renewable Energy Sources* SEC(2005) 1571, access date 10.03.2009, http://ec.europa.eu/energy/res/biomass_action_plan/doc/2005_12_07_comm_biomass_electricity_en.pdf

ExternE, 2005, *Externalities of Energy* Methodology 2005 Update IER Germany, access date: 12.03.2009, http://ec.europa.eu/research/energy/pdf/kina_en.pdf

Galeotti, M., Lanza, A., 1999. *Desperately seeking (environmental) Kuznets.* International Energy Agency, Paris, access date: 20.03.09, http://www.feem.it/NR/rdonlyres/243323FD-09B8-4B80-81D3-DEFC8A9CD175/488/0299.pdf

Grossman, G.; Krueger, A., 1995. Economic growth and the environment, *Quarterly Journal of Economics* 110,2, 353–377.

Hilton, F.G.H.; Levinson, A., 1998. Factoring the environmental Kuznets curve: evidence from automotive lead emissions, *Journal of Environmental Economics and Management* 35 (2), 126–141.

Holtz-Eakin, D.; Selden, T., 1995. Stoking the fires? CO emissions and economic growth, *Journal of Public Economics* 57,1, 85–101. http://www.wunderground.com/education/ipcc2007.asp

IPCC,,2007, Fourth Assessment Report (AR4) *Climate Change 2007* The Intergovernmental Panel on Climate Change 17 November 2007, Valencia, Spain.

Kågeson, P., 1998, *Growth versus the Environment: Is there a Trade-off?*, Kluwer Academic Publishers, Netherlands.

Kovats, R. S.; Haines A., 2005, Global Climate change and health : recent findings and future steps, *Canadian Medical Association Journal*, 172 (4), 501-502.

Kuznets, S., March, 1955. Economic Growth and Income Inequality, *The American Economic Review*, Volume XLV, No 1

Panayotou, T., 2003, Economic Growth and the Environment, *Economic Survey of Europe*, No. 2, 45-72.

Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2006, *World Population Prospects: The 2006 Revision* and *World Urbanization Prospects: The 2005 Revision.*

Suri, V., Chapman, D., 1998. Economic growth, trade and energy: implications for the environmental Kuznets curve. *Ecological Economics* 25, 2, 195–208.

Verbeke, T., De Clercq, M., 2002 *Environmental policy, policy uncertainty and relocation decisions* Working paper, Universiteit Gent, Faculteit Economie En Bedrijfskunde

Weather Underground, access date: 03.02.2009, http://www.wunderground.com/

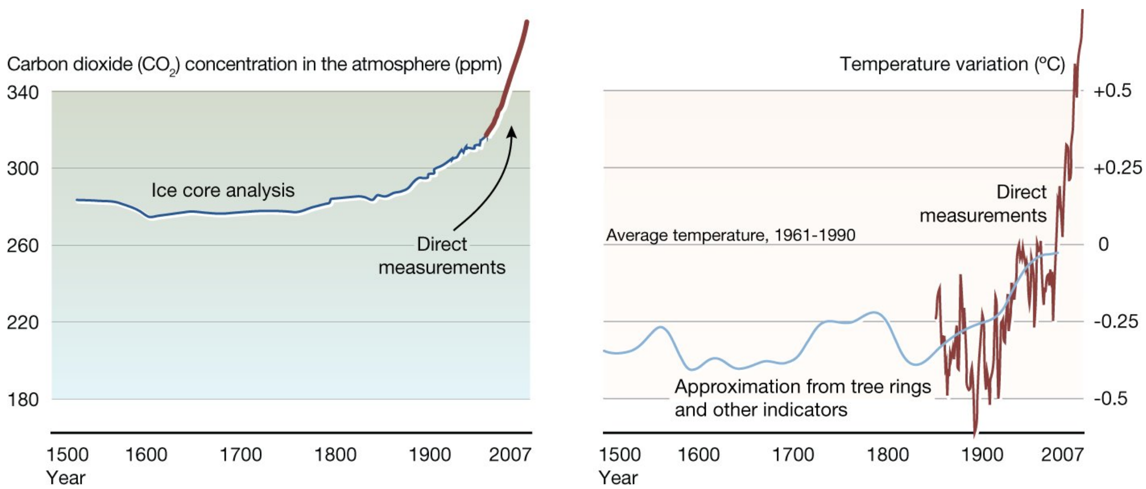
World resource institute access date: 30.03.09, http://earthtrends.wri.org/searchable_db/index.php?action=select_theme&theme=3

