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Economic Development and Pollutants

Brazil's Economic Development

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Bachelor's Thesis in Economics

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Abstract

The purpose of this paper is to investigate the correlation of economic development and pollutants in Brazil from 1960 to 2008. This investigation is conducted by scrutinizing and testing the much contested Environmental Kuznet Curve (EKC); an economic theory relating income to environmental degradation by an inverted U-shape. Empirical tests of Carbon dioxide (CO2) per capita and income (GDP per capita) provided us with the conclusion that there is a strongly positive correlation between these variables. The observed relationship tells us that as income increases, CO2 emissions increase as well, although at a slightly decreasing scale. Thus, the expected inverted U-shape is not observed in Brazil, findings that are in line with previous research. Further, the empirical tests tell us that Brazil is approaching a potential turning point of an EKC. The results indicate that although Brazil may have succeeded in some aspects of approaching a Sustainable Development, there are still issues for improvement.

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1 Introduction

"*I consider that Brazil has a sacred mission to show the world that it is possible for a country to grow rapidly without destroying the environment*" (*Rousseff, 2011).* These words by the Brazilian president Dilma Rousseff are at the heart of what this paper aims to scrutinize; is it possible for a country to grow rapidly without destroying the environment? If so, has Brazil succeeded in this notion?

Climate Change is considered to be one of the biggest challenges to development, receiving heavy attention not only in national policies but also on the global level. Despite the growing importance of Climate Change in the media and in policies, it is still very often much debated and very controversial. The issue remain, and sound and efficient policies that deals with this are an urgent need and of utmost importance.

The link between Climate Change and Sustainable Economic Development was documented already in the Kyoto Protocol from 1997 (United Nation, 2008). In the last couple of years the growing importance of a transition towards a Green Economy has been recognized all around the world. Yet, many policies targeted at reducing the effects of globalization on the environment, such as the Copenhagen agreement; COP-15, have failed. Policies of this kind often fail because of a general belief that Sustainable Development impedes with economic growth.

This paper investigates the trends in economic development and its correlation with pollutants. Due to delimitations, I will perform this investigation by the use of a case study of Brazil. The reason for this choice of a case study is that Brazil provides an interesting case. They have not only experienced a remarkable economic development that dates back to the 1960s, but they have also engaged heavily in policies targeted at environmental protection and development of a Green Economy. Due to the availability of the data this paper will only concern development since 1960. The focus of the paper will be the relationship between economic development and CO2 emissions rate, since CO2 emissions is one of the main contributors to Climate Change (Houghton et al. 2001).

This paper shows that CO2 is positively related to income, but that a turning point is approaching in Brazil. This turning point indicates that as Brazil's economy keeps growing, pollutants are diminishing. Thus, an economy can succeed in combating climate change and at the same time prosper economically which, is what Rousseff referred to in her inauguration speech.

1.1 Purpose

The purpose of this paper is to investigate the correlation of economic development and pollutants and to test the relevance of the Environmental Kuznet Curve. The aim is to show the strengths and potential weaknesses of Brazil's economic development since the 1960s, from an environmental point of view.

1.2 Hypotheses

The hypotheses of the paper will be:

1) *Brazil's economic development between 1960 and 2008 is correlated with the CO2 emissions rate.*

2) *Brazil's economic development between 1992 and 2008 is negatively correlated with pollutants.*

These hypotheses reflect the Environmental Kuznet Curve (EKC), a much studied and examined economic theory, which will be reviewed in section 3. The first hypothesis will test if the variables are correlated and if so, does the relationship follow the curve predicted by the economic theory. The reason for choosing CO2 as a variable is that it is one of the main contributors to Climate Change (Houghton et al. 2001) and also because of the lack of availability of data on other emissions.

The second hypothesis tests if the predicted turning point on the EKC is achieved prior to 1992. The timeframes used are due to availability of data; 1992 is used due to the fact that from 1992 and onwards more variables are available to measure environmental degradation. As will be explained in section 2, there are many causes for environmental degradation and it is therefore interesting to test several variables and the effects of income on these.

2 Background

This section will provide a background to some important concept heavily used within the setting of this paper. It will also provide a brief background about Brazil in the context of Economic and Sustainable Development.

2.1 Climate Change

Climate Change is by the United Nations Framework Convention on Climate Change (UNFCCC) defined as "*a change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods*". (United Nations Framework Convention on Climate Change, 2013)

Lately a lot of research within the field has showed a disturbing increase in the mean global temperature, causing the arctic ice to melt, increasing the sea level and changing the pattern of rainfall among other things. These changes are not only impeding with food security and water insecurity, but they also cause ecological and social changes that endanger species. (World Bank, 2012) (Solomon, Plattner, Knutti & Friedlingstein, 2009)

The causes for Climate Change are, although debated, increases in emissions (mainly CO_2), deforestation and chemicals (Houghton, Ding, Griggs, Noguer, van der Linden, Dai, Maskell & Johnson, 2001). These causes are very much related with industrialization and economic growth.

2.2 Sustainable Development and Green Economy

The expression *Sustainable Development* is defined in the Brundtland report as "*development that meets the need of the present without compromising the ability of future generations to meet their own needs*" (Brundtland, 1987). Moreover, Sustainable Development requires that the basic needs of all are met and that all have the opportunity to satisfy aspirations for a better life.

The Brundtland report, also called Our Common Future, was formulated in 1987 by the Commission on Environment and Development on the request of the General Assembly of the United Nations. They requested a global agenda for change, to address the world's most important challenge: the environmental trends that threaten not only to alter the planet radically, but also threaten the lives of several species, human beings being one of them.

Further, the report notes that there is a widespread and growing recognition that environmental and economic development issues are so intertwined that it is impossible to separate them. An example of this is that environmental degradation can undermine economic development.

The report claims that what is needed now is a new era of economic growth, one that is powerful and yet environmentally and socially sustainable. This new era is a possibility, and must be based on policies that expand, secure and sustain the base of environmental resources.

Mohan Das Gandhi, Selladurai & Santhi (2006) provide an explanation to the process of Sustainable Development. Their model assumes that there are four different forces that drive *the Greening Process;* the transformation process from an unsustainable development toward a sustainable development. These forces are:

1. Regulatory force
2. Consumer force
3. Community force
4. Financial benefit

The consumer force and the community force are both a result of the globalization, where the consumer force reflects the consumption demand for products and services by firms that takes on a responsibility towards the environment. This demand is a result of an increased awareness and better-informed consumers.

The financial benefit force reflects that the Greening Process can be a source of opportunity instead of being a burden in that it can improve efficiency, serves as a comparative advantage and create a good reputation among the society. If a firm or industry implements a cleaner technology they can reduce their need of financial investment in the future as they do not have the costs of cleaning up to assure their compliance with environmental regulation. (Mohan Das Gandhi et al. 2006)

One of the main drivers in attaining a Sustainable Development is a Green Economy. A Green Economy is defined by the United Nations Environment Programme (UNEP) as; a socially inclusive, resource efficient and low carbon economy. According to UNEP (2013) a Green Economy will reduce ecological scarcities and environmental risks and at the same time enhance social equity and human well-being. Further, UNEP states that in a Green Economy the environment is what enables economic growth, as investments that reduce carbon emissions and in other ways are environmentally beneficial are the drivers of employment and income growth.

2.3 Brazil

Brazil is an emerging economy, which since the late 1960s has experienced an impressing economic growth. The result of this development was evident in 2011 when they became ranked as the 6th largest economy in the world, surpassing United Kingdom in rank (Bloomberg, 2011). Brazil has not only experienced an improvement in GDP ranking but has also managed to reduce their inequalities and is now ranked as an upper middle-income country by the World Bank. The combination of the sustained growth and improvements in equalities that Brazil has experienced has caused a substantial drop in absolute poverty. (World Bank, 2013)

Brazil is not only one of the world's fastest growing economies but the country also promotes and focuses on a Green Economy, control of deforestation, renewable energies and preservation of biodiversity among other things. The government has taken measures to achieve a Sustainable Development through a Green Economy, and the constitution of 1988 considers the environment as an important factor in policy-making and economic development. Brazil's transition to a Green Economy will enable Sustainable Development as well as support economic growth and aid social inequalities. (United Nations Environment Programme, 2012)

Brazil has made significant progress towards a Sustainable Development during the past 20 years. The country also strengthened their role as a leader of the transition to Sustainable Development by hosting the United Nations conference on Sustainable Development; *Rio+20.* The conference addressed the institutional framework for Sustainable Development and the concept of Green Economy among other things. Brazil has also collaborated with UNEP to develop policy options for Brazilian regions to achieve a Sustainable Development through a Green Economy. (United Nations Environment Programme, 2012)

Despite the progress of Brazil, they are still facing many issues such as the deforestation of the Amazon, high social inequalities, water contamination, overfishing and poverty reduction (United Nations Environment Programme, 2012). Notably their ranking in the Climate Change Performance Index (CCPI) dropped 19 places into number 33 on the list in 2013. The cause for the drop is due to the change in the index, which now included emissions from deforestation as well as a harsher evaluation of their national policies. (Germanwatch, 2013)

3 Theoretical Framework

This section will provide a review of the most common theory when it comes to the relation of income and pollution; the Environmental Kuznet Curve, which will be tested in section 5.

