

International Trade and CO_2 Emissions: A Dynamic Panel Data Analysis by the STIRPAT Model

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Abstract
This paper focuses on the study of the effect of international trade on CO_2 emissions. The study focuses on a dynamic panel of 176 countries over the period 1995-2012. On the first hand, we will proceed to the estimation of STIRPAT model. Then, we will test the effect of trade and trade intensity with developed countries on CO_2 emissions. The results have been proven with The Environmental Kuznets Curve in the case of the total sample and for developed and developing countries. Concerning the case of the effect of international trade on CO_2 emissions, the results show that international trade increases pollution in developed and developing countries. In the developing countries, pollution increases because of their trade with developed countries. However, if the developed countries trade together the CO_2 emissions are reduced.
Keywords: International Trade- CO_2 Emissions- ECK

1. Introduction

Trade liberalization is seen as a factor that promotes the accumulation of economic wealth for nations and the development of commercial activities in a worldwide scale. During the period 1950-2006, the global mass of commercial movements has increased (27 times) whereas we noticed that the contribution of the international trade increased for the gross domestic products of different countries worldwide passing from 5.5% to 20.5%, [1].

However, some ecologists have considered trade liberalization as one of the factors of air pollution. In this sense, environmental degradation of southern countries is due to a mass production activity and the relocation of high-emission activities in the northern countries which are characterized by less stringent measures for environmental protection. However, some analyzes presented by neoclassical economists considered that the growth and the development of nations are the perfect solutions for the improvement of environmental quality. This controversial idea presented previously was developed in opposition with the concept of “sustainable growth”. In this framework, the northern countries would be able to improve the quality of their environment through wealth accumulation from commercial activities. They have the funds and the financial resources that are able to fight against environmental degradation. Thus, trade liberalization contributes positively to the environmental quality which is explained with the hypothesis based on the Environmental Kuznets Curve. Economic activity is then based on the activities of free trade in order to promote countries growth and to restore the environmental quality, [Grossman and Krueger, (1991); Copeland and Taylor, (2004)].

The Environmental Kuznets Curve did not take into consideration all the responsible elements for environmental degradation. It is therefore necessary to focus on all the determinants of environmental degradation.

If we want to evaluate the relationship between environmental degradation and the income achieved level, the environmental Kuznets curve can bring us the required elements. Nevertheless, its hypothesis cannot be used to explain the impact of trade liberalization on the environmental quality. We must therefore incorporate other indicators that reflect the social, economic and political dimension of the countries. In this work, we will analyze the impact of international trade on CO_2 emissions according to the EKC analysis. We estimate the effect of trade on the environment through an empirical application of the SRIRPAT model on a panel of 176 countries over the period 1995-2012 [2].This paper is organized as follows: section 2 presents the literature revue, section 3 introduces model, data and methodology, debate of the main Empirical results is discussed in section 4 and section 5 concludes.

2. Literature review

2.1 The pollution haven hypothesis

Recently, the study of the impact of international trade on the environmental quality has attracted the attention of some researchers. In this context, the EKC was criticized because of its incapacity to explain the role of the international trade in the pollution emissions reduction in rich countries where strong emissions intensity is only located in low income countries, [Judith M. Dean, (2000)].

[1] World Trade Organization; (the impact of trade opening on climate change, expansion of international trade).
[2] We started our study since 1995 because the data of the trade's variable (trade intensity of developed/developing countries with developed countries) are only available since 1995.

In this context, the environmental Kuznets curve has been criticized because of its inability to explain the role of international trade in reducing emissions in rich countries where a high emissions intensity is only located in low-income countries. This mechanism of the pollution relocation is called "the pollution haven hypothesis, (PHH)", [Matthew A. Cole and Robert J. R. Elliott, (2003)]. The period after the Second World War has marked the development of the international trade resulting from a considerable increase of exchange movements and also from routing actions of goods and merchandises for commercial purpose. It is at the beginning of the 90s that these changes stimulated researchers to deeply analyze the effects of exchange liberalization on environmental quality.

International trade and the degree of the opening of the country to the international level have been considered by previous studies of [Antweiler et al., (2001); Frankel and Rose, (2002) ; Cole, M.A. and Neumayer, E. (2004) ; Lamla, Michael J., (2009) ; Jie He and Patrick Richard, (2009) ; Sharma S.S., (2011)] in the discussion environmental degradation subjects'. By referring to these analyses, the authors justify the importance to take into consideration the trade component in the pollution/income relation whereas the environment can be influenced by exchange movements which have a major effect on the growth different sectors in the economy, [Frankel and Rose, (2002)].

2.2 The effects of international trade

International trade has a contradictory effect on the environment. Indeed, international trade is one of the explanatory factors in the relationship between growth-pollution in the analysis of the EKC. It is an important growth factor as far as it allows improving the national economy, widening market and increasing production. It follows that trade leads to air pollution, [Soumyananda Dina (2004)]. However, the analyses of [Birdsall and Wheeler, (1993); Lee and Roland-Holst, (1997)] show that the liberalization of the exchanges and the commercial opening are not the determining reasons of the environmental degradation.

