MASTER’S THESIS

School of Economics and Management
Department of Economics

How Economic Growth Affects Emissions. An Investigation of the Environmental Kuznets Curve

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May, 28th 2012

ABSTRACT

The Environmental Kuznets Curve (EKC) describes an inverted U-shaped relationship between per capita income and environmental degradation. In this paper this relationship will be analysed by using per capita GDP as proxy for per capita income, and per capita carbon dioxide and sulphur dioxide as representatives for environmental degradation. Using cross-country time series data for ten global countries characterised by different levels of development, I find that there is evidence for an inverted U-shaped EKC. However, there are also other curvatures that explain the relationship between economic growth and emissions. The results suggest that in particular linear functions might explain this relationship. As linear functions might be considered as part of (inverted) U-shaped functions the theory of the EKC is not completely rejected by the finding of linear functions.

Altogether, the empirical results do not indicate particular differences between developing and developed countries. The most striking differences appear between carbon dioxide and sulphur dioxide. In the case of carbon dioxide, both positive linear functions and inverted U-shaped functions seem to explain the relationship between economic growth and emissions. In the case of sulphur dioxide, negative linear functions seem to explain that relationship.

Keywords: Environmental Kuznets Curve, carbon dioxide, sulphur dioxide, GDP, development

LIST OF ABBREVIATIONS

COUNTRIES

AUS	Australia
BRA	Brazil
CHI	China
IND	India
JAP	Japan
MEX	Mexico
RUS	Russia
SAF	South Africa
SWE	Sweden
UK	United Kingdom
USA	United States of America

COMPOUNDS

CO	Carbon monoxide
CO_2	Carbon dioxide
NO_x	Nitrogen oxide
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide
SO_x	Sulphur oxide
SO_2	Sulphur dioxide

VARIABLES

CO2	Carbon dioxide
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
TECH	Technology
SO2	Sulphur dioxide

OTHER

BRIC	Brazil, Russia, India and China (group of fast growing countries)
DW	Durbin Watson (test)
EDGAR	European Database for Global Atmospheric Research
EPA	(U.S.) Environmental Protection Agency
EKC	Environmental Kuznets Curve
GEMS	Global Environment Monitoring System
GLS	Generalised Least Squares
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary Least Squares
TP	Turning Point
USD	United States Dollars

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1. Introduction

The Environmental Kuznets Curve (EKC) has attracted attention from the international community in recent years. The theory of the EKC describes an inverted U-shaped curve between the income of a country and the level of environmental degradation. In other words, a poor, developing country will face increasing environmental degradation with increasing income until it reaches a point where it is wealthy enough that its environmental degradation will decrease with even higher levels of income. Of course, such a development appears to be quite attractive for both developing and developed countries. Developing countries only need to acquire a certain standard of wealth until they can invest into environmental protection. And developed countries simply have to ensure that they keep growing which will reduce their level of environmental degradation automatically.

A scenario as presented by the EKC is naturally appealing for governments and economies. Since the global population has become aware that the worldwide climate might be changing, the pressure has increased on politicians to find a solution that prevents, or at least limits, increasing temperatures and their possibly catastrophic impacts. The catalyst of global warming has been identified quickly. Emissions, specifically greenhouse gases, are blamed to cause damage to the ozone layer and thus decrease the Earth's protection shield against the sun's radiation which might increase global temperatures. As a consequence, politicians are urged to reduce emissions in their countries by regulatory methods or other political tools.

A number of international environmental meetings have been arranged in order to come to an agreement about the global reduction of greenhouse gases. However, a truly effective consensus has never been reached. Some countries, especially developing countries, fear that a reduction in emissions might hamper their economic growth and their progress to become wealthy developed countries. Similarly, developed countries fear that reduced emissions will slow down their economies and decrease their wealth. Therefore, general international agreements about emission reductions have been negatively influenced by fear of reduced growth or wealth.

It is the purpose of this paper to investigate the relationship between economic growth and emissions, and how this relationship differs among countries, in particular between developing and developed countries. The EKC will be used as theoretical foundation to examine this relationship. Thus, it shall be determined how much the idea of the EKC differs between theory and reality.

Data from ten countries are used to investigate the relationship between economic growth and emissions. Five countries (Brazil, China, India, Mexico and South Africa) represent developing countries while the other five countries (Australia, Japan, Sweden, the UK and the USA) represent developed countries. Brazil, China and India are part of a group of countries calling itself BRIC which has been characterised by its rapid economic growth over the last years. South Africa and Mexico are countries that are close to joining this group. As for the developed countries they are selected on the basis of their economic advancement and difference among each other (e.g. the USA as one of the largest polluters as opposed to Sweden which is characterised by modest amounts of emissions).

One of the limitations of this paper is that it focuses on only ten countries. The reason for this is that each country is examined separately as they are quite heterogeneous. For instance, in Australia and Japan carbon dioxide emissions have been increasing over years, while in Sweden, the UK and the USA a trend in reduced carbon dioxide emissions has been observed (Worldbank, 2012). Thus, the countries are examined separately to account for their heterogeneity. Moreover, the paper does not investigate countries defined as underdeveloped as they only have very low amounts of emissions and GDP.

In this paper, the focus lies in particular on carbon dioxide (CO_2) as it remains one of the largest pollutants of worldwide emissions. Per capita GDP shall represent economic growth or per capita income as it is defined in the EKC literature. Both variables are used to examine whether the EKC is truly inverted U-shaped as presented in the original literature, or whether the curvature takes a different shape. Afterwards, these results will be put into perspective by comparing them to another type of emission, sulphur dioxide (SO_2). While carbon dioxide might indirectly influence the wellbeing of humans, sulphur dioxide is directly damaging to human health (Clean Air Trust, 2012). Thus, differences between carbon dioxide and sulphur dioxide will be expected in the results.

Using cross-country time series data, I find that there is evidence for an inverted U-shaped EKC. However, there are also other curvatures that explain the relationship between economic growth and the amount of emissions. The results suggest that in particular linear functions might explain this relationship. In the case of carbon dioxide the relationship seems to be positive, while in the case of sulphur dioxide the majority of results tend towards a negative relationship. Despite these differences, linear functions might be considered as part of (inverted) U-shaped functions. Thus, the theory of the EKC is not completely rejected by the finding of linear functions. Altogether, the empirical results do not indicate particular differences between developing and developed countries, specifically. Differences are found between countries, but these differences apply to both developing and developed countries.

The remainder of this paper is structured as follows. Section 2 presents the theoretical background on the EKC. Section 3 identifies relevant literature and analyses problems that occur when dealing with the EKC. Section 4 introduces the empirical background and methods used in this paper, while section 5 presents the empirical results which are discussed in section 6. Section 7 will conclude.

2. Theoretical Framework

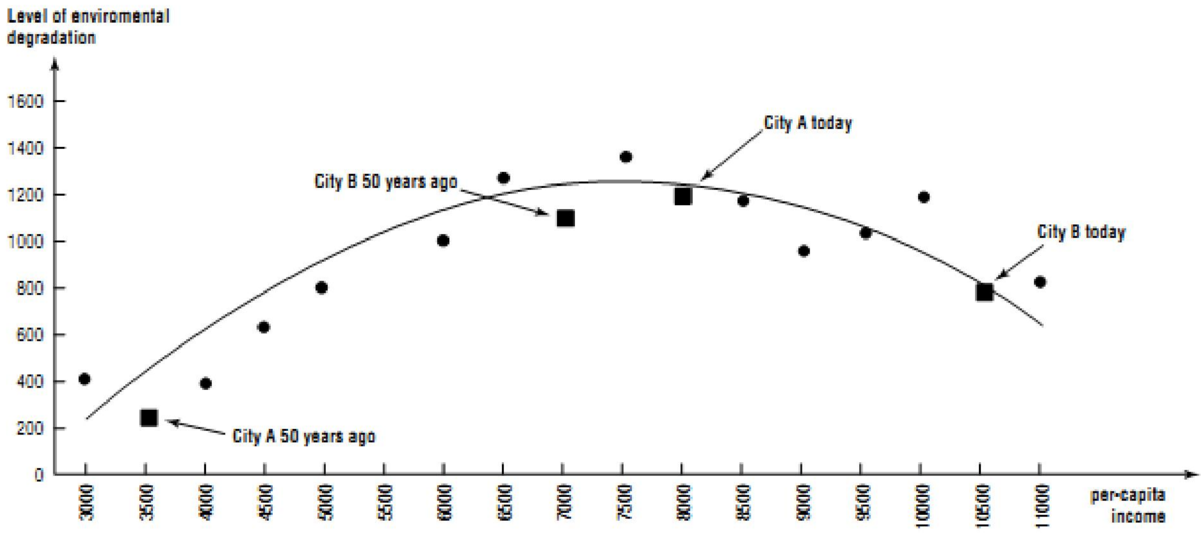
2.1. The Environmental Kuznets Curve

The original Kuznets Curve was discovered by Simon Kuznets in 1955 and describes the relationship between economic growth and income inequality. Kuznets (1955) found out that the relationship is characterised by an inverted U-shaped curve. In other words, a poor country with little economic growth faces rising inequality. However, when the country has reached a certain limit of development, inequality will decrease as the rising wealth of the country is hypothesised to increase the standard of the population on several levels.

It was Grossman and Krueger (1991) who discovered that the Kuznets Curve can also be transferred to environmental issues. They argue that the same inverted U-shaped curve can be applied to the relationship between per capita income and environmental degradation, where environmental degradation may mean anything from waste disposal to water pollution. Similarly to the Kuznets Curve, the Environmental Kuznets Curve increases with low per capita income (i.e. low development) and decreases with high per capita income (i.e. high development). In simple words, developing countries experience increasing environmental degradation while developed countries enjoy decreasing environmental degradation.

Figure 1 shows an example of the EKC. While in most cases the theory of the EKC is applied to countries, Figure 1 compares two cities with each other. In this case, city A represents an underdeveloped city with little per capita income and low environmental degradation. 50 years later, city A has developed and reached the turning point where environmental degradation decreases. To put this into perspective, there is city B which used to be quite developed 50 years ago and has advanced on the EKC to a point where per capita income is high and environmental degradation is decreasing.

Figure 1: An Example of the Environmental Kuznets Curve



Source: Lahiri (2008)

In the last years the EKC gained particular attention when the international community became aware that the global climate might be changing. Consequently, the literature on the EKC increased vehemently, as the relationship between economic growth and especially emissions became of particular interest for the research of the climate change. After all, if the theory of the EKC were correct, everything would be solved on its own. The only thing that countries had to do would be to ensure that they keep growing which would ultimately decrease their emissions automatically.