3.1 Kuznet

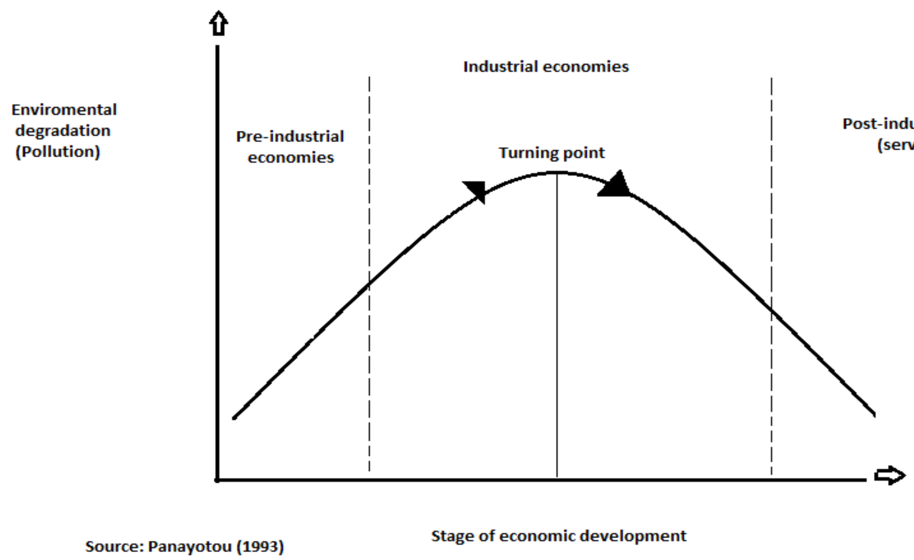
In 1955 Simon Kuznet started to confront the correlation of economic growth and inequalities in income distribution. He noted that economic growth in developed countries is usually associated with a shift away from an agricultural economy into urbanisation and industrialization. Further, he argues that as there is a shift to the non-agricultural sector income equalities will increase and after a long-term stability in income inequalities it will narrow. (Kuznet, 1955)

According to Kuznet the explanation for this relationship may be that there are forces that increase income inequality as economic growth progress as well as contracting forces. This relationship has developed into the famous inverted U-shape, later called the Kuznet U hypothesis. (Kapuria-Foreman & Perlman, 1995)

Although the paper by Kuznet is more speculative than empirical, it has served to be the foundation for further research. The inverted U-shape that has been observed between income inequalities and economic growth was later developed into an inverted U-shape of the relationship between per capita income and environmental degradation; *the Environmental Kuznet Curve (The EKC)* as can be seen in Figure 1.

The EKC indicates that as income increases in an early stage of economic development, the quality of the environment worsens until what is called a turning point is achieved and the environmental quality improves. The turning point varies among countries. (Grossman & Krueger, 1995)

Figure 1: Enviromental Kuznet Curve



The Y-axis of the curve can refer to various indicators of environmental degradation. The turning point occurs at various level of income depending on which indicators of environmental degradation that are used. As the turning point is reached, improvement in the environment is associated with higher levels of income, which implies that economic growth is a mean to potential environmental improvement. The notion behind this hypothesis is that as income rises, the demand for better environmental quality rises as well as it increases the availability of resources to create investments for improvement. (Stern, 2004)

Panayotou (1993) argues that the reason for the associated improvement in income and environmental quality is due to the fact that higher levels of development are not only associated with increased awareness, education and enforcement of environmental regulations but also better technology and structural changes towards a more service-oriented and more information-intensive industries.

3.1.1 Criticism of the EKC

Stern (2004) reviews the theoretical criticism of the EKC in his paper "*The rise and fall of the environmental Kuznet curve*". He states that the EKC model first presented in the World Development Report in 1992, assumes that income is an exogenous variable. This assumption implies that as environmental degradation increases, economic activity is not reduced sufficiently enough to stop the growth process. That is, there is no feedback from the degradation to the economic production and that the economy therefore is sustainable by assumption. This is not a reasonable assumption. If instead the economy at a higher growth level is not sustainable, the attempt for developing countries to achieve a higher growth rate (when they have not yet reached the turning point) may very well be counterproductive, as this high growth rate is not sustainable.

If and when the EKC is observed it may be as a result of trade between countries. According to the Hecksher-Ohlin trade theory, nations will specialize in production of goods that use the factor in which they are relatively well-endowed in. This predicts that developed nations will specialize in human-capital and manufactured capital-intensive goods, while developing nations will specialize in labour-intensive goods and the production that uses their natural resources intensively. As different types of production are more environmental damaging than others this type of specialization may be reflected into the reduction/increase of pollution among countries. This type of scenario is called "*race to the bottom*". (Stern, 2004)

These differences may be further enhanced by the fact that developed countries may have more environmental regulations, which encourages the shift of the polluting activities towards the developing countries. This implies that as the developing countries try to implement environmental regulations and/or specialize in the production of human capital goods, there are none or few countries left for them to outsource the damaging activities to. This implies that it is more difficult for the developing countries to reduce the environmental degradation. (Stern, 2004)

On the other hand recent research does not provide any clear evidence that polluting activities are shifted towards less regulated market as trade is liberalized and other argues that the activities in the developed countries (the more capital-intensive activities) are more polluting. Hence, there is no clear evidence on the impact of trade on pollution.

(Stern, 2004) (Antweiler, Copeland & Taylor, 2001) (Cole & Elliott, 2003) (Copeland & Taylor, 2004)

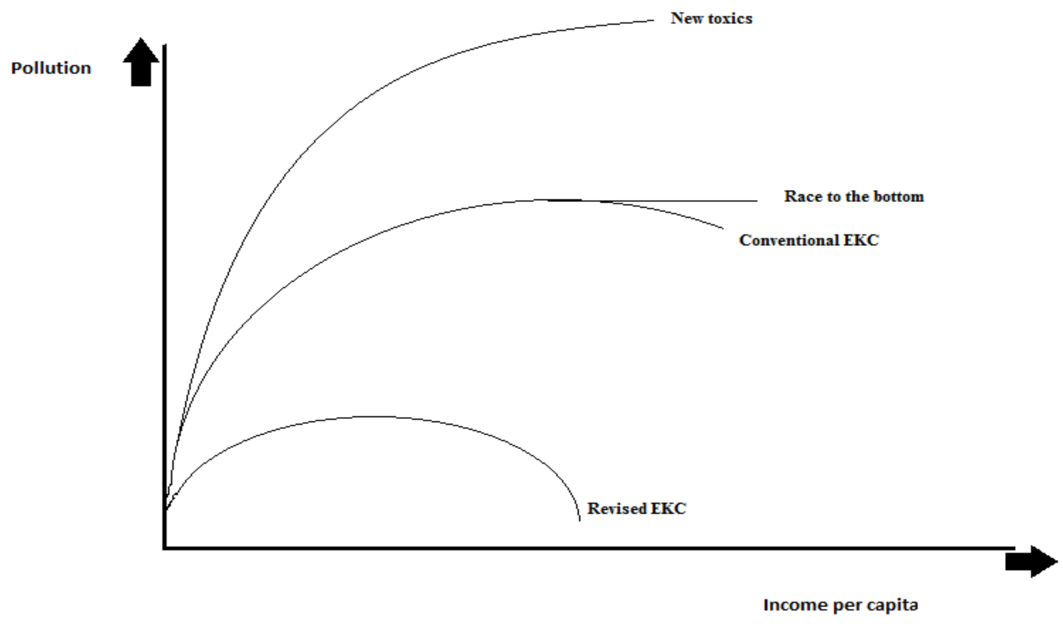
Moreover, the EKC is said to be monotonic as the U-shape is not applicable to all kind of pollutants. So even if some pollutants decline at a certain level of economic development others do not and the overall effect is not reduced.

3.1.2 Revised EKC

As the EKC has received quite heavy criticism and is argued to be rather limited, a lot of research has been made to deal with this. One alternative view developed by Dasgupta (2002) revises the EKC as can be seen in Figure 2. He illustrates that there are four viewpoints of the relationship between pollution and income per capita. The evidence for the revised EKC is drawn from his research, which mostly concerns China. This view does not reject the U-shaped curve but only shifts it down and to the left. This shift is due to technological change. It also states that developing countries has in the last decades, due to the globalization, experienced a trade liberalization, which has encouraged a more efficient use of inputs and less subsidization of activities that are harmful for the environment.

The viewpoint of new toxics argues that although society may lessen some pollutants as income increases, it will at the same time create new pollutants, which will cause the overall environmental degradation to increase. (Dasgupta et al., 2002)

Figure 2: Revised EKC



Source: Dasgupta et al. (2002) and Perman and Stern (2003)

The conclusions that can be made from Dasgupta et al. (2002) is not only that developing countries can improve the environment as the race to the bottom is not a plausible scenario, but also that their peak level of environmental degradation is lower. The peak level is lower in those countries that developed later. The notion behind this is that increased regulation has diminishing returns, so even if regulation and enforcement are increasing with income, the largest increase happens at low and middle-income levels.

3.2 Previous Studies

This section serves as a review of what other research concerning the EKC has established. It will be used later in the analysis to compare this papers result to their results.