As already shown in the analysis of the EKC hypothesis that increased income is the main cause of the environmental deterioration, trade liberalization is one of the growth factor. Thus, trade has a direct effect on the environment, which has not been considered by the previous analysis of [Shafik (1994), Selden and Song, (1994); Grossman and Krueger, (1995)].

Indeed, international trade allows the countries to benefit from a more important competitive advantage. It is considered as the essential factor allowing the countries to enjoy the most evolved techniques of production and to reach "the best green technologies of production", [Cole, M.A. and Neumayer, E. (2004) ; Lamla, Michael J., (2009)].

Then, we can justify the role of the international trade in the improvement of the environmental quality since it allows restricting the increase of noxious fumes. [Cole, M.A. and Neumayer, E. (2004)]. International trade can improve *(technical effect)* and destroy *(effect of scale)* the quality of the environment at the same time. Thus, its effect on the environment is contradictory.

It is necessary to note that the international trade effect is decomposed into three specific effects (scale effect, technical effect and composition effect). The scale effect leads to an increased pollution because of the increase of the production level simultaneously due to an increase of the market's size. The technical effect is explained by the introduction of new improved production technologies and the achievement of technological progress through trade. Finally, if an economy opts for a specialization strategy leading to a modification of the production process, then we speak about the composition effect of international trade, [Lamla, Michael J., (2009)].

Due to the decomposition of the global effect of international trade, the nature of its impact on the environmental quality as well as its sign were remaining imprecise, opening the field to several interpretations, [Grossman and Krueger (1991); Antweiler et al. (2001), Matthew A. Cole and Robert J. R. Elliott, (2003) ; Cole, M.A. and Neumayer, E. (2004) ; Lamla, Michael J., (2009)].

In their work, Antweiler et al. (2001) found a negative relationship between trade and SO_2 emissions, justifying the role of trade in mitigating the emissions of this type of pollutant. Similarly a negative impact of trade on CO_2 emissions has been proven in the study of S.S. Sharma (2011) on the determinants of CO_2 emissions based on a dynamic panel data of 69 countries classified according to the income level during the period 1985-2005.

3. Model, data and methodology

3.1 Theoretical Model

By analyzing the recent empirical studies of the relation between income and pollution, the EKC hypothesis is not proven in large samples of countries. The taking into consideration of the control variables which reflect the economy structure and others is crucial in this type of analysis, [Mazzanti and Musolesi (2009); Lamla, Michael J., (2009)]. Environmental quality is influenced by the degree of used resources to satisfy the specific needs of production and it is also influenced by the type of technologies used to achieve economic activity. For this reason, it is important to take into account "wealth" and "technology", [Aurélien Boutaud et al. (2006)]. Several factors should be included in the analysis of the relationship between the income and the environmental degradation, [Lamla, Michael J., (2009)]. In this sense, we could focus on the intensity of the trade liberalization, the population density, the intensity of the economic activity, foreign direct investments, debts (...).A thorough analysis on the subject of additional variables of the growth model is illustrated in the study of [Soumayananda D., (2004)].

In this part, we will proceed to the analysis of the EKC shape in 176 countries worldwide. The other analyses that were conducted in the same field were studies based on the individual level or/and on the total number of selected countries. Choi et al. (2010) and Martínez-Zarzoso and Grunewald (2009) have classified their sample according to the income level while studying the relationship between income and pollution. However, our sample is classified according to the development level based on the World Bank classification of the World [[1]].

We focus on the IPAT model developed by Ehrlich and Holdren (1971) at the beginning of the 70s; which is based on the "population" as an explanatory variable. According to Keisuke Hiroki I. and O. (2010), population growth can have negative impacts on the environmental quality. Furthermore, the EKC analysis used only "the unity of the population's elasticity" integrated in pollutant emissions per capita) [Hiroki Keisuke I. and O., (2010)].

The basic model is defined by the *equation (1)*:

$$I = P \times A \times T \qquad (1)$$

I represents the environmental impact expressed by the environmental quality indicators.

Several recent analyses focus on the problems of the specifications of the IPAT model, which is not appropriate for testing hypothesis. IPAT model is represented as "identical equations", [Hiroki I. and Keisuke O., (2010)]. It presents some disadvantages which cannot take into consideration the non-monotonic or the non-proportional effects of the variables. The STochastic Regression on Population, Affluence and Technology were developed to overcome these imperfections. A new specification of this model has been developed by Dietz and Rosa (1997), who have proceeded to a modification of the initial equation for a new one, which was more based on the stochastic version. It is named STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology. The STIRPAT model specification is as follows *equation (2)*:

$$I_i = \delta P_i^{\alpha} A_i^{\beta} T_i^{\theta} \varepsilon_i \qquad (2)$$

δ denotes the constant to be estimated. The terms P and A respectively designate pollution and wealth. The term T in this case is expressed in terms of "intensity of use", [Brian C O'Neill et al., (2012)]. According to Brian C. O'Neill et al., (2012) and other analysts in some work, the variable T of intensity is measured by "urbanization" which can be expressed in terms of the urban population as a percentage of the total population. It is sometimes determined by the "economic structure" that can be expressed in terms of the share of industry or production in GDP. The parameters to be estimated are represented respectively by α, β and θ. The term ε denotes the error term in the model, which "captures all the unexplained variance" and it also varies by country. The index *i* designates the countries (transverse units) where the relative proportions of the population, wealth and technology vary according to the country. Based on the model developed by Dietz T and EA Rosa (1997), taking into account the specificity of the time and the specificity of the country, the *equation (2')* is presented as follow:

$$I_{it} = \delta_i P_{it}^{\alpha} A_{it}^{\beta} T_{it}^{\theta} \varepsilon_{it} \qquad (2')$$