The curvature of the EKC can be explained by several factors. One of them is the scale effect which explains the increasing part of the EKC (see e.g. Dinda, 2004). As the economy is growing, more inputs are needed for production which in turn increases the output of bads, e.g. waste and emissions which ultimately influence environmental degradation. The growth of the economy (and thus the growth of income) also influences patterns of production and technology which might reduce environmental degradation due to the use of environmental friendly technology. Thus, the shape of the EKC is explained firstly by the scale effect which describes the positive slope of the EKC, and secondly, by the technology effect which describes the turning point and the negative slope of the EKC.

The scale and technology effects, however, are not the only effects that explain the inverted U-shape of the EKC. One might simply think of levels of income, wealth or development which can affect emissions. With low income people put very low value on environmental quality. They are more concerned about their own standard of living and try to increase their own income and wealth. Hence, they accept jobs that might be highly damaging to the environment in order to secure basic needs, such as money, food and shelter. But as soon as they have acquired a secure basis for living and their income and wealth are increasing, they will start to improve their standard by looking beyond their basic needs. They will start to become more selective, putting higher value on other things which might include environmental quality. As a consequence, they might get more selective about their employment and the way their firm handles environmental issues. Furthermore, if the number of people that appreciates environmental quality highly is rising they are able to put pressure on politicians in order to increase environmental standards and decrease environmental degradation. A change in the legal framework is likely to follow. Thus, the income effect will result in a political effect that might just as well explain the reduction of environmental degradation with rising income. In the literature this effect is often referred to as the regulation or regulatory effect (see Dinda, 2004).

Stern (2004) offers two other effects as explanation for the inverted U-shape of the EKC: the effects of the input and output mix. The output mix is based on institutional economics. In early stages of development the economy basically consists of the primary sector. Agricultural work results in low income and mostly low environmental degradation. However, as soon as the country is developing, the economy shifts from agricultural to industrial work, the secondary sector. Income in the industry sector is usually higher than in the agricultural sector but the output of the industry sector will also require higher levels of emissions, for instance. Only when the economy has shifted to the third sector, the service sector, will emissions decrease as the output mix changes from manufactured goods to service goods. Similarly, the input mix effect follows a related line of argument as the output mix effect. While inputs in the agricultural sector are little damaging to the environment, they will be highly damaging in the industry sector, and again less damaging in the service sector. Thus, the substitution of inputs and outputs might play a large role in explaining the EKC.

Lastly, globalisation and trade effects might offer further explanations for the shape of the EKC. As the world is characterised by a variety of countries with different levels of development, developed countries are able to outsource environmental degradation to less developed countries. This is possible in a number of ways and because of several reasons. It is possible to outsource environmental degradation by reallocating enterprises or parts of enterprises that are environmentally damaging to less developed countries; and it is possible to outsource environmental degradation, in particular emissions, by legal means such as emission trading to pollution havens which are usually poor countries with weak regulations (see Dinda, 2004). To be able to outsource environmental degradation is mainly possible because of the aforementioned reasons. Developing countries might value environmental quality less because basic needs are more important to them. Consequently, their environmental legal framework is weak which allows enterprises with high pollution to reallocate or outsource to these countries. Thus, globalisation will make it possible for developed countries to decrease environmental degradation while developing countries are forced to increase environmental degradation. This effect would explain exactly the inverted U-shape of the EKC (see Dinda, 2004).

2.2. The Shape of the Environmental Kuznets Curve

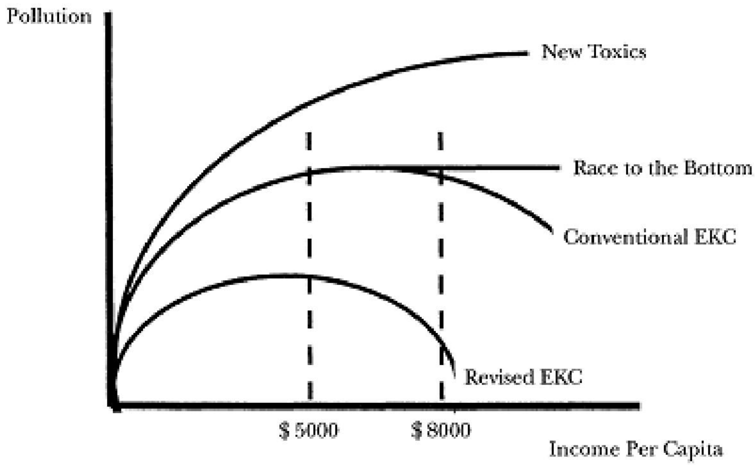
The theory of the EKC has attracted a number of critiques since its occurrence in the scientific literature. The fact that economic growth will ultimately take care of environmental problems seems to be counterintuitive to many people. Economic growth is often associated with greater economic activity, i.e. increased production which in turn increases the utilisation of, perhaps, rare resources for inputs. Moreover, increased economic activity might increase negative externalities such as waste accumulation, emissions and pollution in general. The arguments that wealthier countries value environmental quality higher and that wealthier countries are able to invest more into environmental friendly technology, appear not to convince everybody. As a result, a number of authors have deepened the research on the EKC in order to determine whether the function is truly inverted U-shaped.

The first paper that seems to contradict the theory of an inverted U-shaped EKC is actually the paper that discovered the EKC. Grossman and Krueger (1991) find that "[…] for two pollutants […] concentration increases with per capita GDP at low levels of national income, but decrease with GDP growth at higher levels of income." However, when looking closely at the graphs of those two pollutants, another turning point appears with even higher levels of income, indicating N-shaped functions. Moreover, for suspended particles they find a tentative U-shaped function, indicating that the theory of an inverted U-shaped function might not apply to all types of emissions and environmental degradation.

A number of other authors argue along similar lines, that the inverted U-shape of the EKC only holds for some types of emissions. Cole et al. (1997) state that "[…] meaningful EKCs exist only for local air pollutants whilst indicators with a more global, or indirect, impact either increase monotonically with income or else have predicted turning points at high per capita income levels with high standard errors […]." Similarly, Lipford and Yandle (2010) find ambiguous results when examining the shape of the EKC. For developed countries, they find N-shaped relationships between per capita GDP and carbon dioxide emissions. For developing countries, they only find an N-shaped relationship for China while the relationship is linear or quadratic for other developing countries.

A literature review by Stern (2004) concludes: "[…] the statistical analysis on which the environmental Kuznets curve is based is not robust. There is little evidence for a common inverted U-shaped pathway that countries follow as their income rises. […] It seems unlikely that the EKC is an adequate model of emissions or concentrations." Indeed, Stern (2004) suggests that the true shape of the EKC might be a mix of the "new toxics" EKC and "revised EKC" proposed by Dasgupta et al. (2002) as shown in Figure 2.

Figure 2: Different Scenarios for the EKC



Source: Dasgupta et al. (2002)

Figure 2 presents different scenarios for the EKC. The common inverted U-shaped EKC is labelled as "conventional EKC". The "race to the bottom" curve offers a new scenario in which there is no longer one turning point but instead the curve is first rising and finally levelling out horizontally. This curve is based on globalisation and trade theory, where the race to the bottom refers to the bottom in the sense of environmental standards (Dasgupta et al., 2002). According to this scenario, enterprises with high pollution are forced to relocate in developing countries as high environmental legal standards and thus high costs are burdened on them in developed countries. Due to the outflow of productivity and capital, however, developed countries face reductions on several levels (e.g. employment, income, etc.). These reductions put pressure on politicians which in turn will be forced to reduce the high environmental legal standards. As this effect is taken up by more and more countries, the general effect will not be a reduction in pollution but a continually high level of pollution. Thus, the scenario of the race to the bottom explains a world where the population will trade off high environmental quality for wealth.

The "new toxics" curve is more or less based on the substitution effect. The theory is that enterprises are able to substitute common pollutants that are heavily regulated and thus costly to emit, with other pollutants. In the end, pollution might increase because larger amounts of new emissions occur than it was the case when common emissions were produced. Hence, the "new toxic" curve is monotonically rising. However, Stern (2004) appears not to be convinced about this curve as there has been little empirical evidence so far.

The last curve of Figure 2, the "revised EKC", seems to propose a scenario with which both Stern (2004) and Dasgupta et al. (2002) appear to agree. Again, the curve indicates an inverted U-shaped function as was the case with the original EKC. However, it reaches much lower levels of pollution or environmental degradation, as its turning point shifts to the left and downwards. The argument is that nowadays developing countries might benefit from the experience from developed countries. Developing countries experience a learning effect that is based on legal regulations and technology. As developed countries set high standards of environmental protection, developing countries can do so as well since pollutants might still relocate in developing countries if developing countries set slightly lower standards of environmental protection than developed countries. As for technology, developing countries benefit from more advanced machinery than it had been the case when developed countries were still developing countries. Both effects lead to decreased environmental degradation which results in a flatter curve that reaches its turning point well before previously estimated. Similarly, some authors argue that developing countries might use a shortcut through the EKC which is based on the same argumentation as that used for the "revised EKC"; i.e. developing countries benefit from high levels of environmental regulation in developed countries, and from the diffusion of environmental friendly technology (see Stern, 2002, and Dinda, 2004).

The possibility of N-shaped EKCs that increase with low levels of income, decrease with middle levels of income and increase again with high levels of income has been discussed in recent years as well, but seems to have a hard stance in the EKC literature. Despite the appearance of N-shaped EKCs in Grossman and Krueger (1991) they mostly ignore the second turning point at higher income levels. Other papers do not observe a second turning point as they simply assume that the EKC is inverted U-shaped. While their functions therefore include quadratic terms, cubic terms are disregarded ceteris paribus.

Goklany (1999) was one of the authors who specifically investigated cubic functions. His idea conforms at first with the theory of the original EKC. At the beginning, pollution in countries with little income increases because people value basic needs that might be environmentally degrading higher than environmental quality. As their income rises, environmental quality becomes more important to them, which in turn decreases pollution due to several effects (e.g. technology diffusion, political pressure, legal regulations). However, the trend does not stop there. Goklany (1999) argues that another turning point will appear with even higher income because the society has not considered the amount of costs associated with environmental protection. As environmental protection increases in one country, pollutants will relocate in countries with lower standards of environmental protection. This will increase the outflow of labour and capital which in turn has an effect on the country with high levels of environmental protection. As a result, the country will either decrease its level of environmental protection in order to stop the outflow of capital (and ultimately wealth), or it will reduce its research in innovative, environmental friendly technology which might be too costly to carry on. Both policies will increase the level of environmental degradation which results in an N-shaped EKC.