Yandle, B, Vijayaraghavan M, Bhattarai M (2000*). The Environmental Kuznets Curve: A Primer.* The Property and Environment Research Center. Access date: 27.03.09, http://www.perc.org/articles/article688.php. access date 11.03.2009.

# Appendices

Appendix 1

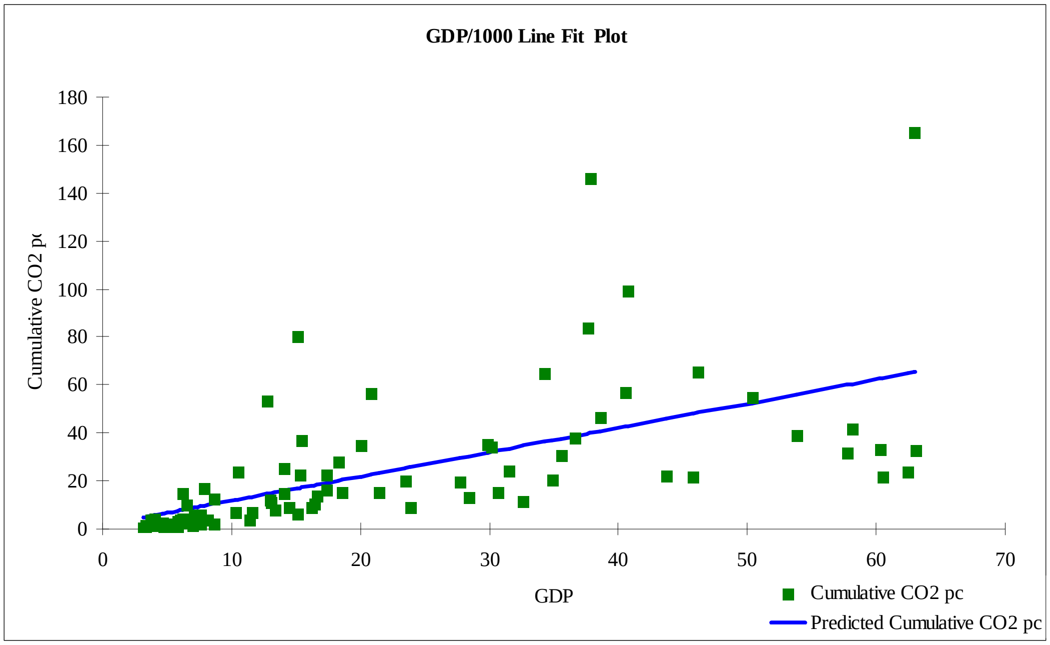
**Historical trends in carbon dioxide concentrations and temperature**