Stern concludes that there are little evidences of an observed EKC among countries that experience increased income per capita. The EKC does not seem to be a very robust and adequate model. (Stern, 2004)

This notion is supported by Copeland & Taylor, which state that the relationship between environmental damage and income may not be as simple and predictable as the EKC hypothesises. (Copeland & Taylor, 2004)

Focacci (2003) & (2005) investigate the trends in emission intensity ratio and energy intensity ratio. One of his paper concerns industrialized countries: Australia, France, Italy, UK and USA and the other concerns 3 different developing countries; China, India and Brazil. He uses the emissions ratio on CO2 to test the relevance of the EKC. When it comes to the EKC he concludes that the curve is not observable in his observations. He concludes that the results are quite different in the 2 papers. When it comes to the developing countries the results among them differ as well. In China and Brazil the trend of carbon emissions-income ratio is decreasing while in India it is increasing. The work by Focacci is only looking at trends and does not estimate the exact EKC or turning point, nor is it using statistical models. (Focacci, 2003) (Focacci, 2005)

Panayotou argues that environmental policies flatten the EKC. He uses Sulfur dioxide (SO2) as the emissions variable and adds to the EKC model variables representing population density, economic growth rate and policy. The results are that economic growth rate and policy as additive terms are highly significant and of right sign. An increase in the economic growth rate will increase emission while an increase in the quality of policy, which is measured as enforcement of contracts, reduces emissions. Population density is insignificant in the model. Although, when the economic growth rate and policies variables were used as multiplicative terms they were no longer significant and was therefore dropped. When it comes to the curvature, the addition of the policy variable lowers the curve significantly. Panayotou concludes that the relationship between income and environment is not as easy predicted as the EKC models it. This is due to the fact that increased economic growth only increase pollution due to industrialization and scale effect but reduces pollution due to other effects as income increases, and it is only partially true that increased economic growth rate beyond the so-called turning point reduces pollution. The reason for the flattening of the EKC in his findings is that institutions and policies can decrease the environmental degradation significantly at low-income levels, and at high-income levels it can speed up improvements of the environmental degradation. (Panayotou, 1997)

An observation of an inverted U-shape of air pollutants and income was found by Selden & Song (1994). For this result a number of countries and time series were tested by the use of pooled cross-section. This confirmation of the EKC by Selden & Song also showed that the turning point was very high compared to other studies. Grossman and Krueger (1993) findings are also in support of the EKC. They also test air pollutants even though they use different observations.

4 Empirical Framework

In this section I will present the data set and the variables used in the empirical tests in section 5 as well as the models. This section will also provide descriptive statistics.

4.1 Methodology

To test the first hypothesis; *Brazil's economic development between 1960 and 2008 is correlated with the CO2 emission rate*; I will use ***Income (GDP per capita)*** as a variable to explain economic development and test it against ***CO2 emissions per capita***. The reason for the chosen time interval is that it, to my knowledge, is the only available interval for the chosen variables.

The first step will be to plot the variables against each other in a scatterplot, to see if the inverted U-shape of the economic theory is observable. To test if the variables are correlated a correlation analysis will be conducted with a bivariate correlation test. Such a test analyses the relationship of 2 variables and tests if the variables are related or not. Further, a causality test will be performed to test if one variable causes the other one. The Granger Causality test will be performed in this regard as we are dealing with two variables. This test will thus tell us if GDP per capita is causing CO2 per capita.

The standard regression model used to test the relevance of the EKC is:

$$\ln (E/P)_{it} = \alpha_i + \gamma_t + \beta_1 \ln (GDP/P)_{it} + \beta_2 (\ln(GDP/P))^2_{it} + \varepsilon_{it} \quad \text{(Stern, 2004)} \qquad (1)$$

E represents emissions, P represents population, $_i$ is country or region $_i$ and $_t$ is years $_t$ (Stern, 2004).

As the EKC model presumes an inverted U-shape, the logged GDP reflects the upward sloping shape on the left-hand side of the curve and the squared GDP variable exists in the model to reflect the downward sloping shape at the right-hand side of the curve. This implies that the logged variable is predicted to be positive and the squared variable is predicted to be of negative sign.

The second hypothesis; *Brazil's economic development between 1992 and 2008 is negatively correlated with pollutants,* which if the EKC has been observed in the above tests, implies that Brazil has reached its turning point. As according to the theory of Kuznet; when income increases beyond the turning point, environmental degradation will decrease with income. I will again test ***Income (GDP per capita)*** against some variables concerning environmental degradation. These variables, which I will refer to as environmental variables, are the following:

- ***CO2 emissions per capita***

-***Estimated rates of annual gross deforestation***

-***Industrial consumption of substances that destroy the ozone layer*** (later referred to as substances)

The reason to why I have added a couple of variables is that these variables are now available within this new time frame and also because I want to try to make the test a bit stronger in the sense that environmental degradation not only concerns CO2 emissions (Houghton et al., 2001).

To test the second hypothesis I will first perform a correlation analysis of the environmental variables. Further, if a correlation is found a regression analysis will be conducted and elaborated on to try and find the true relationship of the variables.

If the EKC has been observed in earlier tests, the second hypothesis will also test the turning point and comparing it to the income level.

The turning point, i.e. the maximum of emissions is calculated as follows:

$T = \exp(-\beta_1/(2\beta_2))$ (Stern, 2004) (2)

4.2 Data and Variables

The data used in the empirical research is annual data estimates for the period 1960-2008. For the first hypothesis; *Brazil's economic development between 1960 and 2008 is correlated with the CO2 emission rate,* the variables used are:

GDP per capita: This variable is collected from the World Bank atlas and it takes the value of the gross domestic product divided by the number of inhabitants at midyear. It is measured in current US dollars. The reason to why I choose to measure it in current US dollars is because Brazil has changed its currency several times during this period and this measurement simplifies interpretation.

CO2 emissions per capita: This variable is also collected from the World Bank atlas and it is measured in metric tons of carbon per capita.

There are 49 observations for each variable used in hypothesis one (1960-2008).

For the second hypothesis; *Brazil's economic development between 1992 and 2008 is negatively correlated with pollutants,* the variables used are:

GDP per capita: See above.

CO2 emissions per capita: See above.

Substances that destroy the ozone layer: This variable is collected from the Brazilian institute of geography and statistics (IBGE). The variable is chosen because the depletion of the ozone layer is highly correlated with Climate Change. It covers the industrial consumption of substances that destroy the ozone layer. The substances that are covered are those contained in the Montreal protocol from 1987. They are measured as tons of potential ozone depletion. This potential is calculated by taking into account the amount of atoms with capacity to destroy ozone per molecule, the effect of ultraviolet light and other radiations in the molecule, the rate of diffusion in the atmosphere and the stability of the product. (IBGE, 2013)

Deforestation: This variable is also collected from the IBGE. The variable estimates gross accumulated loss of forest in the Amazon; it is the total loss of the forest covered territory, which is computed in August of the relevant year. It is expressed in km^2. (IBGE, 2013) The reason for choosing this variable is not only that deforestation, as mentioned before, is one of the main contributor to Climate Change, but also since the Amazon in Brazil is the largest rainforest in the world and is considered to be the lungs of the world.

All the variables for the second hypothesis are annual estimates for the period 1992-2008 amounting to 17 observations for each variable.

4.3 Descriptive Statistics

Detailed tables with descriptive statistics for all data can be found in the appendix 1.

To check for variations in the variables are important before proceeding with formal statistical tests. The reason for this is that if there are no variations in the variables we cannot test the effect of changes in the variables. One can observe variations by examining the minimum and maximum value of the variables. The mean value corresponds to the average value of the observations. It is important that the mean is somewhere in the middle of the minimum and maximum values. The reason for this is that we do not want a variable with values only in either end, as that could cause biased results when performing statistical tests.

In Table 1 the descriptive statistics for first hypothesis can be found. These include GDP per capita and CO2 emissions per capita for 1960-2008. In the GDP variable there are large variations between the minimum and maximum values, the variations in the CO2 variable are not that large although the mean is somewhere in the middle of the minimum and the maximum value.

Table 1: Descriptive Statistics for hypothesis 1

	N	Minimum	Maximum	Mean	Std. Deviation
GDP per capita	49	203.2	8269	23450	1943
CO2 per capita	49	0.6	2.1	1.386	0.4238
Valid N (listwise)	49				

In Table 2 the descriptive statistics for the second hypothesis can be found. It contains GDP per capita, CO2 emissions per capita, Deforestation and Substances for 1992-2008. Again, the variations in the CO2 variable are not that large although the mean is somewhere in the middle of the minimum and the maximum value. The same is true for Deforestation. GDP per capita and Substances exhibit clear variations and the mean is somewhere in the middle of the minimum and maximum.

Table 2: Descriptive Statistics for hypothesis 2

	N	Minimum	Maximum	Mean	Std. Deviation
GDP per capita	17	2527	8629	4404	1668
CO2 per capita	17	1.4	2.1	1.812	0.1833
Deforestation	17	0.15	0.59	0.3653	0.1264
Substances	17	1410	13279	7784	4682
Valid N (listwise)	17				

5 Empirical Findings

This section will provide the results from the empirical tests, which have been conducted in line with the empirical framework provided in section 4. In addition to this, an analysis of these results, in line with the theoretical framework in section 3, will be provided.