In this equation, the index i refers to the country *(i = 1 to N = 176)* and the index *t* designates the time dimension *(i = 1 to T = 17)*. Similarly, ε_{it} is the random error term and the specificity of the country is introduced through the term δit, [Perry Sadorsky, (2014)]. Now we will focus on the study of York et al. (2003) where the variable of technology is integrated as an explanatory variable in the model which is in opposition to the basic development of Dietz T and EA Rosa, (1997) who have not estimated the impact of technology on the emissions. In their study, technology (T) was included in the residual error term.

The extension of the model by the inclusion of technology as an explanatory variable was conducted by York et al (2003). Applying the natural logarithms (ln) to both sides we obtain the *equation (3)* which serves as a linear specification and presented as follow:

$$ln(I_{it}) = \upsilon_i + \alpha ln(P_{it}) + \beta ln(A_{it}) + \theta ln(T_{it}) + \nu_t + e_{it} \qquad (3)$$

υi is the natural logarithm of the constant δ, $ln(\delta i) = \upsilon_i$, which also integrates the specificity of the countries. Similarly to the case of the residual error term, *ei* is relative to the natural logarithm of εi, $ln(\varepsilon i) = e$. The term v_t refers to the time effects. Through this specification, in our study we can introduce the control variables based on the previous empirical literature review. In addition, the introduction of other explanatory variables and squared

[1] The countries list of the sample is described in the appendix.

variables to measure nonlinearities was investigated by York et al (2003). This research attempts to investigate the introduction of explanatory variables such as population growth, technological change, energy consumption, freedom index and trade liberalization. For these ones, the general *equation (4)* is as follow:

$$ln(I_{it}) = \upsilon_i + \nu_t + \kappa(lnI_{it-1}) + \alpha ln(P_{it}) + \beta ln(A_{it}) + \theta ln(T_{it}) + \varphi(Growth\_Pop_{it}) + \lambda ln(ENR\_C°_{it})$$
$$+\vartheta(Freed\_Index_{it}) + \psi ln(Trade_{it}) + \omega ln(Trade\_Dev_{it}) + e_{it} \quad (4)$$

It refers to CO_2 emissions per capita. In order to test the EKC hypothesis, we add the GDP per capita at constant prices (U $ 2005) squared.

Indeed, we will estimate the impact of population, affluence and technology on CO_2 emissions, by integrating control variables relating to population growth, energy consumption, and civil liberty index in the first model *(model(1))* which is presented by the *equation (5)* as follow:

Model (1)

$$\begin{cases} ln(CO_{2it}) = \upsilon_i + \nu_t + \kappa_1(lnCO_{2it-1}) + \alpha_1(lnUrban\_Pop_{it}) + \beta_1(lnGDP_{it}) + \beta_2(lnGDP_{it}^2) + \theta_1(lnInd\_VA_{2it}) \\ +\varphi_1(Growth\_Pop_{it}) + \lambda_1(lnENR\_C°_{it}) + \vartheta_1(Freed\_Index_{it}) + e_{it} \end{cases} \quad (5)$$

$\kappa_1 \quad \alpha_1 \quad \beta_1 \quad \beta_2 \quad \theta_1 \quad \varphi_1 \quad \lambda_1 \quad et \quad \vartheta_1$ *designate the parameters to be estimated*

In the second model *(model (2))*, we will focus on the impact of international trade on CO_2 emissions by integrating the variable of trade openness rate and the variable of openness intensity of developed and developing countries to developed countries. We will have the *equation (6)* as follows:

Model (2)

$$\begin{cases} ln(CO_{2it}) = \upsilon_i + \nu_t + \kappa_2(lnCO_{2it\_1}) + \alpha_2(lnUrban\_Pop_{it}) + \beta_3(lnGDP_{it}) + \beta_4(lnGDP_{it}^2) + \theta_2(lnInd\_VA_{2it}) \\ +\varphi_2(Growth\_Pop_{it}) + \lambda_2(lnENR\_C°_{it}) + \vartheta_2(Freed\_Index_{it}) + \psi_1(lnTrade_{it}) + \omega_1(lnTrade\_Dev_{it}) + e_{it} \end{cases} (6)$$

$\kappa_2 \quad \alpha_2 \quad \beta_3 \quad \beta_4 \quad \theta_2 \quad \varphi_2 \quad \lambda_2 \quad \vartheta_2 \quad \psi_1 \quad et \quad \omega_1$ *designate the parameters to be estimated*

3.2 Data

CO_2 emissions are the main cause of global warming. As an environment indicator, we relied on Carbone dioxide emissions) (Metric tons per person). For the period of 1995-2011, we focused on the database provided by *Energy Information Administration (2014)*. For the year of 2012, we focused on the series of CO_2 emissions in million tons after having divided each value by the population of each country. For the data series of 2012, we used the database provided by *BP Statistical Review of World Energy (2014)*.