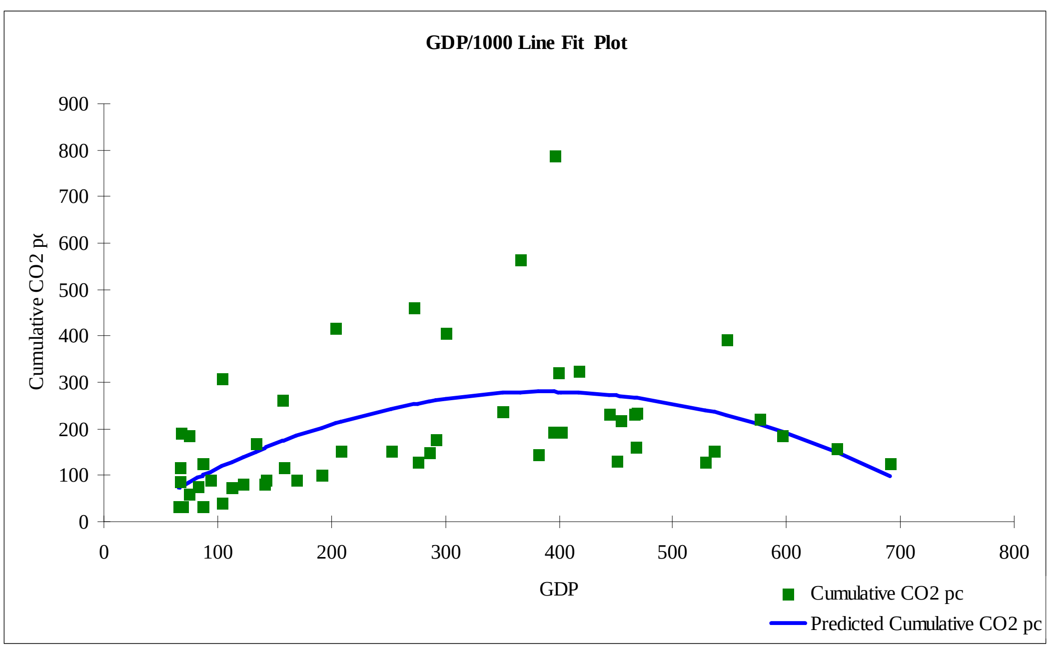

*Source: CRU (2007). CRUTEM3v dataset. Climate Research Unit, University of East Anglia. http://www.cru.uea.ac.uk/cru/data/temperature [Accessed 5 May 2007] Keeling, C.D. and Whorf, T.P. (2005). Atmospheric CO2 records from sites in the SIO air sampling network. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge Mann, M.E. and Jones, P.D. (2003). 2,000 Year Hemispheric Multi-proxy Temperature Reconstructions, IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series #2003-051. NOAA/NGDC Paleoclimatology Program, Boulder, http://maps.grida.no/go/graphic/historical-trends-in-carbon-dioxide-concentrations-and-temperature*