The literature taking account of a possibly cubic function usually finds N-shaped EKCs. Lipford and Yandle (2010) find N-shaped functions for the G8 countries (except Russia) and China, while the function is either linear or quadratic for Brazil, Russia, India, Mexico and

South Africa. Similarly, Canas et al. (2003) find N-shaped functions for industrialised countries, even though they also support inverted U-shaped functions.

3. Literature Review

3.1. Previous Research

Table 1 presents an overview on a selection of relevant literature covering the analysis of the EKC. In some cases the turning points are not exact as they vary between models and years, for instance. Consequently, an approximate value is given for the turning point.

Table 1: Literature on the EKC

Authors	Dependent variables	Explanatory variables	Time	Countries	Turning points	Shape	Functional form
Cole et al. (1997)	CO CO_2 NO_2 SO_2 Susp. partic.	p.c. GDP, exogenous variables	1960 – 1992	Up to 88 countries	9,900 62,700 14,700 6,900 7,300	Inv. U Inv. U Inv. U Inv. U Inv. U	Quadratic logs
Grossman and Krueger (1991)	Fine smoke SO_2 Susp. partic.	p.c. GDP, location, pop. density, gvmt.	1977, 1982, 1988	Up to 42 countries	5,000 4,000 9,000	Inv. U (N) Inv. U (N) Decreasing	Cubic
Holtz-Eakin and Selden (1995)	CO_2	p.c. GDP, fixed effects	1951 – 1986	130 countries	35,400 (8 million)	Inv. U	Quadratic (logs)
Kaufmann et al. (1998)	SO_2	p.c. GDP, economic activity, exports, time	1974 – 1989	23 countries	12,500	U	Quadratic
Lipford and Yandle (2010)	CO_2	p.c. GDP	1950 – 2004	G8 (exc. RUS) RUS, BRA,IND China MEX, SAF	Not reported Not reported Not reported Not reported	N Increasing N Inv. U	Cubed Linear Cubed Quadratic
Magnani (2001)	CO_2 N_2O SO_x	p.c. GDP, time	1970, 1975, 1980, 1985, 1990	152 countries	not reported 11,000 10,000	N N N	Cubic
Panayotou (1997)	SO_2	p.c. GDP, pop. density, p.c. GDP, policy, econ. activity	1982 – 1994	30 countries	5,000	Inv. U	Cubic
Selden and Song (1994)	CO NO_x SO_2 Susp. partic.	p.c. GDP, population density	1979 – 1987	22 OECD and 8 developing countries	19,000 21,700 10,600 9,600	Inv. U Inv. U Inv. U Inv. U	Quadratic
Shafik and Bandyopadhyay (1992)	SO_2 p.c. carbon Susp. partic.	p.c. income, time	1960 – 1990	Up to 149 countries	3,700 7,000,000 3,300	Inv. U Increasing Inv. U	Linear, quadratic, cubic
Stern and Common (2001)	Sulphur	p.c. GDP	1960 – 1990	OECD Non-OECD World	9,200 908,000 101,00	Inv. U Inv. U Inv. U	Quadratic logs
Torras and Boyce (1998)	SO_2 Fine smoke Susp. partic.	p.c. income, inc. inequ., literacy rate, political rights, location	1977 – 1991	Up to 42 countries	4,000 (15,000) 4,000 (15,000) Not reported	Inv. U (N) Inv. U (N) Inv. N	Cubic

Note: Turning points in 1985 USD of per capita GDP.

As mentioned before, Grossman and Krueger (1991) were the first to investigate the EKC which is based on the Kuznets curve originally described by Kuznets (1955). In their paper they examine the effect of economic growth on sulphur dioxide, fine smoke and suspended particles. Using the Global Environment Monitoring System (GEMS) dataset that covers the years 1977, 1982 and 1988, they apply a cross-section analysis focussing on urban areas in 42 countries. They find an inverted U-curve for sulphur dioxide and fine smoke with respect to national income. For the third emission, suspended particles, the curve is monotonically decreasing. However, their graphs appear to show another turning point with very high income, indicating a N-shaped curve for sulphur dioxide and fine smoke, and a tentative U-shaped curve for suspended particles.

Selden and Song (1994) extended the research on the EKC by examining four emissions: sulphur dioxide, suspended particles, nitrogen oxide and carbon monoxide. Using the same cross-national panel data from GEMS with a focus on developed countries, they find an inverted U-shaped curve for the relationship between economic development and all four emissions, thus confirming the shape of the EKC. However, unlike Grossman and Krueger they did not add cubic variables for per capita GDP in their regression which might explain the differences in the results between the two papers. Furthermore, contrary to Grossman and Krueger who estimate the turning points between approximately 4,000 USD and 5,000 USD of per capita GDP (based on 1985 USD) for sulphur dioxide and fine smoke, they calculate the turning points for several types of emission at much higher levels of income, all well above 8,000 USD. That is, in their model countries have to get wealthier until they reach the turning point where emissions will decrease. Moreover, they predict that emissions will rise despite their finding of an inverted U-shaped EKC, as there are quite a number of countries that are far from the turning point they calculated in their paper.

A similar conclusion has been drawn by Holtz-Eakin and Selden (1995). They argue that emissions will keep growing because many developing countries experience growth in both output and population which will increase their necessity to emit. Focussing on the relationship between economic development and carbon dioxide, they adopt a panel data regression from 130 countries covering a timeframe from 1951 till 1986. Analogue to Grossman and Krueger (1991), and Selden and Song (1994) they find an inverted U-shape of the EKC, however neglect the possibility of cubic variables in their regressions.

Cole et al. (1997) continue the trend to use cross-country panel data, with the distinction that they look at a wide variety of emissions that range from the aforementioned emissions to municipal waste, energy consumption and traffic volumes. In contrast to other studies which rely solely on ordinary least squares (OLS) regressions, they apply generalised least squares (GLS) regressions to account for heteroscedasticity. As most other studies they utilise a squared function, arguing that a cubic function might turn to infinity which would be unrealistic when examining the relationship between economic growth and emissions. Using data from 11 OECD countries from 1970 till 1992, they confirm the inverted U-shaped EKC, calculating a turning point (6,900 USD of per capita income for sulphur dioxide) that lies between Grossman and Krueger (1991) and Selden and Song (1994). However, they find that the EKC only exists for local air pollutants. Other emissions that have a global impact (such as carbon dioxide) show monotonically increasing functions with respect to economic growth.

3.2. Issues in the Literature on the Environmental Kuznets Curve

As the aforementioned literature differs in their use and calculation of data it is difficult to compare them and come to a conclusion with respect to the true shape of the EKC and whether it is empirically founded. Structurally, they differ in the databases they use, as well as in the observed timeframe, the analysed countries and their level of development. It might be quite realistic that developed countries have a turning point that occurs at higher levels of income as they are the countries that had to invent environmental friendly technology in the first place. Developing countries might benefit from these inventions and acquire them sooner than when developed countries had a similar level of development. Thus, developing countries might be able to reach the turning point sooner than developed countries.

Another problem that arises is the functional form of the regression. As outlined above, there seems to be disagreement about whether to use linear, quadratic or cubic functions. As the theory of the EKC is based on an inverted U-shaped curve only, many studies simply utilise quadratic functions. A justified argument proposed by Cole et al. (1997) points out that functions going to infinity might be unrealistic when examining the relationship between economic growth and emissions. Obviously, the extreme scenarios of zero or infinitely large levels of emissions seem to be quite implausible.

Empirically, the studies appear to suffer from lack of data, in most cases. Samples with observations below 100 rise concerns about validity. Furthermore, empirical problems such as heteroscedasticity and autocorrelation seem to be largely ignored which raises further doubts about the results. Among the presented literature only Cole et al. (1997) take account of heteroscedasticity by utilising GLS. Moreover, the case of omitted variables seems to be neglected on a large scale. Holtz-Eakin and Selden (1995) explain the exclusion of all explanatory variables except per capita GDP by arguing that the left-out variables might be correlated with per capita GDP which would bias the results and render them inconsistent.

4. Empirical Framework

As the literature on the EKC seems to be in disagreement about the shape of the EKC and about the relationship between economic growth and environmental degradation, I will present my own empirical analysis in this paper. The empirical analysis is presented in the following paragraphs and sections, and focuses on the shape of the EKC, the calculated turning points and how they change when additional variables are added. Moreover, the results of two types of emissions, carbon dioxide and sulphur dioxide, will be compared.

4.1. Data

As the interest of this paper is to critically analyse the EKC, the main focus of the analysis lies on the two variables which are originally presented by Kuznets (1955), and Grossman and Krueger (1991): per capita income and environmental degradation. Per capita income is often synonymously used for economic growth or economic development or simply wealth, and shall be proxied by the variable "per capita GDP" in this paper. Environmental degradation, interchangeably with pollution and various types of pollution (e.g. emissions, water pollution, waster accumulation, etc.), shall be represented by the variable "per capita CO_2". As a comparison, the same empirical analysis will be applied to another type of emission, sulphur dioxide, in order to put all the results into perspective.