The first explanatory variable that measures wealth is expressed in terms of per capita GDP at constant prices (constant $ 2005) which is specified in the EKC relationship since economic growth causes CO_2 emissions. The verification of the hypothesis of the EKC is made through the variable of GDP and GDP squared. In the case where the ECK has an inverted U-shape, we'll obtain a positive coefficient on GDP illustrating an increase in air pollution. Thus, a negative coefficient of GDP squared justifies the existence of a turning point with a decreasing phase). We relied on databases provided by the *World Development Indicators (WDI, 2014)* and *United Nations Statistics Division (2014) (National Accounts)*.

In this research, we will focus on the variable that measures the development of the industry. It is expressed in terms of industrial activity *(Ind_VA)*. It is calculated by the percentage of total production of goods and services in the industrial sector and is expressed by the variable of industrial value added as a percentage of GDP. Here, we relied on the database of the World Bank, *World Development Indicators (2014)*.

Among the factors that affect the environmental quality, we will focus on population growth. We will integrate the variable of population growth as an explanatory variable for the environmental impact. We will specifically use the variable related to the growth rate of the population *(Pop_Growth)* in the manner of [Lamla, Michael J., (2009)]. We relied on) the series of data from the World Bank, *World Development Indicators (2014)*.

In this model, we have incorporated some control variables. Indeed, since energy is a key factor of economic growth, it is also the source of increased CO_2 emissions. In this work, we focused on the variable of energy consumption *(ENER_C °)* (kg of oil equivalent per capita). The data is extracted from the database of the World Bank, *World Development Indicators (2014).*

In our study, international trade is expressed in two specific variables. Indeed, we will integrate the variable related to the intensity of trade openness. The intensity of air pollution also depends on the effect of trade intensity with developed countries. Consequently, in our assessment we have taken into account the variable related to the intensity of trade openness for the developing/developed countries with the developed countries, [Anna Kukla-Gryz, (2008)]. The variables are defined and calculated as follows:

i. The intensity of trade openness *(Trade)* is expressed by the share of the sum of exports and imports in real GDP.

ii. The intensity of trade openness in developing / developed countries with developed countries *(Trade_Dev)*: calculated by the sum of exports from developed countries and imports to developed countries as a percentage of real GDP.

The Data is extracted from the database of the World Bank, World Development Indicators (2014), the World Trade Organization (2014) and UNCTAD Statistics Database (2014).

In addition, democracy can influence the level of CO_2 emissions. As an indicator of democracy, we introduced political rights and civil liberty index [Wan Hai Y. et al, (2014); Ariel B.Y and Roger B., (2014)]. This index is calculated by an ordinary average of political rights and civil liberty index in each country [[1]].

3.3 Estimation methodology

As Agras and Chapman, (1999) and Martínez-Zarzoso and Maurotti, (2011), we have estimated a dynamic panel according to the Generalized Method of Moments (GMM). We used a dynamic panel estimation to control for past years emissions given the revealed persistence of CO_2 emissions. To measure this impact, we introduced the endogenous retarded variable as an additional explanatory variable in the model $(lnCO_{2it-1})$. This approach assumes that today's CO_2 emissions are driven by past emissions.

The choice of the GMM method is intended to fill gaps in the ordinary least square method and the generalized least squares that do not lead to efficient results. This method is able to correct the estimation problems like the simultaneity, reverse causality and omitted variable problems. In studies concerning growth, the GMM technique allowed us to treat the endogeneity of the exogenous variables.

The estimation of the dynamic panel is made in two specific steps. Indeed, a first step of estimating in first difference to eliminate specific effects of countries by differentiating the equation for each period. The lagged values of the explanatory variables are used in the other hand to make the choice of instruments for these variables, [Arellano and Bond (1991)]. After the instrumentation of lagged explanatory variables, the system-GMM estimators proposed by Arellano and Bond (1991) and Blundell and Bond (1998) estimate a combination of the two equations in levels and in first difference, [Blundell and Bond, (1988)]. Two specific tests associated with the estimation by the generalized method of moments. Indeed, the test of the validity of the instrument is the *Sargan* test. If the probability test is greater than 5%, then there is no over-identification problem. In addition, we will proceed to the test of autocorrelation of Allerano Bond in first and in second order. If the probability test is greater than 5%, then we accept the null hypothesis H0 corresponding to the absence of error autocorrelation problems. In our estimation, the results of relevant tests are consistent with assumptions.

4. Empirical results

The results of this empirical study are presented in Table (1).

- For the model (1) and model (2), the estimation results show that the lagged dependent variable has a positive and significant coefficient at 1% level in the case of the total sample. Similarly, we identify a positive and significant coefficient at the 1% level for developed and developing countries. The results justify that CO_2 emissions of each year are strongly influenced by those generated in the previous year.
- Similarly, in the case of the two models, there is a positive and significant coefficient at 1% level of the variable of real GDP per capita in the total sample and for developing countries and at 5 % level in the case of developed countries.
- Similarly, we identify a negative and significant coefficient of the real GDP per capita squared at 1% level for the total sample and for the developing countries and at 5% level for all the developed countries.