5.1 First Hypothesis

: Brazil's economic development between 1960 and 2008 is correlated with the CO2 emission rate;

Figure 3: Scatterplot of CO2 against GDP per capita, 1960-2008

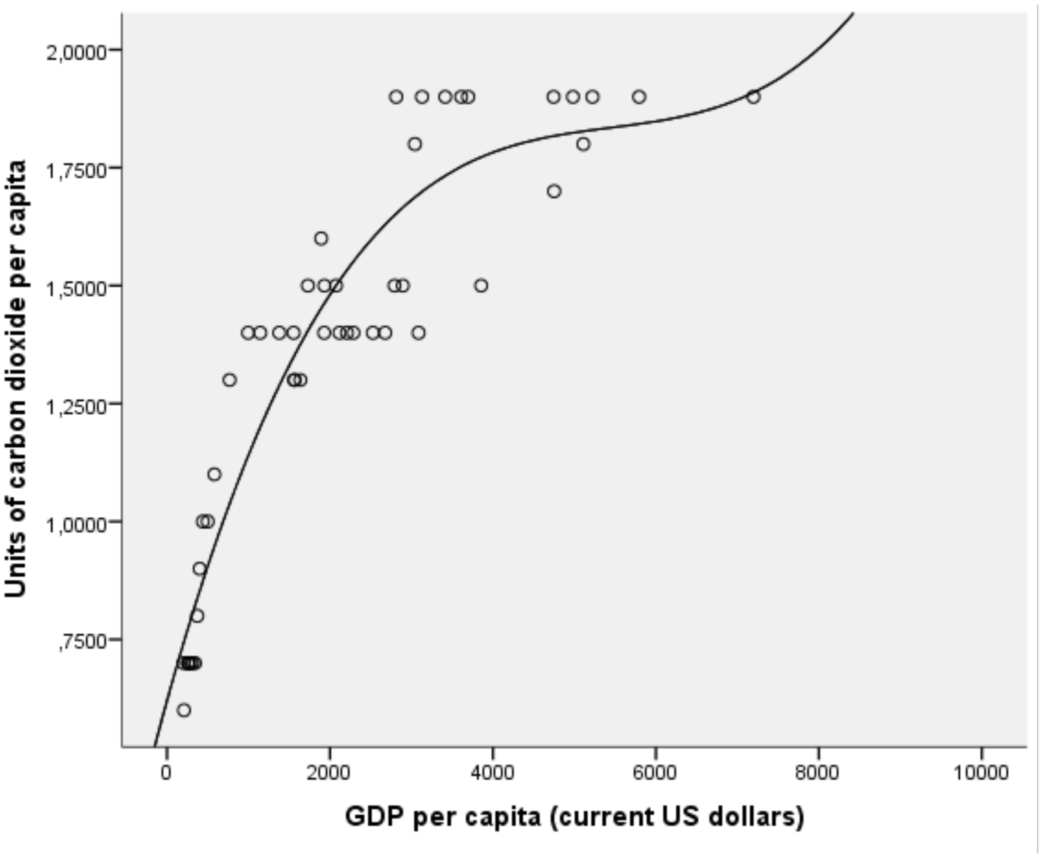


Figure 3 indicates that there is a positive correlation between CO2 per capita and GDP per capita. Further, it seems as that the relationship is increasing, mostly at a decreasing scale, which implies that the relationship is not linear. To investigate this further, a correlation analysis was conducted; the correlation is estimated to be 0.849, which is significant at the 0.01 level. The result from this test confirms that there is a quite strong positive relationship between the variables. 0.849 indicate that the correlation is highly positive although not linear. As the graph indicates a non-linear relationship, a plot of the logged variables is conducted:

Figure 4: Scatterplot of CO2 against GDP per capita, 1960-2008, using logged variables

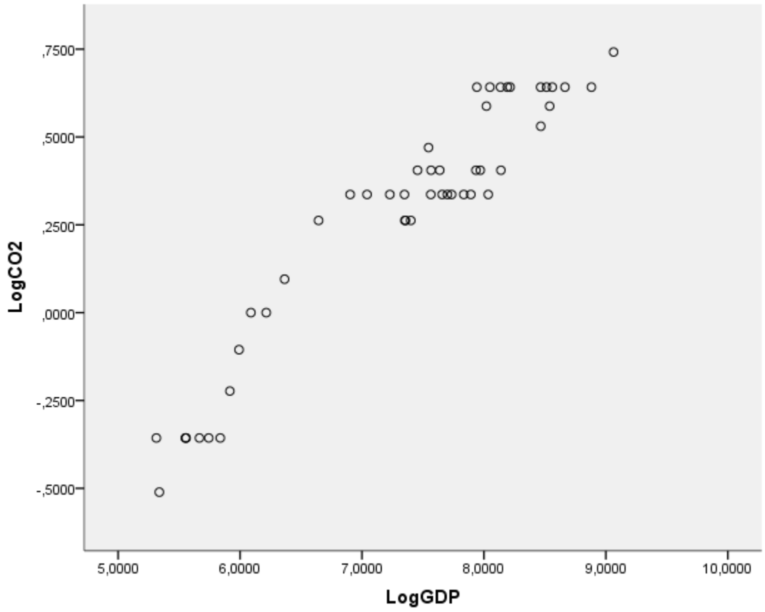


Figure 4 does indeed indicate a positive correlation. A correlation analysis of the logged CO2 emission and the logged GDP variables estimated the correlation to be 0.957, which is significant at the 0.01 level. The correlation results are indeed positive and almost linear. This enables us to perform a linear regression with logged variables, as the EKC model by Stern predicts.

Because a significant correlation is found a causality test is also performed. A Granger Causality test is chosen as we are dealing with 2 variables, this test exam if one of the variables causes the other one. As a Granger Causality test assumes that the time series are stationary, this needs to be tested. (Gujarati & Porter, 2009) A time series that is stationary implies that the mean and variance of the time series does not exhibit a systematically variation over time (Gujarati & Porter, 2009). By first plotting the logged variables of GDP and CO2 against time, as can be seen in appendix 2, it seems as both variables are non-stationary. To properly investigate this, a unit root test is conducted. A unit root test test the null hypothesis that the variables have a unit root which implies that the variables are non-stationary. The Augmented Dickey-Fuller test is a unit root test which is popular to use in time series sample and is also chosen in this paper. When the t-statistics are greater than the critical values we cannot reject the null hypothesis that the variables have a unit root and thus are non-stationary. As can be see in Table 3 this is the case in our sample. The output from this test can be found in appendix 3.

Table 3: Augmented Dickey-Fuller test

	T-statistic	*Critical Value (1% level)*
Log CO2	*-1.878919*	*-4.161144*
Log GDP	*-2.449980*	*-4.165756*

Thus before performing the Granger Causality test the variables need to be transformed into stationary variables. Taking the first-differences of the time series enforces this:

Δln CO2 per capita=ln CO2per capita $_t$ – ln CO2 per capita $_{t-1}$

Δln GDP per capita= ln GDP per capita $_t$ – ln GDP per capita $_{t-1}$

The new variables are then tested for stationary by a unit root test, which confirms that the transformed variables now are stationary. The results from these tests are summerized in Table 4 and can be found in appendix 4.

Table 4: Augmented Dickey-Fuller test on first-diffrence estimators

	T-statistic	*Critical Value (1% level)*
Log CO2	*-5.583154*	*-4.165756*
Log GDP	*-4.499127*	*-4.165756*

The Granger Causality test is conducted to test which of these variables that causes the other one, as there are two variables it is a bilateral causality that is tested. The number of lags used is the automatic chosen by the Schwarz Information Criteria (SIC). (Gujarati & Porter, 2009)

The output from the test is shown in appendix 5. This test cannot reject the hypothesis that CO2 emissions does not cause GDP per capita, as well as it cannot reject the hypothesis that GDP per capita does not causes CO2 emissions per capita at a 10% significance level. As the Granger test is sensitive to the number of lags used, (Gujarati & Porter, 2009) a lower number of lags are also used but the result still stays the same. This suggests that there is independence between the variables. This suggested independence may be misleading as there may be other variables that explain the true relationship, and the Granger Causality test only handles pairs of variables.

In the EKC model by Stern, a squared logged GDP per capita variable is added as it reflects the downward sloping part of the curve. This variable is also tested for stationary by a scatterplot and a unit root test, which indicates that this variable also is non-stationary. The same procedure as before is conducted to make it stationary. The outputs for these can be seen in appendix 6.