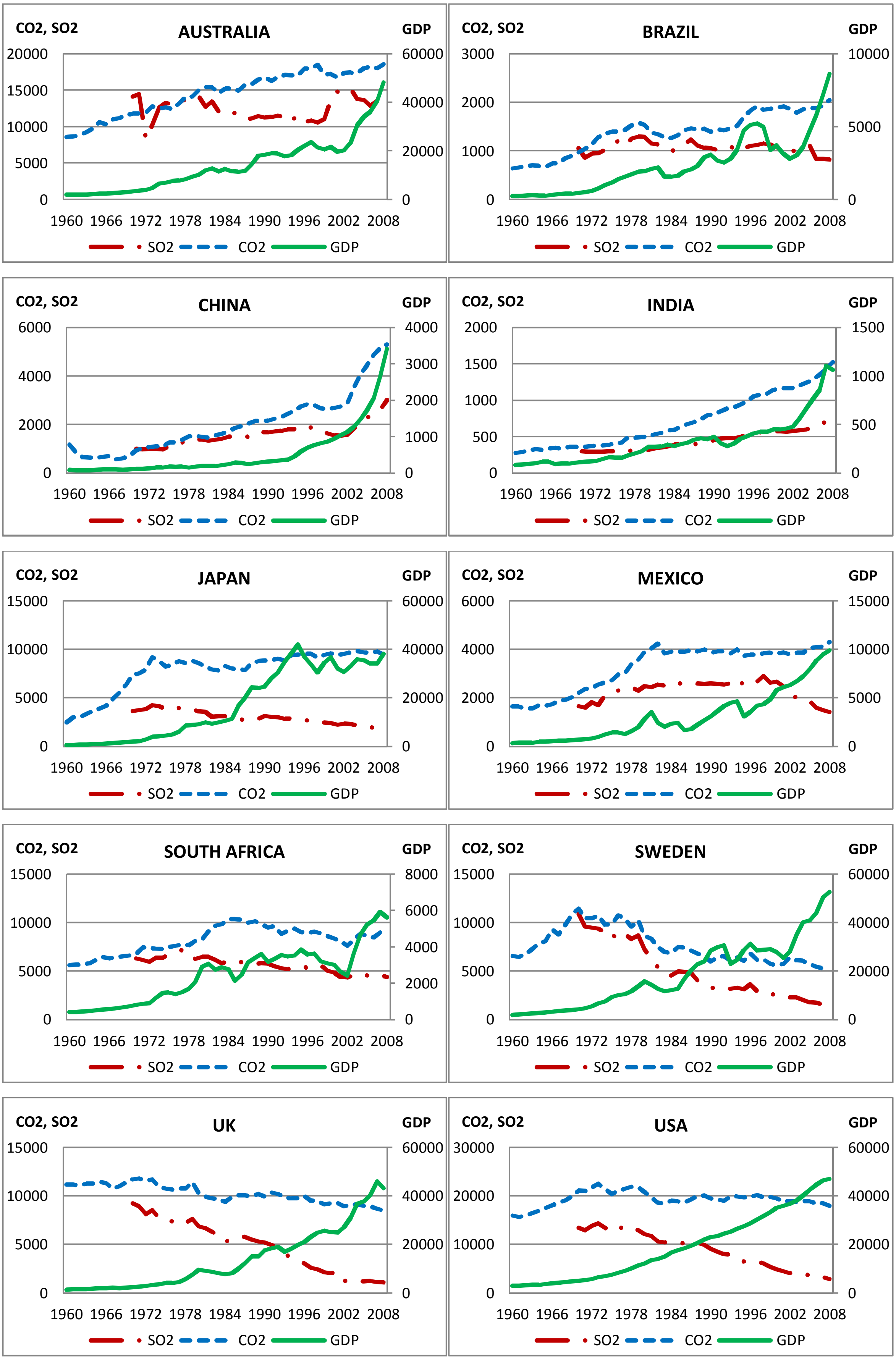
The choice to focus mainly on carbon dioxide as proxy for emissions is based on the fact that it is seen as one of the largest pollutants contributing to global warming. Furthermore, it is emitted in high, countable quantities, which makes an analysis simpler. Thus, due to the damage carbon dioxide can inflict many countries trace the emissions of carbon dioxide nowadays in regular intervals (contrary to other types of emissions) which allows for more reliability, validity and comparability of the data.

Sulphur dioxide is a type of emission that is emitted in lower quantities than carbon dioxide but still contributes on a significant scale to the range of emissions which influence the global atmosphere. Unlike carbon dioxide it is not classified as a greenhouse gas but is still considered as an air pollutant that is produced in particular by the industry, and contributes to the formation of acid rain (Clean Air Trust, 2012). Sulphur dioxide is used as a comparison to carbon dioxide as some authors argue that specifically carbon dioxide has a different relationship to economic growth than other emissions. For instance, Cole et al. (1997) observe a monotonically increasing relationship between carbon dioxide and income, a relationship that one would expect for all types of emissions at first thought. Therefore, a comparison with sulphur dioxide will be presented later in this paper.

The data for most of the variables are retrieved from the databases of the Worldbank, excluding data for sulphur dioxide which is retrieved from EDGAR, the European Database for Global Atmospheric Research. Observations are made for ten countries: Australia, Brazil, China, India, Japan, Mexico, South Africa, Sweden, the UK and the USA. Australia, Japan, Sweden, the UK and the USA represent developed countries from all around the world, while Brazil, China, India, Mexico and South Africa represent developing countries with an equal global representation. Furthermore, Brazil, China and India are part of the country union calling itself BRIC which is known for its advanced development. South Africa and Mexico are countries which are on the verge of receiving the same status as the BRIC countries regarding economic development. Data from low developed countries is not considered as they both emit and grow little which would contribute little to this analysis.

It is the intent of the author to use data from these ten countries and look at the effects of economic growth on carbon dioxide and sulphur dioxide for each country. This is founded on the argument that different characteristics and trends are observed among the countries, even if they were divided and pooled into developed and developing countries. For instance, carbon dioxide emissions have been decreasing over the years in Sweden, the UK and the USA while the opposite has been observed for Australia and Japan (see Figure 3). Thus, the β-coefficients can be interpreted for each country, as opposed to when using aggregated panel data, which is a method many authors seem to prefer when analysing the EKC.

Figure 3: CO_2, SO_2 and GDP per capita, 1960-2008



Note: CO2 in kg per capita. SO2 in kg per capita, multiplied by 100. GDP in current USD per capita.

The total period of observations covers a timeframe of 49 years, from 1960 till 2008. However, the data are not complete and unfortunately differ among the variables and sources. Data from the Worldbank usually cover the years 1960 till 2008 in the case of per capita GDP and per capita carbon dioxide. The data from EDGAR cover a timeframe from 1970 till 2008, thus 39 years for all ten countries and sulphur dioxide.

The two variables which will be included in the second model (FDI and technology) differ largely in their availability, so that often many years have to be dropped due to lack of data. FDI is measured in net inflows and current USD (i.e. 2012), while the level of technology is determined by the high-technology exports of a country, in current USD (i.e. 2012). Both FDI and technology are included in the expanded model as they are expected to have an effect on the amount of emissions. For instance, the variable technology is assumed to affect emissions negatively, as technology is considered to improve the efficiency and quality of machinery and thus reduce the amount of emissions. The effect of FDI is ambiguous yet. On the one hand, FDI might improve technology which would lead to reduced emissions. On the other hand, FDI might increase economic activity, and thus increase emissions.

Table 2: Descriptive Statistics

Variable	Unit	Time	Source	Expected Sign	Description
CO2	kg p.c.	1960-2008	Worldbank	Dependent variable	"Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring." (Worldbank, 2012)
SO2	kg p.c.	1970-2008	EDGAR	Dependent variable	SO2 is produced from public electricity and heat production, energy and manufacturing industries, construction, domestic aviation, road and rail and other transportation, inland navigation, residential and other sectors, fugitive emissions from oil and gas, production of chemicals and metals and pulp/paper/food/drink, savannah and agricultural waste burning, forest and grassland and fossil fuel fires, waste incineration
GDP	2012 USD p.c.	1960-2008	Worldbank	+	"GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources." (Worldbank, 2012)
FDI	2012 USD	Approx. 1988-2008	Worldbank	+ / -	"Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors." (Worldbank, 2012)
TECH	2012 USD	Approx. 1988-2008	Worldbank	-	"High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery." (Worldbank, 2012)

4.2. Methodology

The basic point-of-departure function describing the EKC is of quadratic form:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \beta_2 x_{it}^2 + \varepsilon_{it} \quad (1)$$

where y corresponds to environmental degradation and x corresponds to income for country i in year t. Both variables are calculated on per capita basis. ε is the error term.

In many cases, natural logarithms (*ln*) are used for simplification of the regression. Furthermore, a vector of exogenous explanatory variables (X_{it}) that might influence the dependent variable, y_{it}, is included to take account of omitted variable bias and avoid inconsistent and biased results. This vector often differs among authors, in the sense that different variables are included into it. Typical examples are population density (Selden and Song, 1994), trade intensity and the level of technology (Cole et al., 1997).

In this paper X_{it} will be neglected in the first model and included in the second model in the form of two variables that are added to the regression simultaneously. The variables representing X_{it} are foreign direct investment (FDI) and technology, as both are expected to have an effect on emissions. As explained in the theoretical part of this paper, a certain technology effect might exist, which influences the EKC in such a way that the curve slopes downwards. Including the variable technology into a regression is thus expected to have a negative effect on the amount of emissions. The variable FDI was chosen on the basis that its effect on emissions is at first glance not totally clear. FDI might decrease the amount of emissions if it supports technological advancement but it also might increase the amount of emissions if it promotes economic activity.

Many authors use panel data regressions in order to analyse the EKC. The advantage of panel data is that one can rely on a large number of observations, as in a panel data analysis all observations are put into one regression. On the other hand, due to the heterogeneous nature of all the aggregated data of the countries, fixed country effects have to be included. Moreover, the results can solely be interpreted in a general manner and differences between countries cannot be analysed. That being the case, this paper does not implement panel data regressions. Instead, three different types of functions are regressed separately on each of the ten countries. The advantage of this method is that it is more flexible regarding the estimation of the coefficients. With this method one can interpret the coefficient of every single country, whereas in a panel data regression one is restricted to a general interpretation of all countries combined. Thus, this method takes care of the heterogeneity of all observed countries. Intercepts for country effects are therefore not needed and dropped out of the regression. By contrast, a major disadvantage of this method is the small number of observations for each country.

The three point-of-departure regressions used in this paper are thus:

$$ln(y_{it}) = \beta_0 + \beta_1 ln(x_{it}) + \varepsilon_{it} \quad (2)$$

$$ln(y_{it}) = \beta_0 + \beta_1 ln(x_{it}) + \beta_2 ln(x_{it})^2 + \varepsilon_{it} \quad (3)$$

$$ln(y_{it}) = \beta_0 + \beta_1 ln(x_{it}) + \beta_2 ln(x_{it})^2 + \beta_3 ln(x_{it})^3 + \varepsilon_{it} \quad (4)$$

where (2) is linear, (3) quadratic, and (4) cubic in their nature.