The EKC hypothesis is proven. We have justified the existence of an inverted U shape curve. This result is in accordance with Mazzanti and Musolesi, (2009) that found an inverted U shape relationship between emissions and GDP and had justified this relation by policy events such as the UNFCCC, the Kyoto Protocol and price shocks such as the oil price shock in the1980's. However, In Figure 1 and Figure 2 for the years 2000 and 2010, the relationship between economic growth and air pollution, we see that the developed countries are in the second phase of the Environmental Kuznets Curve:

[1] The freedom index corresponds to a specific classification of countries in terms of their political rights and civil liberty index. This is an assessment carried on the degree of the countries freedom published by Freedom House Organization. The range of this evaluation is between 1 and 7. If the calculated index is close to 1, it is qualified as high and an index close to 7 is qualified as low. For a country with an index between 1 and 2.5, it is considered as a free country. If the index is between 3 and 5.5, the country is qualified as Partly Free. An index that evaluates between 5.5 and 7 indicates that the country is not free.

Figure 1: Relationship between economic growth and CO_2 emissions in 2000

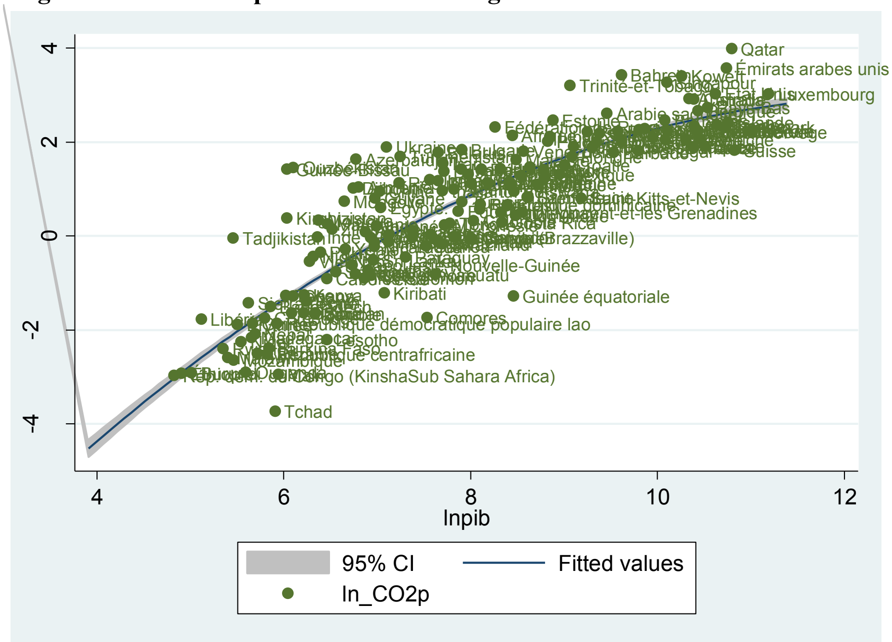
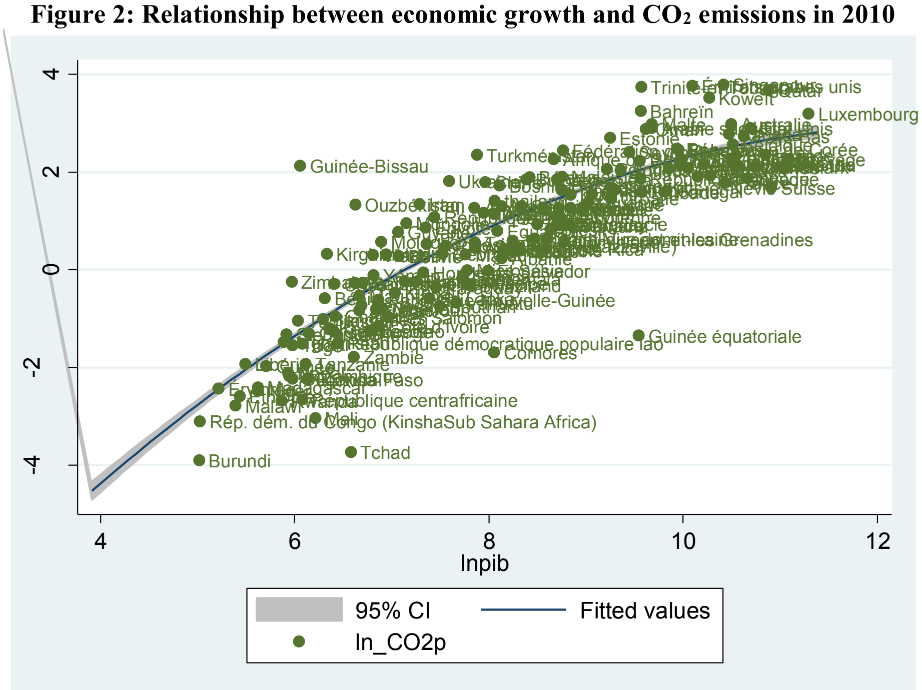


Figure 2: Relationship between economic growth and CO_2 emissions in 2010



Empirically, the verification of the EKC hypothesis in all countries sample could be explained by the implemented policies undertaken to reduce emissions in most countries around the world, [[1]].