Now when the variables are transformed and checked for, estimating the regression is what is left. The standard EKC model regression is estimated as follow:

$$\ln(\text{CO2 per capita}) = \alpha_i + \beta_1 \ln(\text{GDP per capita}) + \beta_2 (\ln(\text{GDP per capita}))^2 + \varepsilon_{it} \qquad (1)$$

Our model becomes:

$$\Delta \ln(\text{CO2 per capita}) = \alpha_i + \Delta \beta_1 \ln(\text{GDP per capita}) + \beta_2 \Delta (\ln(\text{GDP per capita}))^2 + \varepsilon_{it} \quad (3)$$

By running the regression on the first-difference form of the variables potential problems of multicollinearity, autocorrelation and non-stationary variables are removed. Multicollinearity implies that some or all of the explanatory variables in a regression model exhibits a linear relationship and thus explain the same thing. Autocorrelation is defined by Gujarati & Porter (2009) as ‘correlation between members of series of observations ordered in time or space’. In our sample autocorrelation would imply that if the economy booms in one year this would not only affect the GDP per capita in that year but also in the preceding years. The reason for conducting the regressions with first-difference variables is that empirical test of time series data assumes stationary time series, if this assumption is violated spurious regression results may be likely to occur. A spurious regression is when there is a nonsense regression; one that concludes a significant relationship when there is really none. (Gujarati & Porter, 2009)

The transformed variables makes it easier to interpret the results as they now represent the relative change, which is what we are interested in as we want to estimate if there has been an improvement or not in the given year. By using the first-difference form the number of observations is reduced from 49 to 48. The outputs are given in appendix 7 and are summarized in Table 5:

Table 5: Regression results standard model

	CO2 per capita
Constant	*0.015 (0.010)*
GDP per capita	*0.396 (0.398)*
GDP per capita squared	*-0.018 (0.026)*
F-Value	*2.621*
R^2	*0.104*
Adjusted R^2	*0.065*
N	*48*

Note: All variables are estimated by using first difference and the natural logarithm (ln)

As can be seen in Table 5 all variables are of expected signs but they are not significant. As the variables are insignificant, not much emphasis is put on the estimators. Further, both the F-value and the R^2 values are very low, which normally indicates that the model is a bad fit. Although, when performing a regression with first-difference variables low R^2 values are a common occurrence as they study the behavior of variables around their trend values (Gujarati & Porter, 2009). Thus, the low R^2 does not necessarily imply that the model is bad.

By examining scatterplot 1, it shows that the curve has not yet turned into a downward slope as the predicted EKC model. This may indicate that the squared variable should be dropped. Removing this variable from the above model and re-running the regression provides us with output that can be seen in appendix 8 and which are summarized in Table 6:

Table 6: Regression results standard model excluding squared variable

	CO2 per capita
Constant	*0.016* (0.009)*
GDP per capita	*0.127* (0.058)*
F-Value	*4.834*
R^2	*0.095*
Adjusted R^2	*0.075*
N	*48*

* Significant at the 0.01 level (2-tailed). Note: All variables

In this adjusted model the variables are now significant at the 0.01 level and they are of right sign. In this model if GDP per capita increases with one percent, on average there would be a 0,127 percent increase in CO2 emissions per capita. The F-value and the R^2 values are still very low, although the adjusted R^2 has somewhat improved, which tells us that this model is somewhat better. The low R^2 values and F-value could indicate that the puzzle of the correlations of CO2 per capita and GDP per capita is not as easily predicted as the EKC model predicts, but they are more likely caused by the fact that we are using first difference variables.

These results suggest that the relationship between CO2 emissions and GDP per capita for Brazil does not adhere to the predicted Environmental Kuznet Curve. It could still be the case that Brazil has or soon will reach the turning point, as the correlation has increased at a diminishing pace. The first hypothesis of this paper cannot be rejected as proven in Figure 3 and the correlation analysis.

5.2 Second Hypothesis

: *Brazil's economic development between 1992 and 2008 is negatively correlated with pollutants*

As this hypothesis tests the combined effect of pollutants, a correlation analysis was conducted for the environmental variables as can be seen in Table 7. The correlation analysis shows that there are no strong correlations between deforestation and substances. There is however a negative correlation between substances and CO2 emissions, as well as for substances and CO2 emissions, but as these are of the wrong sign and not that strong they are ignored. As the number of observations is low, not much emphasis is put on these results.

Table 7: Correlation between the variables, 1992-2008

	CO2 per capita	Deforestation	Substances
CO2 per capita	1	-0.470*	-0.519*
Deforestation	-0.470*	1	0.380
Substances	-0.519*	0.380	1
GDP per capita	0.576*	-0.737**	-0.437

* Correlation is significant at the 0.05 level (2-tailed)** Correlation is significant at the 0.01 level (2-tailed)

As the results from the correlation analysis of the environmental variables, probably due to low number of observations, are more or less insignificant, the empirical testing of the combined effect of the environmental variables from the paper is dropped. Instead the trends of the environmental variables during this time are plotted in Figure 5-8 to simply observe their trends.