Equations (2), (3) and (4) serve as basis for the first model. Afterwards, all three equations will be expanded by two additional variables, FDI and technology. Unfortunately, the data provided by the Worldbank defines FDI in terms of net inflows. It thus happens that there are some negative values of FDI and consequently, logarithms of both additional variables cannot be taken. Both models are applied to both carbon dioxide and sulphur dioxide. To give an example, the regression including linear, quadratic and cubic terms for per capita GDP, and all additional variables, has the following form in the case of per capita carbon dioxide:

$$ln(CO2_{it}) = \beta_0 + \beta_1 ln(GDP_{it}) + \beta_2 ln(GDP_{it})^2 + \beta_3 ln(GDP_{it})^3 + \\ + \beta_4(FDI_{it}) + \beta_5(TECH_t) + \varepsilon_{it} \quad (5)$$

In order to determine the shape of the EKC, one has to look at the sign of the coefficients (see e.g. Dinda, 2004). As equation (4) contains most coefficients and variables the following interpretation will focus on the cubic function. There are several possible outcomes:

1) $\beta_1 = 0 \rightarrow \beta_2 = \beta_3 = 0$: a linear function, or no relationship at all between CO_2 and GDP
2) $\beta_1 > 0$ and $\beta_2 = \beta_3 = 0$: a monotonic increasing function
3) $\beta_1 > 0, \beta_2 > 0 \rightarrow \beta_3 > 0$ or $\beta_3 = 0$: a monotonic increasing function
4) $\beta_1 > 0, \beta_2 < 0$ and $\beta_3 = 0$: an inverted U-shaped function

5) $\beta_1 > 0, \beta_2 < 0$ and $\beta_3 > 0$: a N-shaped function
6) $\beta_1 < 0$ and $\beta_2 = \beta_3 = 0$: a monotonic decreasing function
7) $\beta_1 < 0, \beta_2 < 0 \rightarrow \beta_3 < 0$ or $\beta_3 = 0$: a monotonic decreasing function
8) $\beta_1 < 0, \beta_2 > 0$ and $\beta_3 = 0$: a U-shaped function
9) $\beta_1 < 0, \beta_2 > 0$ and $\beta_3 < 0$: an inverted N-shaped function

A special focus lies on points 4) and 5) as they represent the case of the inverted U-shaped function, i.e. the original EKC, and the case of the N-shaped function, i.e. the modern version of the EKC. I do not expect that case 1) will appear in the forthcoming results as there certainly should be a relationship between economic growth and the level of emissions.

When analysing the results in the next section, a cautionary remark about the interpretation of the coefficients should be given to the reader. In the case that the results imply linear functions for the EKC (and I strongly suspects that such results might appear) this does not mean exclusively that the typical inverted U-shape of the EKC is rejected. On the contrary, a linear function might just represent a fraction of the whole function. If there are results that suggest a positive linear relationship between economic growth and emissions, this relationship might indeed refer to the increasing part of the inverted U-shaped function. In a similar manner, a negative relationship might refer to the declining part of the inverted U-shaped function, indicating high-income countries that have passed the turning point.

Finally, the turning point (TP) for the quadratic function is calculated by using the following formula:

$$TP = \exp\left(\frac{-\beta_1}{2\beta_2}\right) \quad (6)$$

5. Results

5.1. Carbon Dioxide

Table 3 presents the results for the effect of per capita GDP on per capita carbon dioxide. The results of all three regressions are reported in the table, including moving averages to take account of possible misspecification. Durbin-Watson, Breusch-Godfrey and Breusch-Pagan tests were conducted in order to test for autocorrelation and heteroscedasticity, respectively. As all results suffered from either autocorrelation and/or heteroscedasticity, one moving average after each other was included until no misspecification was left. All three specifications (linear, quadratic and cubic) show high values of both R^2 and adjusted R^2, indicating that the explanatory variables are well explained. Moreover, as not all results are unusually high significant and the Durbin-Watson (DW) tests are not too low, spurious regressions can be ruled out.

Table 3A: The Relationship between Carbon Dioxide and GDP

Linear	AUS	BRA	CHI	IND	JAP	MEX	SAF	SWE	UK	USA
C	7.49 (0.11)***	5.09 (0.17)***	4.58 (0.23)***	2.95 (0.28)***	7.37 (0.29)***	6.59 (0.21)***	7.72 (0.21)***	10.28 (0.42)***	9.90 (0.07)***	9.84 (0.23)***
GDP	0.23 (0.01)***	0.29 (0.02)***	0.50 (0.04)***	0.63 (0.05)***	0.17 (0.03)***	0.19 (0.02)***	0.17 (0.03)***	-0.14 (0.04)***	-0.07 (0.01)***	0.002 (0.02)
MA(1)	0.71 (0.12)***	1.10 (0.12)***	1.10 (0.09)***	1.02 (0.10)***	1.39 (0.13)***	1.20 (0.11)***	1.17 (0.14)***	0.93 (0.12)***	0.77 (0.14)***	1.43 (0.13)***
MA(2)	0.52 (0.12)***	1.08 (0.12)***	1.20 (0.05)***	0.91 (0.11)***	1.34 (0.20)***	1.18 (0.12)***	0.83 (0.20)***	1.11 (0.10)***	0.37 (0.14)**	1.23 (0.20)***
MA(3)		0.51 (0.13)***	0.78 (0.09)***	0.71 (0.10)***	1.28 (0.20)***	0.94 (0.15)***	0.74 (0.20)***	1.00 (0.09)***		1.06 (0.20)***
MA(4)					1.02 (0.19)***	1.06 (0.13)***	0.34 (0.15)**	0.62 (0.11)***		0.58 (0.14)***
MA(5)					0.38 (0.13)***	0.72 (0.11)***				
R^2	0.98	0.98	0.98	0.98	0.98	0.98	0.95	0.92	0.90	0.90
Adj. R^2	0.97	0.98	0.98	0.98	0.98	0.98	0.95	0.91	0.89	0.89
DW	1.79	1.86	1.60	1.72	2.18	1.64	1.94	1.93	1.91	1.74
Breusch Godfrey	0.99 (0.64)	2.05 (0.41)	3.26 (0.23)	2.23 (0.38)	6.65 (0.05)	5.96 (0.07)	4.51 (0.14)	0.50 (0.80)	3.48 (0.20)	0.77 (0.72)
Breusch Pagan	0.12 (0.74)	0.18 (0.67)	1.77 (0.19)	0.06 (0.81)	4.15 (0.05)	1.47 (0.23)	1.23 (0.27)	0.57 (0.45)	0.003 (0.95)	1.33 (0.25)
Quad.	**AUS**	**BRA**	**CHI**	**IND**	**JAP**	**MEX**	**SAF**	**SWE**	**UK**	**USA**
C	4.17 (0.88)***	2.44 (0.90)**	1.58 (1.07)	3.37 (1.71)**	1.02 (1.33)	-1.60 (0.97)	4.13 (1.79)**	-1.87 (2.94)	8.61 (0.42)***	2.17 (2.34)
GDP	0.97 (0.20)***	1.03 (0.25)***	1.49 (0.36)***	0.48 (0.61)	1.64 (0.30)***	2.29 (0.26)***	1.14 (0.48)**	2.51 (0.64)***	0.22 (0.09)**	1.64 (0.50)***
GDP^2	-0.04 (0.01)***	-0.05 (0.02)***	-0.08 (0.03)***	0.01 (0.05)	-0.08 (0.02)***	-0.13 (0.02)***	-0.06 (0.03)*	-0.14 (0.03)***	-0.02 (0.01)***	-0.09 (0.03)***
MA(1)	0.56 (0.13)***	1.12 (0.14)***	1.03 (0.12)***	1.02 (0.10)***	1.46 (0.09)***	1.00 (0.12)***	1.13 (0.15)***	0.91 (0.13)***	0.68 (0.14)***	1.32 (0.14)***
MA(2)	0.50 (0.13)***	1.03 (0.15)***	0.95 (0.14)***	0.91 (0.11)***	1.43 (0.13)***	0.64 (0.12)***	0.71 (0.21)***	0.55 (0.13)***	0.33 (0.13)**	1.05 (0.21)***
MA(3)		0.42 (0.14)***	0.51 (0.13)***	0.70 (0.10)***	1.38 (0.11)***		0.63 (0.21)***		-0.40 (0.15)***	0.82 (0.21)***
MA(4)					0.96 (0.05)***		0.29 (0.15)*		-0.87 (0.13)***	0.45 (0.15)***
MA(5)									-0.75 (0.12)***	
R^2	0.98	0.99	0.99	0.98	0.99	0.98	0.96	0.88	0.93	0.92
Adj. R^2	0.98	0.98	0.98	0.98	0.99	0.98	0.95	0.87	0.92	0.91
DW	1.80	1.91	1.87	1.71	2.32	1.79	1.95	1.92	1.97	1.87
Breusch Godfrey	1.22 (0.59)	1.66 (0.49)	0.37 (0.85)	2.46 (0.35)	5.62 (0.09)	2.29 (0.37)	2.69 (0.32)	6.27 (0.06)	2.40 (0.37)	0.34 (0.87)
Breusch Pagan	0.69 (0.50)	0.07 (0.93)	1.18 (0.32)	0.03 (0.97)	1.09 (0.34)	0.69 (0.50)	2.40 (0.10)	1.35 (0.27)	2.41 (0.10)	1.58 (0.22)
TP	184425	29733	11076	0	28283	6685	13360	7819	245	9055

Notes:

Values in parentheses are standard errors. Exceptions: Breusch-Godfrey and Breusch-Pagan; here values in parentheses are the respective p-values.

Stars indicate p-values.* indicates significance at 10% level, ** at 5% level, *** at 1% level.

The number of observations applies to each specification separately; i.e. the linear model has 49 observations for each country, as do the quadratic and cubic models, respectively.