In this context, some measures have been implemented by a number of countries around the world assuring the reduction of greenhouse gas emissions in the industrialized countries such as the ratification of the General Agreement in 1992 by the *United Nations* on the subject of climate change, followed by the birth of the *Kyoto Protocol* in 1997 and finally the Marrakech agreements established in 2001, [Kyoto Protocol, (1998)[2]].

[1] In particular, as part of reducing greenhouse gas emissions and the fight against the harmful potential effects on global climate change, Tunisia opted for a strategy of several well-defined action: **i-** Prevent, eliminate and restrict harmful gas emissions; **ii-** identify and control sectors and regions that could have serious air pollution problems; **iii-** carry out energy inventories in order to achieve energy savings and reduce pollution that results from energy consumption, **iv-** establish and develop the balanced management of air quality.

[2] Protocole de Kyoto (1998) à la Convention cadre des Nations Unies sur les changements climatiques, Nations-Unies. FCCC/INFORMAL/83, GE.05-61647 (F) 070605 090605.

These agreements have been approved in the beginning of 2005 to minimize greenhouse gases emissions over the period from 2008 to 2012 in a *"Rio-Kyoto climate regime"*, [Berthaud, P. et al. (2004); Odile, Blanchard et al. (2005)].

We integrated other explanatory variables in the estimated model. Indeed, in the model (1) and model (2) the variable of urbanization has a positive and significant coefficient at 1% level in the case of the total sample, and for developed and developing countries. Urbanization in the developed and developing countries generates increased dioxide carbon emissions. A high intensity of CO_2 emissions can be identified in large cities with massive population. The place of the agricultural sector is declining with the growth and the industrialization of the economy.

The industrial activity is based on the implementation of manufacturing factories in urban areas, which explains that urbanization is the cause of increased CO_2 emissions. This ephemeral movement of urbanization has led to a gradual decline in the population in cities which prompted countries to deal with this urban agglomeration, [Henderson, (2003)].

Table 1: Dynamic Panel Estimation: GMM method (Arellano-Bond) [1]

Endogenous variable	$lnCO_2$					
	Model (1)			*Model* (2)		
Sample	All countries	Developed countries	Developing countries	All countries	Developed countries	Developing countries
lnCO2 (t-1)	0.4423537 (106.46)***	0.342938 (5.86)***	0.5656128 (146.30)***	0.4464664 (106.72)***	0.3352709 (6.89)***	0.5721769 (106.98)***
Exogenous variables						
lnUrban_Pop	0.8654808 (30.38)***	2.054928 (8.02)***	0.1352458 (6.30)***	0.8680599 (28.86)***	1.692368 (9.53)***	0.1129344 (3.35)***
ln_GDP	0.1257847 (13.61)***	0.3759839 (2.05)**	0.2176694 (22.10)***	0.1361286 (16.42)***	0.4561939 (2.02)**	0.2034438 (16.38)***
(ln_GDP)²	-0.0085089 (-14.86)***	-0.0231966 (-2.54)**	-0.0129614 (-22.31)***	-0.009072 (-17.19)***	-0.0269211 (-2.35)**	-0.0151771 (-17.20)***
lnInd_VA	0.1547215 (28.46)***	0.1608943 (4.62)***	0.1267282 (15.52)***	0.1490713 (27.18)***	0.1716686 (2.85)***	0.1161048 (18.22)***
Growth_Pop	0.0087362 (10.93)***	0.0147261 (2.76)***	0.0071257 (10.26)***	0.0086769 (10.89)***	0.0102003 (1.79)*	0.0069364 (9.11)***
lnENER_C°	0.419398 (41.86)***	0.7184546 (15.27)***	0.3775516 (48.85)***	0.4159218 (37.50)***	0.7061305 (16.11)***	0.3817503 (41.29)***
Freed_Index	0.0086443 (6.60)***	0.0031793 (0.38)	0.0136371 (8.42)***	0.0088297 (6.57)***	-0.008144 (-0.84)	0.0139806 (12.54)***
lnTrade				0.0102138 (5.79)***	**0.0712845 (2.67)*****	**0.0117079 (10.08)*****
lnTrade_Dev				0.0063968 (3.24)***	**-0.1340687 (-5.94)*****	**0.0193975 (5.62)*****
Constant	-6.917845 (-69.30)***	-15.25841 (-9.80)***	-4.243865 (-38.15)***	-6.997318 (-69.66)***	-13.27696 (-10.11)***	-4.331504 (-44.83)***
Observations number	1862	517	1345	1860	517	1343
Countries number	150	35	115	150	35	115
Instruments number	144	144	131	146	146	133
Sargan test [prob > Chi 2] [5]	135.374 (0.4748)	30.49226 (1.0000)	108.4086 (0.8055)	135.7636 (0.4654)	31.40037 (1.0000)	109.3564 0.7870
Allerano – Bond test [AR(1)] [6]	-5.4314 (0.0000)	-2.8644 (0.0042)	-4.8277 (0.0000)	-5.4205 (0.0000)	-3.1026 (0.0019)	-4.8598 (0.0000)
Allerano – Bond test [AR(2)] [7]	-1.1042 (0.2695)	0.74708 (0.4550)	-1.2702 (0.2040)	-1.0818 (0.2794)	0.11279 (0.9102)	-1.2675 (0.2050)