Appendix 2

**Poor economies GDP/1000 line fit plot**



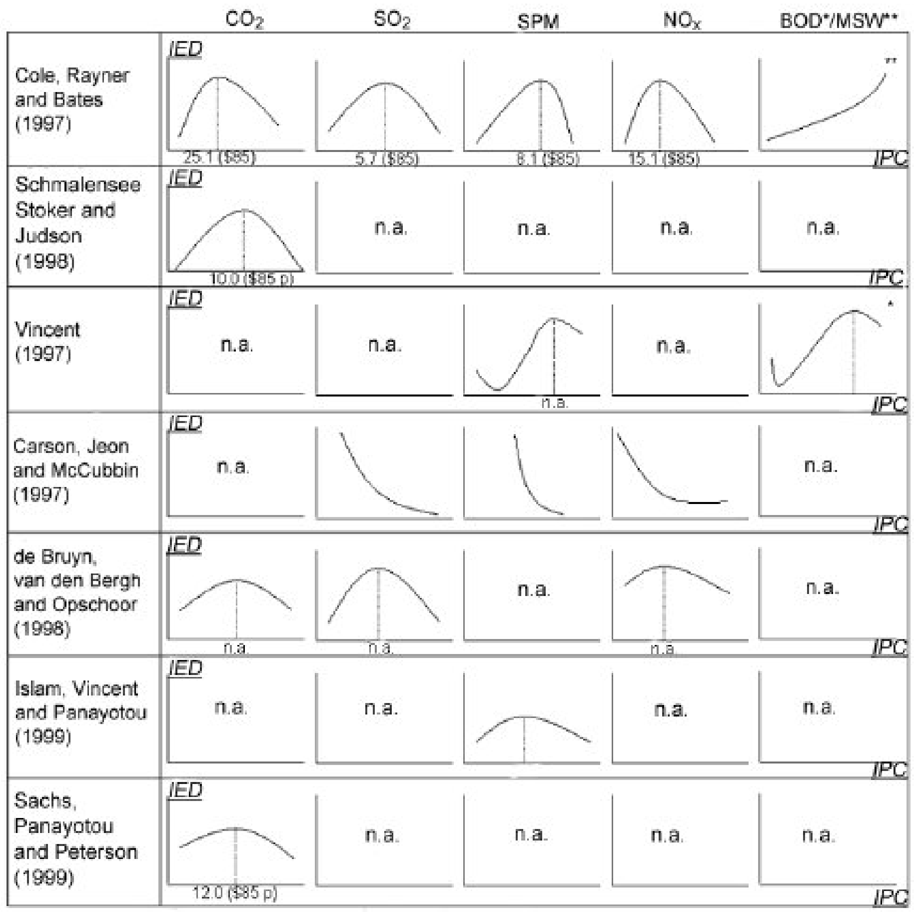

**Rich economies GDP/1000 line fit plot**




*Source: own*

## Appendix 3[1]

**Selected estimates of the empirical relationship between income per capita (IPC) and selected indicators of environmental degradation**