Figure 5: Time trend of CO2 per capita, 1992-2008

Measured in metric tons

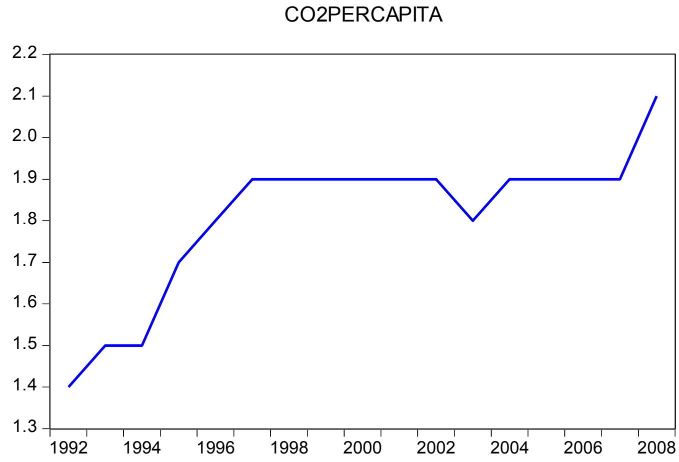


Figure 6: Time trend of Deforestation, 1992-2008

Measured in km²

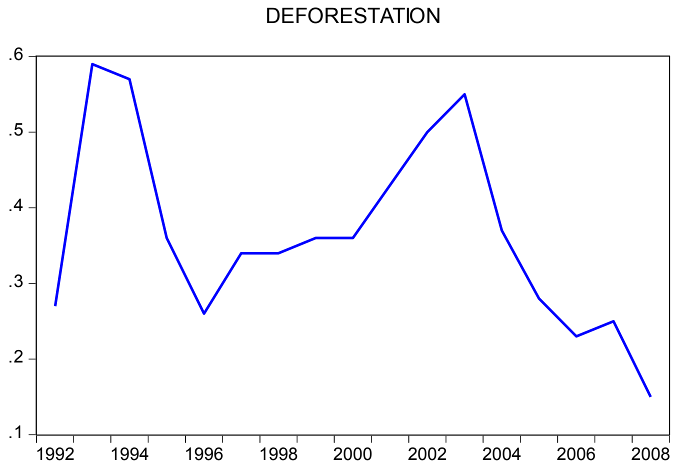


Figure 7: Time trend of Substances, 1992-2008

Measured as tons of potential ozone depletion

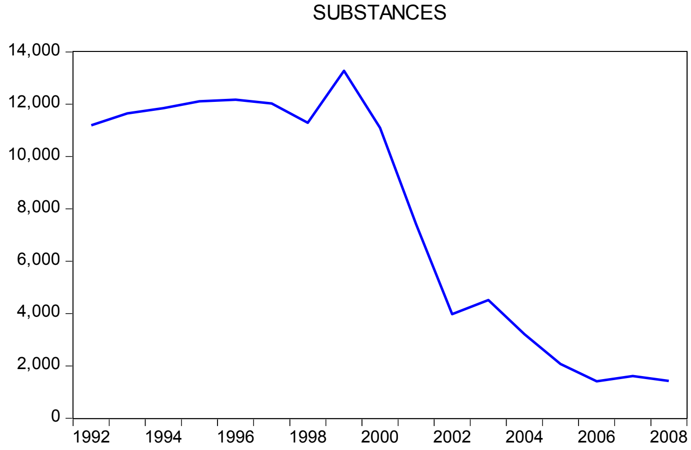


Figure 8: Time trend of GDP per capita, 1992-2008

Measured in current US dollars

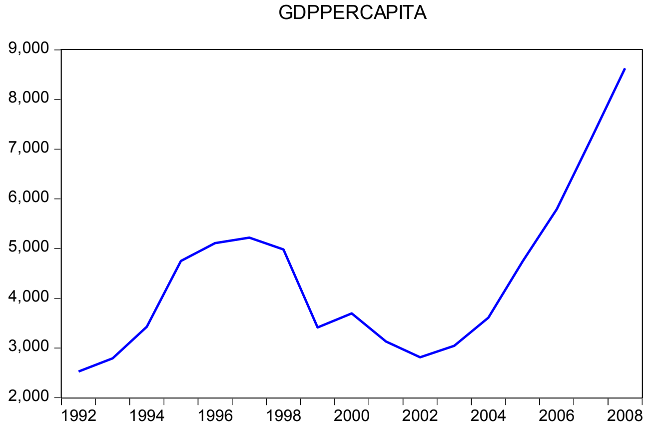


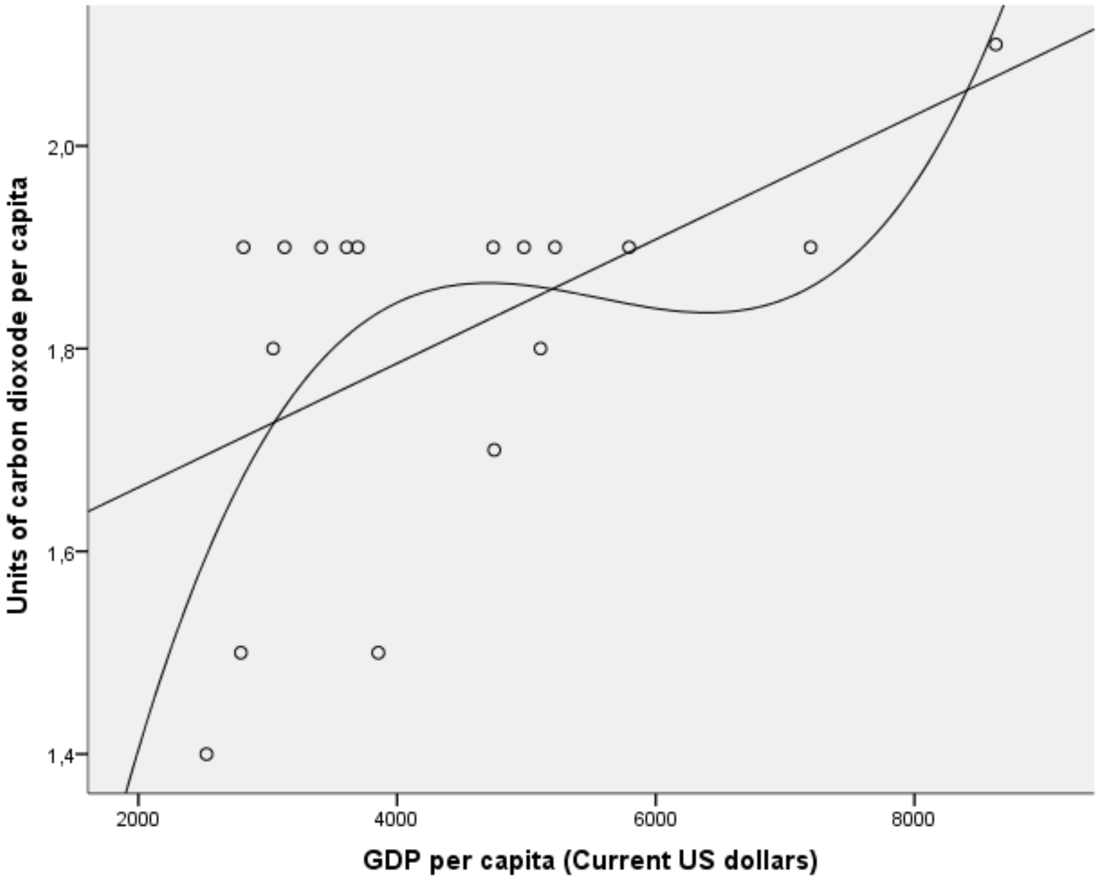
Figure 5-8 indicates that GDP per capita has increased during this time period, while deforestation and substance has decreased from the early 21th century. CO_2 per capita on the other hand seem to exhibit a stagnation between 1997-2007 but has increased yet again the last year [1]. This may again be an indication that Brazil has reached a turning point.

Instead of testing the combined effects of the variables against GDP per capita, an individual test of CO_2 per capita against GDP per capita was conducted. The reason for this is that it adds on the first hypothesis; to further test the relevance of the EKC. The first step to see if Brazil's economic development between 1992 and 2008 is negatively cor-

[1] A cubic term was first added in the original model to deal with 2008's observation, but as the result proved to be insignificant the observation is considered as an outlier in this case.

related with CO2 per capita is to examine a scatterplot of the relationship, as can be seen in Figure 9.

Figure 9: Scatterplot of CO2 per capita against GDP per capita, 1992-2008



By examining Figure 9 it seems as there is no significant relationship between GDP per capita and CO2 emissions per capita for the years 1992 to 2008. A correlation analysis estimates the correlation to be 0.552, which is significant at the 0.05 level. A correlation of 0.552 implies that the relationship is somewhere in the middle of being perfectly linear (1) and uncorrelated (0), this implies that the relationship is somewhat weakly positive. A plot of the logged variables was conducted but did not improve the linearity.

This result indicates that the relationship has not yet crossed the *turning point*; where the relationship is negatively correlated. Although, as the correlation is much weaker than in the first hypothesis, it would seem as the relationship is approaching this turning point.

5.3 Analysis

The empirical tests of the first hypothesis of this paper; *Brazil's economic development between 1960 and 2008 is correlated with the CO2 emission rate,* provided some interesting results. As predicted by the EKC model a significant correlation between GDP per capita and CO2 emission per capita was found, further it proved to be a strongly positive correlation. The EKC theory predicts that a change in income causes a change in emissions rate, but the correlation that was found in our dataset could not prove such a causal relationship. This result is not surprising as the Granger Causality test that was used only can handle two variables. There may very well be other variables that are significant for the causality, which would affect the outcome of this causality test.

Both scatterplots and regression analysis of the relationship between CO2 emissions per capita and GDP per capita show that the observed relationship in Brazil between 1960 and 2008 does not correspond with the predicted relationship by the conventional EKC model. This conclusion is in line with the conclusion by Focacci (2005). Nor does the observed relationship correspond to the revised EKC model in section 3.1.2 although, the observed relationship seen in Figure 3 resembles the curve representing *New Toxics* in the revised EKC model in section 3.1.2. This curve is an indicator of that even if some toxics are reduced as income increases, they are more than offset by new toxics and the overall environmental degradation is to be even worse (Dasgupta et al., 2002). This line of thought may explain why CO2 emissions rate seems to be increasing in Brazil even though, as explained in section 2.3, they have taken measures to improve their environmental performance as well as they have experienced improvement in income. As the correlation between income and CO2 emissions is very high, it may be that the "bad" forces of increasing income on CO2 emissions rate may be so high that they offset the "good" forces such as enhanced policy actions, improved education and increased awareness that follow with an increase in income according to the economic theory. It may also be that the measures that Brazil has taken have simply been ineffective or have been targeted at other pollutants.

The results from the regression analysis in section 5.1 indicate that the EKC model is a bad fit for the observed data, in that the predicted inverted U-shape is not found. That is, the EKC model is not a realistic model for the Brazilian development; this conclusion is in line with the conclusion in the paper by Focacci (2005). The regression results provide variables that are of right signs; the expected positive sign of the logged GDP per capita and the expected negative sign of the squared GDP per capita variable is confirmed which, even though the model is inadequate, serves as a check of the data.

By examining Figure 3, one could argue that the EKC may be observable only that Brazil has not yet reached their turning point. If this would be the case, then the second regression model used in section 5.1 would be the right one. This model provides significant variables but it only explains 9,5 % of the observed data. This seems to be evidence in favor of the perception that the true relationship between economic development and pollutants are more complicated than predicted by the EKC. This is in line with the work by Panayotou (1997) who examines the relevance of other potential explanatory variables to emissions rate. But one needs to be cautious about this interpretation as the regression models used in this paper make use of first difference variables, which generally implies low R^2 (Gujarati & Porter, 2009).

The second hypothesis, *Brazil's economic development between 1992 and 2008 is negatively correlated with pollutants,* was removed due to insignificant results. This is probably due to the low number of observations, not much emphasis is put on this relationship of combined pollutants with GDP per capita. Although, individual plots of the environmental variables were provided. What is interesting from these plots is that although CO2 emissions per capita seem to be increasing, both deforestation and substances that destroy the ozone layer seems to be decreasing from the early 21^{th} century and onwards. These results are in line with section 2.3, which tells us that Brazil promotes control of deforestation and in other ways are committed and takes measure towards a sustainable development. Section 2.3 also tells us that although Brazil is taking efforts towards sustainable development and a better environment they are still facing many issues, which this continuing increase in CO2 emissions and their drop in the CCPI ranking is an indicating proof of. This conclusion is also in line with the above discussion on the resemblance with the new toxics curve in the revised EKC model in section 3.1.2.

Instead of testing the combined effect of different pollutants more emphasize was again put on the relationship between GDP per capita and CO2 per capita, but now the emphasize was put on the smaller timeframe 1992-2008. One can argue that by examining Figure 3 of the first hypothesis, the correlation between CO2 emissions per capita and GDP per capita does not seem to be decreasing since the mid 90's. On the contrast it seems to be increasing. This is further enhanced by Figure 5, which shows the trend in CO2 emissions per capita from 1992 to 2008, during this time period CO2 has increased but in the last 10 years it has stagnated. A correlation analysis of the relationship indicates that although there is a positive correlation, this correlation is much smaller than the correlation analysis of 1960-2008. This indicates that although Brazil has not passed the turning point on a potential EKC, it seems as they are approaching such a point. This approaching turning point may be a result of improved policies but may also be due to an increased awareness, which alters the demand, and improved and reformed technology as income has increased.

As this paper tries to test if Brazil has succeeded to grow rapidly without destroying the environment, it seems as the results are a bit ambiguous: Brazil has failed in the notion that CO2 emissions rate are still increasing, but at the same time they have succeeded in that deforestation and substances that destroy the ozone layer are decreasing. They have also succeeded in the notion that although CO2 emissions increase with income they are doing so at a decreasing rate.

The fact that CO2 emissions increase as income increases, but does so at a decreasing rate, may be explained by the EKC theory; even though there are some forces that increase the environmental degradation as income grows, these forces are somewhat offset by other forces such as increased awareness and enhanced policies, which also increase with economic development. This may imply that the new era of economic growth, which is needed according to the Brundtland report (1987), has not yet fully occurred, although it seems as it is on the right track. Further, the so-called Greening Process by Mohan Das Gandhi et al. (2006) seems to have started.