Notes: [1] Dynamic panel data estimation with Generalized Method of Moments (GMM) of the Arellano-Bond. Estimation are made using two-step System GMM. Model (1): corresponds to an estimate model without integrating trade variables. Model (2): corresponds to an estimate model with the integration of trade variables.
[2] (***), (**) and (*) represent statistical significance at 1%, 5%, and 10% levels, respectively. **[3]** T-students are provided in parentheses.
[4] All variables were transformed into natural logarithm, except the variable of population growth rate and the variable of civil liberty index. **[5]**: The Sargan test is the test of the validity of the instruments. If the probability

of the test is greater than 5%, there is no over-identification problem (in our case study all the instruments are valid). **[6]**: This is the first order autocorrelation test. **[7]**: This is the second order autocorrelation test. If the probability test is greater than 5%, then we accept the null hypothesis H_0 corresponding to the absence of error autocorrelation problems. The average autocovariance of the second order of residuals is 0.

- For the industrial structure indicator, we notice that the variable of value industry added is positively correlated with CO_2 emissions. We identify a positive and significant coefficient at 1% level for the total sample and for all developed and developing countries for (in) both models. For both models, the population growth leads to increased CO_2 emissions. Indeed, for the variable of the population growth rate, we find a positive and significant coefficient sign at 1% level in the total sample, and in the developed and developing countries. However, in the case of developed countries in the model (2), we find a positive and significant coefficient at the 10% level.
- Similarly, energy consumption leads to increased CO_2 emissions, which is justified by a significant positive coefficient at 1% level for all countries and for developed and developing countries in both models.
- In the case of freedom index, it has a positive and significant coefficient at 1% level for the total sample and in the developing countries in the first model. In contrast, we observe a positive and insignificant coefficient in the case of developed countries.
- For the model (2), we notice that civil liberty increases CO_2 emissions in the case of the total sample and in developing countries. In the case of developed countries, we identify a negative and insignificant coefficient. Indeed, the most democratic countries are the industrialized countries. Investors are encouraged to invest in democratic countries by the establishment of new factories which cause increased CO_2 emissions. As a result, civil liberties have not played an important role in mitigating carbon emissions.
- For the total sample, we identify a positive and a significant coefficient of trade opening variable at 1% level. Similarly, for developed and developing countries, international trade negatively affects the environment.
- Finally, the trade intensity coefficient of developed and developing countries with developed countries is positive and significant at 1% level in the case of the total sample and in the case of developing countries. Nevertheless, the estimated model for developed countries shows that the variable of trade intensity has a negative and a significant coefficient at 1% level. Trade intensity of developed countries with developed countries does not increase pollution. However, it contributes to the reduction of CO_2 emissions.

5. Conclusion

In this research paper, we tried to develop a theoretical analysis of STIRPAT model and analyze the effects of international trade on CO_2 emissions as well as verifying the EKC hypothesis. We are based on a panel of 176 countries over the period 1995-2012. In the first model, we studied the effect of wealth, population, urbanization, industrial structure, consumption of energy and civil liberty on CO_2 emissions for the total sample, as well as for all developed and developing countries. In the second model, we have integrated international trade variables related to trade openness and trade openness intensity of developed / developing countries with developed countries. The Results show that in both models the environmental Kuznets curve has been verified for the total sample and in the case of developed and developing countries. Moreover, we have seen that the urbanization negatively affects the environmental quality. In this study, the impact of technology is measured in terms of industrial activity.

The results showed that the industrial activity increases CO_2 emissions since the use of more efficient and advanced technology can overcome the effects of economic growth which leads to environmental degradation. The population growth contributes to an increase of carbonic emissions for the total sample and for developed and developing countries. Despite the development level of the developed countries, the implemented energy consumption policies do not guarantee its efficiency. Moreover, population growth requires higher energy consumption. Indeed, population growth leads to the deterioration of the environmental quality and to the intensification of pollutant emissions which is explained by several factors. Birdsall, (1992) focused on two main factors. As we know, the demand for energy increases with the increase in population. This is due to the growth of the industrial sector and the transports, as well as an increase in production for the needs of the population. This increase in energy demand will encourage the countries to increase the production of energy that is required in industry, and will motivate other sectors which use substances and combustible materials that could generate greenhouse gas emissions, [Birdsall, (1992) ; Anqing Shi, (2003)].

Energy consumption contributes to an increase of CO_2 emissions. It is therefore necessary to opt for measures that control energy consumption. Besides, civil liberties have not played an important role for the reduction of CO_2 emissions.