TP = turning point; DW = Durbin Watson test

Table 3B: The Relationship between Carbon Dioxide and GDP

Cubic	AUS	BRA	CHI	IND	JAP	MEX	SAF	SWE	UK	USA
C	1.89 (9.43)	-1.08 (5.58)	-7.01 (5.08)	40.17 (9.80)***	-25.15 (4.71)***	-29.08 (6.98)***	2.02 (18.90)	-93.64 (23.79)***	8.79 (6.61)	-59.92 (16.34)***
GDP	1.72 (3.12)	2.53 (2.36)	5.83 (2.56)**	-19.4 (5.25)***	10.99 (1.69)***	13.28 (2.77)***	2.00 (7.70)	32.51 (7.76)***	0.17 (2.23)	21.59 (5.25)***
GDP^2	-0.12 (0.34)	-0.26 (0.33)	-0.79 (0.42)*	3.56 (0.93)***	-1.18 (0.20)***	-1.58 (0.36)***	-0.18 (1.04)	-3.39 (0.84)***	-0.01 (0.25)	-2.21 (0.56)***
GDP^3	0.003 (0.01)	0.01 (0.02)	0.04 (0.02)*	-0.21 (0.05)***	0.04 (0.01)***	0.06 (0.02)***	0.01 (0.05)	0.12 (0.03)***	-0.0001 (0.01)	0.08 (0.02)***
MA(1)	0.57 (0.13)***	1.12 (0.14)***	0.98 (0.13)***	1.02 (0.13)***	0.95 (0.13)***	1.15 (0.12)***	1.13 (0.15)***	0.74 (0.14)***	0.72 (0.15)***	1.16 (0.14)***
MA(2)	0.50 (0.13)***	1.04 (0.15)***	0.87 (0.15)***	0.73 (0.17)***	0.43 (0.13)***	1.28 (0.06)***	0.72 (0.21)***	0.40 (0.14)***	0.33 (0.15)**	0.47 (0.14)***
MA(3)		0.41 (0.14)***	0.46 (0.14)***	0.43 (0.13)***		0.62 (0.12)***	0.64 (0.22)***			
MA(4)							0.29 (0.15)*			
R^2	0.98	0.99	0.99	0.99	0.99	0.99	0.96	0.91	0.91	0.92
Adj. R^2	0.98	0.98	0.98	0.98	0.99	0.99	0.95	0.90	0.89	0.91
DW	1.80	1.96	1.89	1.84	1.89	2.01	1.95	2.07	1.93	1.77
Breusch Godfrey	1.36 (0.56)	1.07 (0.64)	0.13 (0.94)	1.64 (0.50)	5.92 (0.07)	0.19 (0.93)	2.95 (0.30)	3.37 (0.23)	2.08 (0.41)	5.86 (0.07)
Breusch Pagan	0.55 (0.65)	0.22 (0.88)	0.98 (0.41)	1.37 (0.26)	1.47 (0.23)	0.91 (0.44)	1.57 (0.21)	1.67 (0.19)	2.25 (0.10)	1.25 (0.30)
Obs.	49	49	49	49	49	49	49	49	49	49
Trend	Linear Inv. U	Linear Inv. U	Linear Inv. U, N	Linear Inv. N	Linear Inv. U, N	Linear Inv. U, N	Linear Inv. U	Linear Inv. U, N	Linear Inv. U	Inv. U N

Notes:
Values in parentheses are standard errors. Exceptions: Breusch-Godfrey and Breusch-Pagan; here values in parentheses are the respective p-values.
Stars indicate p-values.* indicates significance at 10% level, ** at 5% level, *** at 1% level.
The number of observations applies to each specification separately; i.e. the linear model has 49 observations for each country, as do the quadratic and cubic models, respectively.
TP = turning point; DW = Durbin Watson test

In most cases, both the R^2 and adjusted R^2 increase gradually from the linear to the quadratic and cubic specification, indicating that quadratic and cubic functions might fit better than the linear function. In spite of this, this does not mean rejection of the linear specification as the R^2 and adjusted R^2 are still quite high for the linear specification. Two exceptions in this trend are Sweden and the UK. In the case of Sweden, the R^2 and adjusted R^2 are relatively low for the quadratic specification, compared to the linear and cubic specifications. Possibly, the quadratic function does not fit so well to Sweden's case than other functions. In the case of the UK, the R^2 and adjusted R^2 are lower for the cubic specification, indicating that the cubic function does not fit so well to the UK than other functions. Despite the relative small differences of the R^2 and adjusted R^2 between all specifications, this might give a first trend that quadratic and cubic functions might fit slightly better to most of the observed countries.

Significance levels in the linear model are on a general level very high and thus a linear relationship between carbon dioxide and GDP can be fitted to all countries. An exemption is the USA where the coefficient for GDP is insignificant, suggesting a non-linear relationship.

This is somewhat in accordance with Figure 3. Looking at the development of carbon dioxide in the USA, one is inclined to detect a tentative inverted U-shaped function of carbon dioxide that is not linear as a whole.

While most of the coefficients are positive, indicating rising levels of carbon dioxide with rising levels of GDP, this does not hold in the case of Sweden and the UK. For both countries the coefficients are negative, indicating decreasing levels of carbon dioxide with rising levels of GDP. Thus, while all developing countries, as well as Australia and Japan, appear to emit more the more they are growing on an economic level, Sweden's and the UK's carbon dioxide emissions seem to decrease with increasing economic growth. That being so, it is possible that Sweden's and the UK's relationship between economic growth and emissions might be shaped by the EKC after all, where both countries have already passed the turning point. Comparing these results to Figure 3, there seems to be indeed an inverted U-shaped curve when looking at Sweden's development of carbon dioxide. However, such a trend is more difficult to discern in the case of the UK where there appears to be a linear, decreasing development of carbon dioxide.

Looking at the quadratic regressions significance levels appear to be decreasing for all countries involved. Only for Australia, Brazil, South Africa and the UK are the coefficients significant for all variables. For all other countries, either the intercept or the GDP variables are insignificant. For those countries where all coefficients are significant, however, an inverted U-shaped relationship between carbon dioxide and economic growth is observed, thus confirming the existence of the EKC for at least a handful of countries. Be that as it may, rejecting the EKC on basis of insignificant intercepts might be a bit too harsh. Of course, significant intercepts contribute to a perfect model but in our case, we are more interested in the relationship between GDP and emissions. Under these circumstances, EKCs are observed for all countries with the exemption of India. Hence, the results seem to confirm the inverted U-shape of the EKC strongly, when ignoring insignificant intercepts.

The turning points differ largely for all countries. The lowest turning points are calculated for the UK, at 245 USD of per capita GDP, and for Mexico at 6,685 USD. The highest turning points are observed for Australia, accumulating 184,425 USD, and for Brazil accumulating 29,733 USD. Since both the highest and lowest turning points apply to both developed and developing countries, no difference for these two types of country groups can be determined.

Thus, the theory that developed countries might benefit from the experience of developing countries and therefore reach their turning point at an earlier stage (see “revised EKC” in Figure 2) is not supported at all by these results.

Results suggesting a N-shaped curve apply to six out of the ten analysed countries: China, India, Japan, Mexico, Sweden and the USA. In the case of India, the curve is inverse N-shaped, indicating decreasing, increasing and decreasing amounts of carbon dioxide with increasing economic growth. Like in the case of the linear and quadratic specification, differences between developing and developed countries do not seem apparent, as the N-shaped curve can be observed for both developing and developed countries.

Altogether, the results indicate a variety of differences for the countries observed in this study. Different shapes of curves can be inferred from the results for all countries, and there is no trend that developing countries follow a different path than developed countries. What nearly all countries have in common is a linear positive relationship between carbon dioxide and economic growth. Additionally, the inverted U-shape seems to apply to most countries if one ignores insignificant intercepts. And yet, even if one accepts only perfect models where all coefficients and the intercept are significant, these results do not mean that the theory of the EKC may be rejected. In that case, the high significance of the linear model might imply that some countries might not have reached the turning point yet or already have passed it, hinting towards an inverted U-shaped function.

In order to determine whether other variables influence the output of carbon dioxide and thus the curvature of the EKC, two other variables, FDI and technology, are included in the second model. However, including these two variables seems to worsen the results on several levels. Firstly, the R^2 and adjusted R^2 terms decrease for all specifications, indicating less explanation of the specifications by the explanatory variables. Secondly, some results suffer from autocorrelation which cannot be corrected for by including moving averages, autoregressive terms or time lags. And thirdly, the level of significance has dropped dramatically for all specifications. Consequently, for some countries neither the linear model, nor the quadratic or cubic models seem to fit.

Several explanations offer themselves for the reduced validity of the second model due to the inclusion of further variables. To begin with, the number of observations decreases by over one half between model 1 and model 2. Hence, lack of observations raises doubts about the relevance and significance of the results in model 2. Also, as mentioned above, in some cases the net inflows of FDI are negative which leads to a drop of the natural logarithms for both FDI and technology. Implementing a model that includes logarithms for some variables and excludes them for others might lead to results that are indeed difficult to interpret. One could, of course, drop the logarithms for all variables, but Stern (2004) argues that the inclusion of logarithms for emissions and GDP is necessary as it would be unrealistic to allow these indicators to become zero or negative. Thus, the exclusion of logarithms might hamper the interpretation of results.

A problem that emerged during the implementation of the regression and which might hint to another explanation for the low validity of the results is multicollinearity. In this case, there might be a high correlation between all the explanatory variables. For instance, FDI might be highly correlated with GDP, as positive inflows of FDI are expected to increase the GDP. Likewise large exports of technology would increase the GDP. According to Verbeek (2008), the problem of multicollinearity might only be solved by including further information into the regression and thus increase the variance of the variables. As no further data is available and dropping the two variables FDI and technology would lead to the original results in model 1, adjustments for multicollinearity are not possible. Hence, the results will not be reported here as they suffer from several empirical problems. Moreover, I refrain from including additional variables in the next section where sulphur dioxide will be analysed, as the model would suffer from similar problems.

5.2. Sulphur Dioxide

Table 4 shows the relationship between per capita sulphur dioxide and per capita GDP. Except for the results for the Australian quadratic specification, there are no cases of either autocorrelation or heteroscedasticity. Like in the previous output, the R^2 and adjusted R^2 are high in most cases, indicating good explanation of the explanatory variables. Again, both the R^2 and adjusted R^2 seem to increase the more explanatory variables are put into the regression, indicating that the quadratic and cubic functions might fit better than the linear function. A noticeable exemption is Australia, where the R^2 and adjusted R^2 are rather low in the case of the quadratic specification. However, as mentioned before, the Australian quadratic specification suffers from heteroscedasticity.