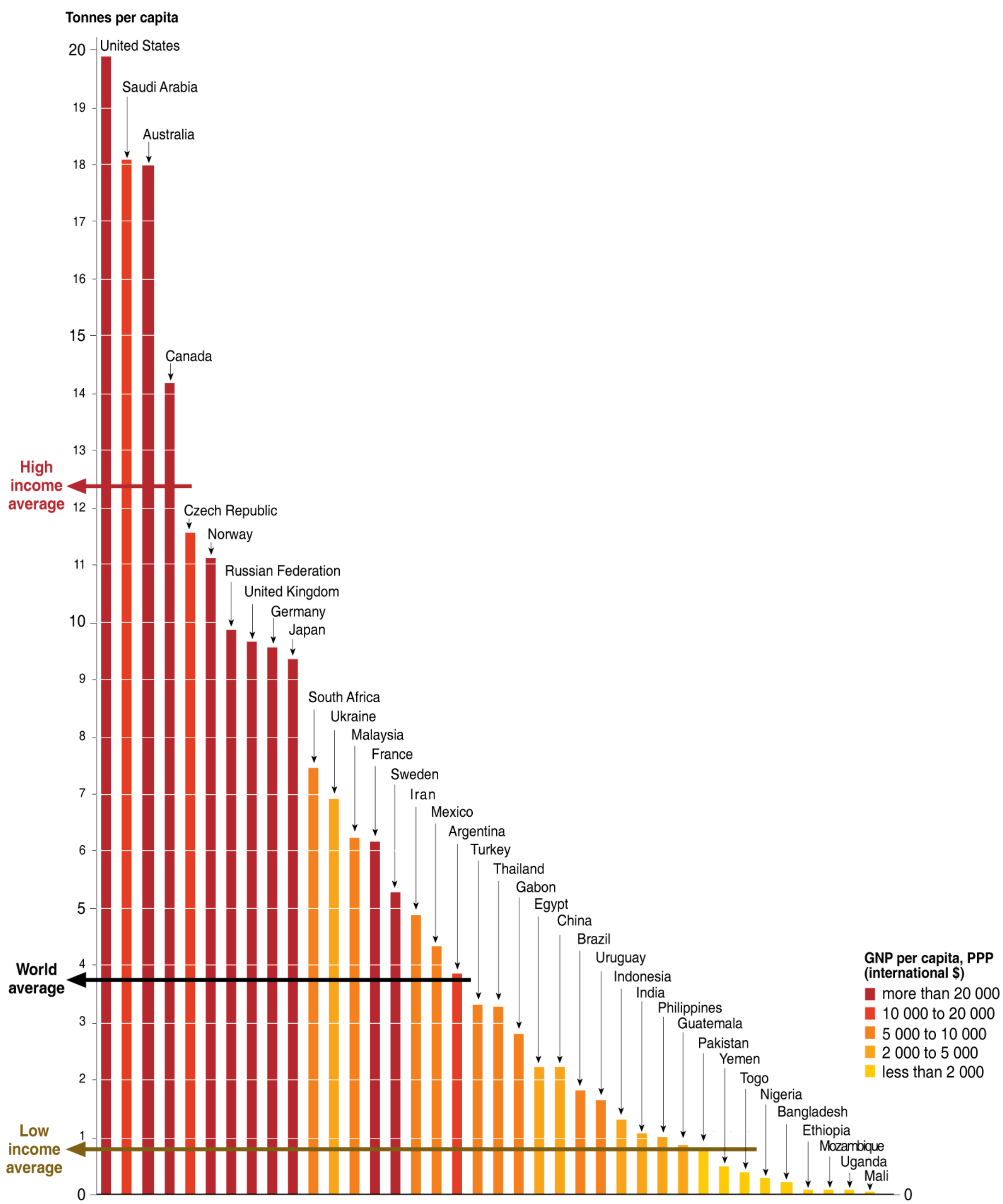



***Source:*** N. Shafik and S. Bandyopadhyay, *Economic Growth and Environmental Quality: Time-Series and Cross-Country Evidence*, World Bank Policy Research Working Papers, No. 904 (Washington, D.C.), June 1992; T. Panayotou, *Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development*, ILO Technology and Employment Programme Working Paper, WP238 (Geneva), 1993; G. Grossman and A. Kreuger, "Environmental impacts of a North American free trade agreement", *The U.S.-Mexico Free Trade Agreement* (Cambridge, MA, The MIT Press, 1993**)**; N. Shafik, "Economic development and the environmental quality: an econometric analysis", *Oxford Economic Papers*, Vol. 46, 1994; T. Selden and D. Song, "Environmental quality and development: is there a Kuznets curve for air pollution emissions?", *Journal of Environmental Economics and Management*, Vol. 27, Issue 2, September 1994; G. Grossman and A. Kreuger, "Economic growth and the environment", *Quarterly Journal of Economics*, Vol. 110, Issue 2, May 1995; M. Cole, A. Rayner and J. Bates, "The environmental Kuznets curve: an empirical analysis", *Environment and Development Economics*, Vol. 2, Issue 4, 1997; R. Schmalensee, T. Stoker and R. Judson, "World carbon dioxide emissions: 1950-2050", *The Review of Economics and Statistics*, Vol. 80, Issue 1, February 1998; J. Vincent, R. Ali, et al, *Environment and Development in a Resourcerich Economy: Malaysia under the New Economic Policy* (Cambridge, MA, Harvard University Press, 1997); R. Carson, Y. Jeon and D. McCubbin, "The relationship between air pollution emissions and incomes: US data", *Environment and Development Economics*, Vol. 2, Issue 4, 1997; S. de Bruyn, J. van den Bergh and J. Opschoor, "Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves", *Ecological Economics*, Vol. 25, Issue 2, May 1998; N. Islam, J. Vincent and T. Panayotou, *Unveiling the Income-environment Relationship: An Exploration into the Determinants of Environmental Quality*, Harvard Institute for International Development, Development Discussion Paper No. 701, May 1999; J. Sachs, T. Panayotou and A. Peterson, *Developing Countries and the Control of Climate Change: A Theoretical Perspective and Policy Implications*, CAER II Discussion Paper, No. 44 (Cambridge, MA), November 1999. Gathered by Panayotou 2003.

1 The studies on this page did not cover lack of clean water, lack of urban sanitation or deforestation.

Appendix 4

## CO2 Emissions in 2002




*Source: World Bank, online database, 2004, http://maps.grida.no/go/graphic/national_carbon_dioxide_co2_emissions_per_capita*