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Environmental Impact determinants: An empirical analysis based on the STIRPAT model

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Abstract

This paper attempt to investigate the impact of economic and population growth, urbanization level, energy intensity and Kyoto protocol obligations on carbon dioxide emissions using the STIRPAT model (STochastic Impacts by Regression on Population, Affluence and Technology). Our sample of countries is decomposed into groups according to the revenue level and the analyzed period extends from 1980 through 2010. Using several methods to estimate panel data, we find that there is a significant effect of economic growth, population growth, urbanization level and Kyoto protocol on emissions level and this effect depends on the revenue level.

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Keywords: Panel data, economic growth, CO_2 emissions, Kyoto protocol;

1. Introduction

Several researchers considers anthropogenic factors such as economic growth, energy consumption, population, technology, economic and political institutions, attitudes and beliefs, urbanization as causes of negative environmental impacts. Since the complicated aspect of the environmental question, it seems very useful to understand the respective influence of such driving forces on environment in order to adopt the more appropriate policy.

The studies of the CO_2 emissions determinants were explored within the Environmental Kuznets Curve (EKC) hypothesis in the last two decades. This hypothesis allows testing the inverted U-shape of the pollution-income relationship. However, results don't conduct to a decisive conclusion supporting this hypothesis. For this, the addition of explanatory variables was supported by some researchers. Besides, decomposition analysis and efficient frontier methods was used in recent studies that appeals for explanatory variables such as technological change, affluence, population. Among these models, the IPAT developed in the seventies by Erlich and Holdren (1971). However, this model was criticized. Therefore, a reformulation of this model into a stochastic equation was presented by Dietz and Rosa (1997) allowing for empirical hypothesis tests. In view of this, the current research employs the STIRPAT model (STochastic Impacts by Regression on Population, Affluence, and Technology) to analyze the influences of population, industrialization level, affluence, technology, urbanization level and Kyoto protocol ratification on the environment. In fact, this paper makes two primary contributions to the current state of the art. First, the paper contributes by a static and a dynamic estimation of three different specifications including population, industrial activity, energy efficiency, urbanization and Kyoto protocol ratification. Second, it is the first paper to explore the driving forces of CO_2 emissions and the variability of their impact within geographical regions. In addition to this a comparison is made between results from the estimation according to the level of income of the studied countries and their geographical belonging.

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This paper is structured as follows: section 2 introduces a literature revue for the STIRPAT model. Section 3 provides an empirical investigation including estimation methodology and data. Section 4 presents estimation results and Section 5 concludes.

2. Literature revue

The first authors who developed a stochastic version of the IPAT model to estimate the effects of population, affluence, and technology on national CO_2 emissions were Dietz and Rosa (1997). Their results suggested that, population and economic growth intensify GHG emissions. Besides, the introduction of the technology term in the STIRPAT model is controversy. In fact, some studies include it in the error term. However, others considered it as a variable that must be considered separately. The first study that included the technology as explanatory variable was conducted by York et al (2003) that found that industrialization increases CO_2 emissions, but not as significantly as urbanization does. In addition, Cole and Neumayer (2004) investigated a panel data composed of 86 countries during the period 1975-1998 and found a positive link between CO_2 emissions and population, urbanization rate, energy intensity, and smaller household sizes. And Fan et al (2006) used data covering 93 countries belonging to different income levels during the period 1975-2000 to estimate the STIRPAT model and suggested that for developing countries or low income level, the impact of GDP per capita is very important.

Moreover, Martinez-Zarzoso (2008) studied countries of different income groups during the period 1975-2003 and found that the impact of population growth on emissions is slightly different for upper, middle, and low income countries and that urbanization had a very different impact on emissions for low and lower-middle-income countries and upper-middle income countries. By their analysis of the driving forces of CO_2 emissions in India during the period from1960 to 2007, Behera and Vishnu (2011) showed that urbanization, population, service sector, industrial sector and GDP per capita had negative effects on environment. Recently, Sanglimsuwan (2012) estimated the impact of changes in population, GDP and the structure of economy on carbon dioxide emissions for 83 countries from 1980 to 2007. Results suggested that higher population and higher percentage of working-age population lead to higher CO_2 emissions.

The importance of present international climate negotiations and their effectiveness may affect future decision making. For this, it is primordial to evaluate past negotiations. The evaluation of policy events on carbon emissions was conducted for the first time by Mazzanti and Musolesi (2009) how studied 20 countries during the period 1960-2001and found that income-emissions relationship is affected by policy events such as the UNFCCC in 1992 and the Kyoto Protocol in 1997.For this reason and to assess the impact of the reduction commitments of Kyoto Protocol on various GHG emissions, Hiroki and Keisuke (2010) used a data set of 119 countries for the years: 1990, 1995, 2000 and 2005. Their main findings are that the effects of the Kyoto Protocol ratification is significantly negative for the CO_2 and CH_4 emissions and are significantly positive for other GHG emissions. Moreover, Grunewald and Martínez-Zarzoso (2011) estimated a dynamic panel data model for a cross-section of 213 countries over the period 1960-2009 and indicated that obligations from the Kyoto Protocol have a measurable reducing effect on CO_2 emissions.