Table 4A: The Relationship between Sulphur Dioxide and GDP

Linear	AUS	BRA	CHI	IND	JAP	MEX	SAF	SWE	UK	USA
C	4.41	2.58	1.39	-1.10	5.31	3.59	5.45	11.76	10.42	11.85
	(0.60)***	(0.32)***	(0.18)***	(0.25)***	(0.34)***	(0.41)***	(0.40)***	(0.80)***	(0.93)***	(0.95)***
GDP	0.04	-0.03	0.23	0.45	-0.20	-0.06	-0.18	-0.82	-0.72	-0.76
	(0.06)	(0.04)	(0.03)***	(0.04)***	(0.04)***	(0.05)	(0.05)***	(0.08)***	(0.10)***	(0.10)***
MA(1)	0.66	0.86	1.01	0.97	0.91	1.21	1.06	1.08	1.11	1.87
	(0.11)***	(0.15)***	(0.03)***	(0.12)***	(0.12)***	(0.16)***	(0.14)***	(0.14)***	(0.04)***	(0.05)***
MA(2)	0.38	0.45	0.93	0.70	0.69	1.02	0.62	0.60	1.08	1.78
	(0.05)***	(0.16)**	(0.02)***	(0.12)***	(0.12)***	(0.19)***	(0.21)***	(0.14)***	(0.05)***	(0.06)***
MA(3)	1.03					0.12	0.51		0.90	0.86
	(0.04)***					(0.16)	(0.15)***		(0.03)***	(0.03)***
MA(4)	0.44									
	(0.11)***									
R^2	0.76	0.49	0.95	0.96	0.90	0.81	0.86	0.96	0.97	0.98
Adj. R^2	0.72	0.44	0.94	0.96	0.89	0.78	0.85	0.96	0.96	0.98
DW	1.91	1.98	1.43	1.60	1.49	1.79	1.58	1.79	1.77	1.97
Breusch	5.66	3.72	3.63	5.55	6.19	2.73	3.99	2.49	1.52	5.60
Godfrey	(0.09)	(0.19)	(0.20)	(0.08)	(0.06)	(0.31)	(0.18)	(0.34)	(0.53)	(0.08)
Breusch	0.32	0.01	0.12	0.02	0.02	0.07	0.31	0.02	1.06	1.95
Pagan	(0.58)	(0.92)	(0.73)	(0.90)	(0.89)	(0.79)	(0.58)	(0.89)	(0.31)	(0.17)
Quad.	**AUS**	**BRA**	**CHI**	**IND**	**JAP**	**MEX**	**SAF**	**SWE**	**UK**	**USA**
C	8.48	-3.68	2.82	-0.92	-0.95	-15.91	-1.03	-2.83	-16.63	-35.76
	(5.13)	(1.56)**	(1.26)**	(1.85)	(3.75)	(1.79)***	(4.05)	(9.99)	(6.90)**	(3.38)***
GDP	-0.79	1.63	-0.27	0.38	1.15	4.86	1.45	2.20	5.14	9.02
	(1.09)	(0.41)***	(0.39)	(0.63)	(0.81)	(0.45)***	(1.05)	(2.06)	(1.49)***	(0.70)***
GDP^2	0.04	-0.11	0.04	0.01	-0.07	-0.31	-0.10	-0.15	-0.31	-0.50
	(0.06)	(0.03)***	(0.03)	(0.05)	(0.04)	(0.03)***	(0.07)	(0.11)	(0.08)***	(0.04)***
MA(1)	0.77	0.50	1.28	0.97	0.90	0.44	1.23	1.00	0.84	0.72
	(0.09)***	(0.14)***	(0.17)***	(0.12)***	(0.13)***	(0.15)***	(0.13)***	(0.14)***	(0.16)***	(0.13)***
MA(2)			1.47	0.70	0.68		0.69	0.56	0.74	
			(0.21)***	(0.12)***	(0.12)***		(0.13)***	(0.14)***	(0.18)***	
MA(3)			1.17						0.53	
			(0.20)***						(0.17)***	
MA(4)			0.36							
			(0.18)*							
R^2	0.35	0.57	0.97	0.96	0.91	0.87	0.87	0.96	0.97	0.99
Adj. R^2	0.30	0.53	0.97	0.96	0.90	0.86	0.86	0.96	0.97	0.99
DW	1.95	2.03	1.85	1.60	1.58	1.74	1.65	1.91	1.92	1.55
Breusch	2.01	5.10	2.17	5.72	6.03	4.82	4.45	1.00	0.11	5.58
Godfrey	(0.42)	(0.10)	(0.42)	(0.08)	(0.07)	(0.11)	(0.14)	(0.66)	(0.95)	(0.08)
Breusch	5.45	1.72	1.35	0.39	0.52	0.52	0.65	1.57	0.99	0.13
Pagan	(0.01)	(0.19)	(0.27)	(0.68)	(0.60)	(0.60)	(0.53)	(0.22)	(0.38)	(0.88)
TP	19438	1651	29	0	3693	2537	1408	1530	3985	8267
Cubic	**AUS**	**BRA**	**CHI**	**IND**	**JAP**	**MEX**	**SAF**	**SWE**	**UK**	**USA**
C	-136.41	13.22	-20.13	36.65	-48.26	39.41	-8.87	-65.87	8.38	116.34
	(52.38)**	(14.64)	(6.11)***	(14.89)**	(61.36)	(12.61)***	(41.18)	(131.43)	(70.31)	(46.07)**
GDP	43.78	-5.16	10.48	-19.05	17.47	-16.51	4.52	21.85	-3.04	-38.33
	(16.53)**	(5.87)	(2.92)***	(7.68)**	(19.15)	(4.85)***	(16.14)	(40.88)	(22.87)	(14.34)**
GDP^2	-4.52	0.79	-1.61	3.33	-1.93	2.43	-0.50	-2.19	0.57	4.40
	(1.73)**	(0.78)	(0.46)***	(1.31)**	(1.99)	(0.62)***	(2.10)	(4.23)	(2.47)	(1.48)***
GDP^3	0.16	-0.04	0.08	-0.19	0.07	-0.12	0.02	0.07	-0.03	-0.17
	(0.06)**	(0.03)	(0.02)***	(0.07)**	(0.07)	(0.03)***	(0.09)	(0.15)	(0.09)	(0.05)***
MA(1)	0.64	0.49	0.95	0.87	0.86		1.23	1.01	0.81	0.63
	(0.04)***	(0.14)***	(0.15)***	(0.14)***	(0.18)***		(0.13)***	(0.14)***	(0.16)***	(0.15)***
MA(2)	0.96		0.45	0.64	0.94		0.68	0.57	0.69	
	(0.01)***		(0.16)***	(0.14)***	(0.14)***		(0.14)***	(0.15)***	(0.20)***	
MA(3)					0.96				0.50	
					(0.12)***				(0.18)***	
MA(4)					0.37					
					(0.16)**					
R^2	0.72	0.58	0.96	0.97	0.94	0.90	0.87	0.96	0.97	0.99
Adj. R^2	0.67	0.53	0.95	0.96	0.93	0.89	0.85	0.96	0.97	0.99
DW	1.79	2.00	1.73	1.67	1.58	1.31	1.65	1.93	1.90	1.70
Breusch	0.97	4.39	5.46	3.44	5.79	5.05	4.53	0.80	0.29	2.03
Godfrey	(0.67)	(0.15)	(0.10)	(0.24)	(0.10)	(0.10)	(0.15)	(0.72)	(0.89)	(0.42)
Breusch	1.21	0.45	0.62	1.62	0.37	0.36	0.62	1.18	0.77	0.63
Pagan	(0.32)	(0.72)	(0.61)	(0.20)	(0.78)	(0.78)	(0.61)	(0.33)	(0.52)	(0.60)

Table 4B: The Relationship between Sulphur Dioxide and GDP

	AUS	BRA	CHI	IND	JAP	MEX	SAF	SWE	UK	USA
Obs.	39	39	39	39	39	39	39	39	39	39
Trend	N	Inv. U	Linear N	Linear Inv. N	Linear	Inv. U Inv. N	Linear	Linear	Linear Inv. U	Lin., Inv. U, Inv. N

Notes:

Values in parentheses are standard errors. Exceptions: Breusch-Godfrey and Breusch-Pagan; here values in parentheses are the respective p-values.

Stars indicate p-values.* indicates significance at 10% level, ** at 5% level, *** at 1% level.

The number of observations applies to each specification separately; i.e. the linear model has 39 observations for each country, as do the quadratic and cubic models, respectively.

TP = turning point; DW = Durbin Watson test

Like in the case of carbon dioxide, the linear model seems to fit well for most of the countries in the case of sulphur dioxide. However, in the majority of cases the relationship is now negative, indicating decreasing amounts of sulphur dioxide with increasing economic growth. Out of the significant results, only for China and India is the relationship positive, which is in accordance with the graphs in Figure 3.

For the quadratic model, significance levels decrease on a general level when looking at sulphur dioxide. The quadratic model only seems to hold for Brazil, Mexico, the UK and the USA. For these countries, an inverted U-shaped relationship can be observed, hinting towards a tentative existence of the EKC in the case of sulphur dioxide. The turning points range from 1,651 USD of per capita GDP for Brazil to 8,265 USD for the USA, with 2,537 USD for Mexico and 3,985 USD for the UK in between. Thus, in the case of sulphur dioxide it might be possible that developing countries (Brazil and Mexico) reach their turning points earlier than developed countries, which would conform to the theory of the revised EKC in Figure 2.

Finally, the results suggest that cubic functions hold for Australia, China, India, Mexico and the USA. N-shaped functions can be fitted to Australia and China, while inverted N-shaped functions can be applied to India, Mexico and the USA. Again, as in the case of the linear and quadratic specifications, a clear trend is difficult to detect and differences between developing and developed countries are hardly observable. Altogether, there seems to be a decreasing trend in the case of emitting sulphur dioxide. As there are such noticeable differences between carbon dioxide and sulphur dioxide, this occurrence shall be discussed, among other things, in the next section. Table 5 shows the summary of the results regarding the shape of the functions.

Table 5: Summary of Results

Function	AUS	BRA	CHI	IND	JAP	MEX	SAF	SWE	UK	USA
Carbon Dioxide										
Linear	/	/	/	/	/	/	/	\	\	
Quadratic	∩	∩	(∩)		(∩)	(∩)	∩	(∩)	∩	(∩)
Cubic			(N)	И	N	N		N		N
Sulphur Dioxide										
Linear			/	/	\		\	\	\	\
Quadratic		∩				∩			∩	∩
Cubic	И		N	И		И				И

Notes:
/ indicates an increasing linear function and \ indicates a decreasing linear function.
∩ indicates an inverted U-shaped function.
N indicates an N-shaped function and И indicates an inverted N-shaped function.
Brackets indicate that the intercept is insignificant, but that the functions are accepted in spite of this.