To conclude this section it seems that Brazil still needs to take further action to decrease CO2 emissions. Further, it seems as that increases in income may be harmful in that it increases these emissions rate, at least at these levels of income. This does not mean that economic growth in the future may necessarily be bad for environmental development. This is true as the results show that the relationship is a more complicated one and it may in the future be offset by improved policies and education as previous studies by Panayotou (1997) and theory predicts.

6 Conclusion

This paper investigates the correlation of economic development and pollutants, mainly *CO2 emissions*; a pollutant that is one of the main contributors to Climate Change. The investigation is conducted by a case study of Brazil. Brazil is chosen for this investigation as they have experienced an impressive economic growth in the past decades while at the same time are said to be highly committed to an environmentally sustainable development.

The Environmental Kuznet curve (EKC) is a much debated economic theory that deals with the correlation of environmental degradation and income per capita. This theory is examined in this paper and its relevance is empirically tested. It is further used to analyse this papers results.

Two hypotheses that reflect the Environmental Kuznet Curve were tested in this paper; *Brazil's economic development between 1960 and 2008 is correlated with the CO2 emissions rate,* and *Brazil's economic development between 1992 and 2008 is negatively correlated with pollutants*. The investigations were conducted by empirical tests of annual data that was retrieved from the World Bank.

The first hypothesis could not be rejected as the empirical tests shows a strong and positive correlation, but the correlation could not be proven to be as a causal relationship as predicted in the economic theory. Further, the relationship does not follow the EKC model, which predicts an inverted U-shape. Instead the observed relationship proves to be a trend that is increasing but at a somewhat decreasing rate. This result may indicate that Brazil has not yet reached their turning point on the EKC curve, but also that they are currently at the turning point although not yet passed it.

The second hypothesis was dropped as it turned out that the low number of observations produced insignificant results. Instead simple trends of environmental variables were examined. These trends indicate that CO2 emissions have not decreased but instead increased since 1992. At the same time deforestation and substances that destroy the ozone layer have decreased in the last years. This indicates that Brazils environmental policies have succeeded in some aspects while have failed in other aspects. Further action by Brazil is thus needed to reduce CO2 emissions, and the correlation of economic development and pollutants is not a simple one with a one size fits all policy solution.

Moreover, a further investigation of the relationship between GDP per capita and CO2 per capita was again conducted, although, this investigation was focused on a shorter timeframe. The result from this analysis indicate that Brazil are approaching a potential turning point as even though the correlation between these variables is still positive, it is much lower during the short timeframe than during the longer timeframe, which was tested in hypothesis 1.

6.1 Suggestion for further Research

The second hypothesis *Brazil's economic development between 1992 and 2008 is negatively correlated with pollutants* turned out to give insignificant results. At the same time the individual plots of the trends in these environmental variables provided some interesting results, indicating that more emphasis should be put on analysing these in more depth. This could be accomplished by gathering more data by extending the time interval. Although, this may be a problem in that the environmental variables used for this paper, at this point in time, could not be found for a longer time interval. Finding other environmental variables for analysis could potentially solve this problem.

Further, a more political in depth analysis of why the different environmental variables provide trends in opposite directions should attract more analysis.

In the future it would be interesting to analyse if the increasing trend of CO2 emissions will turn into a decreasing trend as higher income is achieved.

As Brazil is a highly diversified country, a potential point of interest to aim future research at would be the regional differences in Brazil's economic and environmental development. Again, the availability of data may provide difficulties in this regard.

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Appendix 1 Descriptive statistics

Descriptive statistics for hypothesis 1

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error
GDP per capita (current US$)	**49**	**203,2**	**8629,0**	**2349,906**	**277,5724**	**1943,0065**	**3775274,350**	**1,141**	**,340**
CO2 emission per capita (metric tons per capita)	**49**	**,6**	**2,1**	**1,386**	**,0605**	**,4238**	**,180**	**-,366**	**,340**
Valid N (listwise)	**49**								

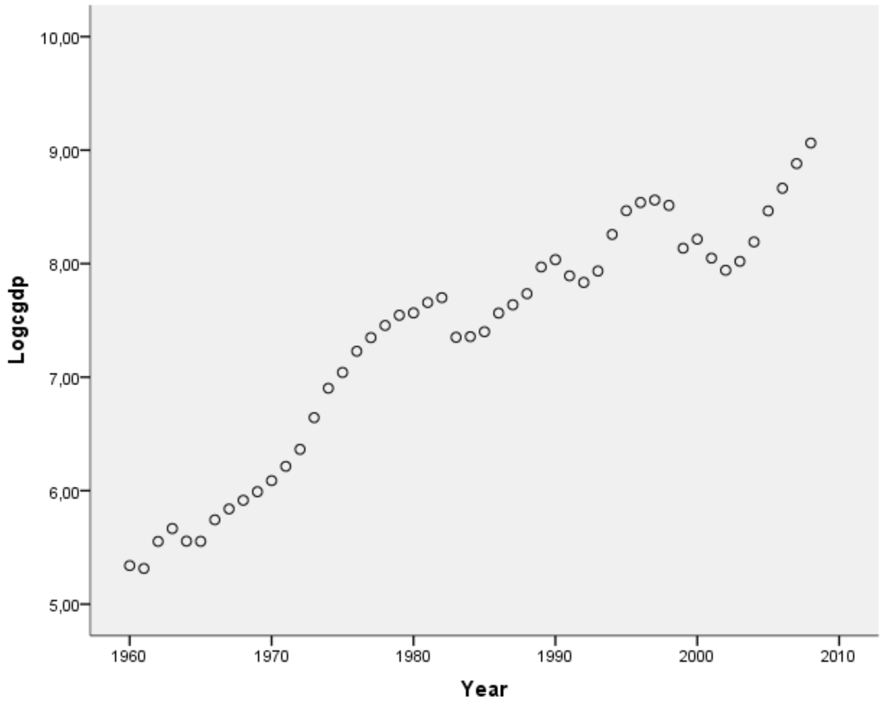
Descriptive statistics for hypothesis 2

Descriptive Statistics

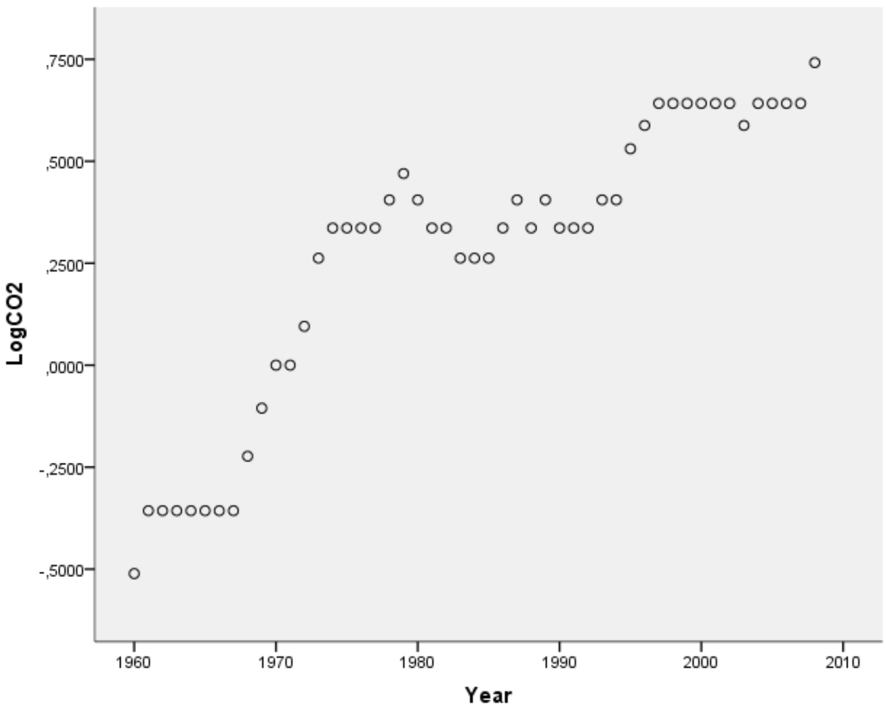
	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
GDP per capita current Us dollars	**17**	**2527**	**8629**	**4404,29**	**1668,010**	**2782258,346**	**1,203**	**,550**
CO2 emission per capita (metric tons per capita)	**17**	**1,4**	**2,1**	**1,812**	**,1833**	**,034**	**-1,161**	**,550**
Substances	**17**	**1410**	**13279**	**7784,12**	**4682,188**	**21922886,360**	**-,325**	**,550**
Deforestation	**17**	**,1500**	**,5900**	**,365294**	**,1263981**	**,016**	**,430**	**,550**
Valid N (listwise)	**17**							

Appendix 2 Stationary check: time trends of the logged GDP and CO2 variables

GDP per capita



CO2 per capita



Appendix 3 Unit root test- Augumented Dickey-Fuller

CO2 per capita

Null Hypothesis: LOGCO2 has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.878919	0.6499
Test critical values:	1% level	-4.161144	
	5% level	-3.506374	
	10% level	-3.183002	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOGCO2)
Method: Least Squares
Date: 05/28/13 Time: 16:36
Sample (adjusted): 1961 2008
Included observations: 48 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGCO2(-1)	-0.106765	0.056823	-1.878919	0.0667
C	0.014888	0.023765	0.626489	0.5342
@TREND(1960)	0.001596	0.001422	1.122406	0.2676