As already mentioned, the volume of trade in the world has increased in the recent decades, and the share of trade in GDP has increased from 5.5% in 1950 to 20.5% in 2006. International trade contributes to an increased wealth, but it negatively affects the environment through increased emissions caused by transport (flow of goods, for example, transported by delivery vans) and mass production (which requires the exploitation of nature) to meet the global demand. Several factors have contributed to the development of international trade. Indeed, the technological development allows countries to benefit from a reduction in the transportation cost [1] and communications cost (case of jet engine reducing the cost of air and maritime transport). Despite the fact that international trade increases pollution, the EKC hypothesis has been proven in the case of developed and developing countries. We conclude that the wealth accumulated during the first phase of development has been devoted to improve the environmental quality. Thus, the environment is considered as a "luxury good" or "Higher good". Trade liberalization allows developing countries to benefit from new technological discoveries necessary to improve the industrial sector. It allows countries to use natural resources efficiently.

In this study we distinguished between trade and the intensity of trade with developed countries. The results show that trade which is measured by the sum of imports and exports as a percentage of GDP increases pollution. The distinction between global trade and trade intensity is significant. Indeed, we found that trade intensity leads to reduced emissions in developed countries, which explains that developed countries adopt policies and measures that protect the environment. In the case of developed countries, trade with other rich countries is profitable to reduce CO_2 emissions. We can explain this by the nature of products imported from these countries and the transfers of clean technologies. Developed countries safeguard respect for rules and standards to protect the environment.

This is not the case of developing countries. Indeed, trade intensity with developing countries increases pollution. In the case of developing countries, trade liberalization with no rules and standards protecting the quality of the environment leads to a transfer of polluting activities from rich to poor countries in order to minimize the production costs and benefit from low labor costs. This phenomenon explains the relocation of polluting activities known as "pollution haven hypothesis (PHH)."

If the rich countries have a comparative advantage resulting from specialization in high-pollution industries in their local markets, and if the standards and the rules of the environmental protection in these countries are strict, this will lead to relocate such activities in the countries where restrictions are lower to increase their income. Investors in polluting activities will benefit from an advantage in terms of cost and labor (manufacturing costs of polluting goods are very low in developing countries), [Pethig (1976); Siebert et al. (1980); McGuire (1982); Copeland and Taylor, (1994)].

It is therefore necessary to adopt appropriate measures to protect environmental quality and to promote a green trade and a green growth. International trade can both improve *(technical effect)* and deteriorate *(scale effect)* the environmental quality. So, its effect on the environment is contradictory. The effect of global trade is divided into three specific effects *(scale effect, technical effect and composition effect)*. The estimation of the impact of its effects on the environment will be the subject of a future study.

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Appendix
Countries list

Hungary	Afghanistan	grenade	Papua New Guinea
Ireland	Antigua and Barbuda	Guatemala	Paraguay
Iceland	Saudi Arabia	Guinea	Peru
Italy	Argentina	Equatorial Guinea	Philippines
Latvia	Bahamas	Guinea-Bissau	Qatar
Lithuania	Bangladesh	Guyana	Rep, Rep of Congo (Kinshassa)
Malta	Barbados	Haiti	Rep, Dem Lao People
Norway	Belize	Honduras	Syrian Arab Republic
Netherlands	Bhutan	Solomon Islands	Central African Republic
Switzerland	China	Kuwait	Senegal
Australia	Colombia	Lebanon	Seychelles
Israel	Comoros	Libya	Sierra Leone
Japan	Rep of Congo (Brazzaville)	New Zealand	Republic of Korea
Luxembourg	Rep, People's Rep of Korea	Albania	Costa Rica
Portugal	Brazil	Indonesia	Tanzania
Romania	Burundi	Iraq	St. Lucia
United Kingdom	Cambodia	Jordan	Saint Kitts and Nevis
Slovak Republic	Cameroon	Kenya	Saint Vincent and the Grenadines
Slovenia	Cape Verde	Kiribati	Samoa
Czech Republic	Burkina Faso	Iran	Rwanda
suede	Chile	Micronesia	São Tomé and Príncipe
Germany	Azerbaijan	Cuba	Maurice
Austria	Belarus	Djibouti	Mauritania
Belgium	Bosnia And Herzegovina	Dominique	Mexico
Bulgaria	Croatia	Egypt '	Mongolia
Canada	Georgia	El Salvador	Mozambique
Cyprus	Kyrgyzstan	United Arab Emirates	Nepal
Denmark	Moldova	Ecuador	Nicaragua
Spain	Russian Federation	Eritrea	Niger
Estonia	Tajikistan	Ethiopia	Nigeria
United States	Macedonia	Fiji	Oman
Finland	Uzbekistan	Gabon	Uganda
France	Turkmenistan	Gambia	Pakistan
Greece	Ukraine	Ghana	Panama
Poland	Bolivia	India	Dominican Republic
South Africa	Liberia	Armenia	Turkey
Algeria	Madagascar	Sudan	Uruguay
Angola	Malaysia	Sri Lanka	Vanuatu
Bahrain	Malawi	Suriname	Venezuela
Benin	Mali	Swaziland	Viet Nam
Botswana	Morocco	Chad	Yemen
Jamaica	Namibia	Thailand	Zambia
Lesotho	Singapore	Togo	Zimbabwe
Trinidad and Tobago	Tunisia	Tonga	Ivory Coast

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