6. Discussion

The previous results have shown that a general trend in the relationship between emissions and economic growth is difficult to discern. In short: the question how economic growth affects emissions cannot be answered in one sentence. To begin with, one has to diversify between countries, their level of development and the type of emission that is considered. Table 5 is a perfect example that an interpretation of the results might be difficult, as there is such a variety among the results regarding the different countries and the two types of emissions. Unfortunately, one type of specification that fits to one country and both types of emissions is observed in the least of cases. Accordingly, I cannot say how economic growth affects emissions. However, I can say that, in the case of sulphur dioxide, economic growth affects emissions in a negative way for Sweden and the UK, by way of example.

For most countries, even though several functions seem to apply to them, the trend seems to be clear. For instance, in the case of Australia and carbon dioxide, the results suggest both a linear increasing function and an inverted U-shaped function. Such a result seems plausible as the linear increasing function might represent a part of the whole inverted U-shaped function. But even so, the case of India appears contradictory, for example. For some it might be difficult to see similarities between a linear increasing function and an inverted N-shaped function. Of course, the linear increasing function could represent the middle part of the inverted N-shaped function; but it seems somewhat counterintuitive that one result suggests an increasing function while the inverted N-shaped function basically incorporates a decreasing function. Thus, one wonders in the case of India, whether the ultimate relationship between the level of emissions and economic growth is rising or falling.

As it turns out, it is difficult to say whether there are or are not differences between developed and developing countries. The results suggest such a huge range of possible outcomes, that it is difficult to discern any trend or differences between developed and developing countries. For example, in the case of both carbon dioxide and sulphur dioxide an inverted U-shaped function applies to developing and developed countries, indicating similarities between both types of country groups. On the other hand, one might be tempted to see differences. For example, in the case of carbon dioxide the results suggest a linear negative relationship between economic growth and emissions for two developed countries (Sweden and the UK), while the majority of developing countries are suggested to have a linear positive relationship. On account of this, as there is such a large range of possibilities for the relationship between economic growth and emissions, it was likely a good idea not to pool the data into developed and developing countries.

Looking at the turning points of the EKCs, very little can be inferred from the results. In the case of sulphur dioxide, one might be tempted to argue that developed countries have higher turning points than developing countries (e.g. 8,267 USD for the USA and 1,651 USD for Brazil). However, as the inverted U-shaped functions only apply to four out of the ten analysed countries, such a conclusion might be rather dangerous.

Nothing can be concluded in the case of carbon dioxide, as the turning points range from 245 USD to 184,425 USD where the maximum and minimum values both apply to developed countries, and the turning points for developing countries are in between. Thus, one is tempted to argue that the EKC is only little founded in the case of carbon dioxide, as these turning points are very extreme. This finding is partly in accordance with Cole et al. (1997) who observe that "[t]urning points for per capita carbon dioxide emissions […] clearly fall well outside the observed income range […]. Thus, carbon dioxide emissions monotonically increase within the observed income range and little confidence can be had in the estimated turning points." However, unlike Cole et al. (1997) who argue that there is a monotonically increasing function for carbon dioxide, the results in this paper also confirm an inverted U-shaped function. Furthermore, in this paper, most turning points fall within the observed income range. Only the turning points for Australia, Brazil, China and South Africa are well outside the income range, in the case of carbon dioxide. In the case of sulphur dioxide, all turning points are within the observed income range.

The most noticeable difference in the results is found when comparing carbon dioxide to sulphur dioxide. In the linear specification, the overall relationship between GDP and carbon dioxide seems to be positive. In the case of sulphur dioxide, this relationship seems to be negative. Likewise, the inverted U-shaped function seems to fit to nearly all countries in the case of carbon dioxide, while it can be fitted to only four countries in the case of sulphur dioxide.

Several possible explanations offer themselves for why there is such a difference between carbon dioxide and sulphur dioxide. The first explanation that comes to mind is that, for some reason, it is easier to reduce the emissions of sulphur dioxide. For instance, technological advancement might have contributed more to the reduction of sulphur dioxide than carbon dioxide.

Another possible explanation might be that sulphur dioxide is more damaging to humans than carbon dioxide, which would lead to stricter regulations and law enforcement in the case of sulphur dioxide. At first thought this might be counterintuitive as carbon dioxide is, unlike sulphur dioxide, a greenhouse gas (see e.g. EPA, 2012). As greenhouse gases are considered to damage the ozone layer and as a result might increase global warming, carbon dioxide might be quite damaging to humans. Despite this, carbon dioxide does not have direct negative health effects on humans. On the contrary, up to a certain level it is quite healthy for humans (see e.g. Lenntech, 2012). Sulphur dioxide, on the other hand, is directly damaging to human health (Clean Air Trust, 2012). Thus, governments might be more concerned about setting up a strict legal framework in the case of sulphur dioxide, as it is affecting human health directly, while carbon dioxide might have an effect on human health in the long run. Since governments seldom think in the long run, legislative actions could explain why the emissions of sulphur dioxide are decreasing for most countries. Sulphur dioxide is more or less locally concentrated which would cause governments to regulate sulphur dioxide rather than carbon dioxide, which has more of a global impact. In the end, the local impact of sulphur dioxide might explain why it is decreasing for most countries.

As it turns out, a number of countries have changed their legal framework in order to restrict sulphur dioxide. In 1999, the European Union expanded an already existing council directive which requires member states of the European Union to limit emissions of sulphur dioxide (Europa, 2012). In a similar manner, the USA has started to revise its standards for emissions of sulphur dioxide in 2010 (EPA, 2012). However, these new regulations would only explain recent developments and not the decrease of sulphur dioxide over the last 40 years. On the other hand, the trend of increasing carbon dioxide might explain why many developing countries, as well as the USA, are reluctant to sign contracts such as the Kyoto Protocol which aims to reduce greenhouse gas emissions (United Nation, 2012).

Looking at the rather poor actions most of the countries have taken to prevent environmental degradation, it remains a question whether these countries actually do believe in the existence of the EKC. This paper has shown that a linear model might be perhaps more applicable to the relationship between economic growth and emissions, as the significance levels are typically high for the linear model and for most of the countries. But on the other hand, a linear function does not necessarily mean that a quadratic function cannot exist. Some of the results actually do imply that the linear function might be part of the quadratic function (e.g. in the case of carbon dioxide: Australia, Brazil, South Africa and the UK). Arguably, in the case of sulphur dioxide, the results from the quadratic specification are somewhat disappointing in the sense that they support inverted U-shaped functions only in four out of ten cases. And in a similar manner, the (inverted) N-shaped curves apply only to a handful of the analysed countries. But despite this, one cannot completely rule out the existence of the EKC, in particular since the EKC seems to explain the relationship between GDP and carbon dioxide rather well.

Of course, the results presented in this paper might suffer from problems which could bias the results and thus the interpretation of the EKC. Empirically, I have taken account of autocorrelation and heteroscedasticity but perhaps the variable per capita GDP might pose a problem. While GDP is often a good indicator of the economic situation, one might argue that it is not good enough to be used as proxy for income (or wealth, as is the actual meaning with respect to the EKC). Even if GDP decreases in a developed country, it does not necessarily mean that the country gets less wealthy. It might be simply a result of an economic downturn. Thus, the dependency of GDP on economic fluctuations might hamper the results as GDP is more of an economic indicator than an indicator of wealth, income or development. Likewise, the number of observations might not be enough to render valid results, which is the major disadvantage of implementing regressions for each country, and not using panel data.

Theoretically, the EKC will remain a target for critique. There are clearly factors that speak for the inverted U-shaped relationship between environmental degradation and per capita income. Technological advancement is one of these factors. But there are also factors where opinions get divided. For instance, the trade effect is often used to explain the inverted U-shaped curve: high-income countries outsource polluters to low-income countries which reduces the amount of environmental degradation in the high-income country. Of course, this explains the inverted U-shaped curve well, but it only explains it for the high-income countries. In the long run, as low-income countries develop to high-income countries the trade effect will disappear for these countries as the number of low-income countries decreases. Hence, the argument is that the previously low-income countries that have developed to high-income countries will not be able to outsource the polluters as no low-income countries are left due to the limited number of countries on this planet. Thus, the trade effect does not explain the EKC for all countries.

In the end, economic activity means a certain production of output. This output does not mean exclusively goods and services. It also means waste and emissions and pollution. In that case, environmental degradation is inevitable due to economic activity. It will be up to us how much we are willing to trade off economic welfare for environmental protection; and this might just as well cause the EKC to change its direction. In this sense, one should remember that the EKC is a theoretical concept. In theory, the level of emissions can be zero. In reality, that is highly unlikely to happen.

6. Conclusion

The aim of this paper is to use the EKC as foundation for analysing the relationship between economic growth and emissions. Furthermore, the paper analyses how well the curvature of the EKC is explained by economic growth and emissions.

In order to answer these questions, several indicators are needed. To begin with, in the original literature the EKC is defined by per capita income and environmental degradation. In this paper, economic growth is represented by per capita income and emissions are represented by environmental degradation. Economic growth is proxied by the variable per capita GDP and emissions are proxied by the variables per capita carbon dioxide and per capita sulphur dioxide, respectively. In an expanded model, two further variables, FDI and technology, are included.

Using cross-country time series data for ten countries characterised by different degrees of development, I find that the relationship between economic growth and emissions is often characterised by a linear relationship. In the case of carbon dioxide, the relationship is positive for most countries, while in the case of sulphur dioxide, the relationship is mostly negative. However, the theory of the inverted U-shaped EKC cannot be rejected. Firstly, the quadratic specifications do support an inverted U-shaped function for some countries, in particular in the case of carbon dioxide. And secondly, a linear relationship between economic growth and emissions does not completely rule out a possibly quadratic relationship. As a result, this paper does not reject the existence of the EKC but also points out that other curvatures might explain the relationship between economic growth and emissions likewise.

Expanding the model and including two other variables, technology and FDI, does not lead to any results. The results suffer on a large scale from insignificance to autocorrelation and heteroscedasticity. These problems could not be corrected and adjusted for due to lack of data and possibly multicollinearity.

Another issue that is investigated in this paper is whether there are differences between developed and developing countries. I refrain from pooling the countries used in this paper and using panel data on purpose due to the heterogeneity of the countries. Instead I define Australia, Japan, Sweden, the UK and the USA as developed countries and Brazil, China, India, Mexico and South Africa as developing countries, and compare the results. However, the results differ on such a large scale for all countries that no comparison is possible. Every country seems to have its own relationship between economic growth and emissions.

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