R-squared	0.107792	Mean dependent var	0.026098
Adjusted R-squared	0.068138	S.D. dependent var	0.059554
S.E. of regression	0.057489	Akaike info criterion	-2.813987
Sum squared resid	0.148724	Schwarz criterion	-2.697037
Log likelihood	70.53569	Hannan-Quinn criter.	-2.769791
F-statistic	2.718335	Durbin-Watson stat	1.483612
Prob(F-statistic)	0.076822		

GDP per capita

Null Hypothesis: LOGGDP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.449980	0.3504
Test critical values:	1% level	-4.165756	
	5% level	-3.508508	
	10% level	-3.184230	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOGGDP)
Method: Least Squares
Date: 05/28/13 Time: 16:35

Sample (adjusted): 1962 2008
Included observations: 47 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGGDP(-1)	-0.138133	0.056381	-2.449980	0.0184
D(LOGGDP(-1))	0.433118	0.135023	3.207728	0.0025
C	0.833683	0.315417	2.643115	0.0114
@TREND(1960)	0.009036	0.004190	2.156694	0.0367

R-squared	0.249890	Mean dependent var	0.079787
Adjusted R-squared	0.197556	S.D. dependent var	0.145101
S.E. of regression	0.129980	Akaike info criterion	-1.161602
Sum squared resid	0.726480	Schwarz criterion	-1.004142
Log likelihood	31.29764	Hannan-Quinn criter.	-1.102349
F-statistic	4.774965	Durbin-Watson stat	1.973880
Prob(F-statistic)	0.005845		

Appendix 4 Unit Root test- Augumented Dickey-Fuller- on first diffrence estimators

CO2 per capita

Null Hypothesis: FIRSTDIFCO2 has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.583154	0.0002
Test critical values:	1% level	-4.165756	
	5% level	-3.508508	
	10% level	-3.184230	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(FIRSTDIFCO2)
Method: Least Squares
Date: 05/28/13 Time: 16:42
Sample (adjusted): 1962 2008
Included observations: 47 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FIRSTDIFCO2(-1)	-0.818109	0.146532	-5.583154	0.0000
C	0.027118	0.018986	1.428300	0.1603
@TREND(1960)	-0.000328	0.000632	-0.518863	0.6065

R-squared	0.421125	Mean dependent var	-0.001151
Adjusted R-squared	0.394813	S.D. dependent var	0.073173
S.E. of regression	0.056924	Akaike info criterion	-2.832491
Sum squared resid	0.142576	Schwarz criterion	-2.714396
Log likelihood	69.56354	Hannan-Quinn criter.	-2.788051
F-statistic	16.00476	Durbin-Watson stat	1.857153
Prob(F-statistic)	0.000006		

GDP per capita

Null Hypothesis: FIRSTDIFGDP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.499127	0.0041
Test critical values:	1% level	-4.165756	
	5% level	-3.508508	
	10% level	-3.184230	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(FIRSTDIFGDP)
Method: Least Squares
Date: 05/28/13 Time: 16:43
Sample (adjusted): 1962 2008
Included observations: 47 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FIRSTDIFGDP(-1)	-0.629500	0.139916	-4.499127	0.0000
C	0.067769	0.044226	1.532335	0.1326
@TREND(1960)	-0.000636	0.001481	-0.428969	0.6700

R-squared	0.315092	Mean dependent var	0.004468
Adjusted R-squared	0.283960	S.D. dependent var	0.162103
S.E. of regression	0.137170	Akaike info criterion	-1.073486
Sum squared resid	0.827890	Schwarz criterion	-0.955391
Log likelihood	28.22691	Hannan-Quinn criter.	-1.029046
F-statistic	10.12111	Durbin-Watson stat	1.867431
Prob(F-statistic)	0.000242		

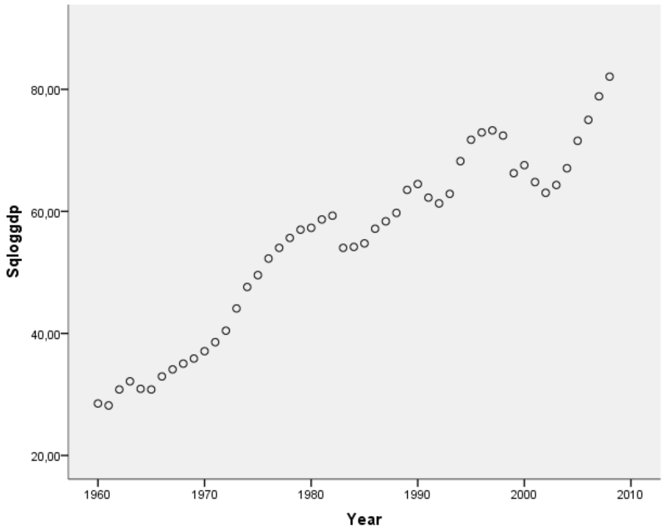
Appendix 5 Granger Causality test

Pairwise Granger Causality Tests
Date: 04/12/13 Time: 18:00
Sample: 1 49
Lags: 12

Null Hypothesis:	Obs	F-Statistic	Prob.
FIRST_DIFF_GDP does not Granger Cause FIRST_DIFF_CO2	36	0.75849	0.6798
FIRST_DIFF_CO2 does not Granger Cause FIRST_DIFF_GDP		0.62271	0.7861

Appendix 6 Stationary tests for squared GDP per capita

Time trend



Unit Root test- Augmented Dickey-Fuller

Null Hypothesis: LOGGDPSQ has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=10)

		t-Statistic
Augmented Dickey-Fuller test statistic		-2.698982
Test critical values:	1% level	-4.165756
	5% level	-3.508508
	10% level	-3.184230

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOGGDPSQ)
Method: Least Squares
Date: 05/29/13 Time: 14:03
Sample (adjusted): 1962 2008
Included observations: 47 after adjustments

Variable	Coefficient	Std. Error	t-Statistic
LOGGDPSQ(-1)	-0.176143	0.065263	-2.698982
D(LOGGDPSQ(-1))	0.481707	0.134370	3.584927
C	5.897613	2.018717	2.921466
@TREND(1960)	0.174940	0.068022	2.571832

R-squared	0.276760	Mean dependent var
Adjusted R-squared	0.226301	S.D. dependent var
S.E. of regression	1.966505	Akaike info criterion

Sum squared resid	166.2870	Schwarz criterion	4.429117
Log likelihood	-96.38395	Hannan-Quinn criter.	4.330911
F-statistic	5.484879	Durbin-Watson stat	2.096145
Prob(F-statistic)	0.002787		

First difference estimator

Null Hypothesis: FIRSTDIFFSQGDP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.336373	0.0063
Test critical values:	1% level	-4.165756	
	5% level	-3.508508	
	10% level	-3.184230	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(FIRSTDIFFSQGDP)
Method: Least Squares
Date: 05/29/13 Time: 14:06
Sample (adjusted): 1962 2008
Included observations: 47 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FIRSTDIFFSQGDP(-1)	-0.604886	0.139491	-4.336373	0.0001
C	0.712098	0.662350	1.075108	0.2882
@TREND(1960)	0.000451	0.022609	0.019931	0.9842

R-squared	0.299505	Mean dependent var	0.075106
Adjusted R-squared	0.267664	S.D. dependent var	2.456578
S.E. of regression	2.102256	Akaike info criterion	4.385601
Sum squared resid	194.4572	Schwarz criterion	4.503696
Log likelihood	-100.0616	Hannan-Quinn criter.	4.430041
F-statistic	9.406367	Durbin-Watson stat	1.941234
Prob(F-statistic)	0.000397		

Appendix 7 Regression standard model

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	**first dif log gdp sq, first dif log gdp**	**.**	**Enter**

a. All requested variables entered.

b. Dependent Variable: first dif log co2

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	**,323[a]**	**,104**	**,065**	**,0576001**

a. Predictors: (Constant), first dif log gdp sq, first dif log gdp

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	**,017**	**2**	**,009**	**2,621**	**,084[a]**
	Residual	**,149**	**45**	**,003**		
	Total	**,167**	**47**			

a. Predictors: (Constant), first dif log gdp sq, first dif log gdp

b. Dependent Variable: first dif log co2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	**,015**	**,010**		**1,580**	**,121**
	first dif log gdp	**,396**	**,398**	**,960**	**,994**	**,326**
	first dif log gdp sq	**-,018**	**,026**	**-,658**	**-,682**	**,499**

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	**first dif log gdp sq, first dif log gdp**	**.**	**Enter**

Appendix 8 Regression standard model excluding squared variable

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	**first dif log gdp[a]**	**.**	**Enter**

a. All requested variables entered.

b. Dependent Variable: first dif log co2

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	**,308[a]**	**,095**	**,075**	**,0572641**

a. Predictors: (Constant), first dif log gdp

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	**,016**	**1**	**,016**	**4,834**	**,033[a]**
	Residual	**,151**	**46**	**,003**		
	Total	**,167**	**47**			

a. Predictors: (Constant), first dif log gdp

b. Dependent Variable: first dif log co2

Coefficients[a]

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	**,016**	**,009**		**1,728**	**,091**
	first dif log gdp	**,127**	**,058**	**,308**	**2,199**	**,033**

a. Dependent Variable: first dif log co2