3. Methodology and data

3.1. Methodology

During the last three decades, the growth of population, wealth and technology are jointly presented as responsible for the environmental impact by economic and scientific researches. In this sense, Ehrlich and Holdren (1971) were the first to try to explain dynamics of environmental impact, population and human well beings. The formulation of this relation was conducted with a simple identity, known as, IPAT. Their research results suggested that population growth entails a negative impact on the environment which is not proportional and that affluence is one of the main drivers of the CO_2 emissions. Furthermore, Dietz and Rosa (1997) considered human activities as the essential driving force of CO_2 emissions. For this they divided human activities into four anthropogenic forces that are: population (P), economic activity or affluence (A), technology (T) describing technical standard of production.

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

Where I represent environmental impact

Several researches such as Dietz and Rosa (1994), Dietz and Rosa (1997) and York et al, (2003) used this simple formulation to investigate the interactions populations, economic growth and technological development. However, Since the IPAT model is an accounting equation, it presents some drawbacks among them the fact that this model is not useful for statistic analysis since statistic associations don't reflect causal relationship and that it cannot consider non-monotonic or non-proportional effects of the variables. To overcome these imperfections, the Stochastic Regression on Population, Affluence and Technology (STIRPAT) was developed by Dietz and Rosa (1997) allowing for empirical hypothesis test. The STIRPAT model specification is as follows:

$$I_i = \propto P_i^{\beta} A_i^{\gamma} T_i^{\delta} \varepsilon_i \quad (2)$$

α Represents the constant term; β, γ and δ parameters to be estimated and ε is the error term. A: represents affluence measured by GDP per capita, P: Population is measured by the number of inhabitants and T: Technology changes' proxies are industrial activity calculated by the share of the manufacturing industry in total GDP and energy efficiency measured by GDP per unit of energy use. Estimated values of A, P, T and ε vary across countries represented by i. By applying the natural logarithms (*ln*) to both sides we obtain:

$$lnI_i = \alpha_0 + \beta ln(P_i) + \gamma ln(A_i) + \delta \ln(T_i) + \mu_i \quad (3)$$

Where $ln\alpha = \alpha_0$ and $ln\varepsilon_i = \mu_i$

These forms permit a simple calculation of environmental impact elasticity according to each anthropogenic factor. In fact, STIRPAT model was used to analyze the effect of explanatory variables on environment. However, there isn't accordance about the importance of these factors. For this, the present paper attempt to estimate next equations in order to detect their relevance. The first model which referred to as model 1, regresses CO_2 emissions on total population, GDP per capita, industrial activity and Kyoto protocol ratification. Its functional form is as follows:

$$lnCO_{2it} = \alpha_i + \lambda_t + \beta_1 lnP_{it} + \beta_2 lnGDP_{it} + \beta_3 lnIA_{it} + \beta_4 KyotoRat + \vartheta_{it} \quad (4)$$

Where ϑ_{it} is the error term.

Model 2 tests however the impact of population, GDP per capita, energy efficiency and Kyoto protocol ratification. The regression is as follows:

$$lnCO_{2it} = \alpha_i + \lambda_t + \beta_1 lnP_{it} + \beta_2 lnGDP_{it} + \beta_3 lnEE_{it} + \beta_4 KyotoRat + \vartheta_{it} \quad (5)$$

The third model regress CO_2 emissions on total population, GDP per capita, industrial activity, energy efficiency and Kyoto protocol ratification. Its functional form is as follows:

$$lnCO_{2it} = \alpha_i + \lambda_t + \beta_1 lnP_{it} + \beta_2 lnGDP_{it} + \beta_3 lnIA_{it} + \beta_4 lnEE_{it} + \beta_5 KyotoRat + \vartheta_{it} \quad (6)$$

The dependent variable in our model is CO_2 Emissions measured in kilo tons. α_i and λ_t are country and year specific effects, which are used to control for unobservable country heterogeneity and for common time-varying effects that could affect emissions. In fact, following some of the pioneer researches, such as Cramer (1998) who tested whether the elasticity of emissions with respect to population is unity we incorporate total population (P) as explanatory variable measured in number of inhabitants. In fact, increasing emissions may be led by growing population. Moreover, anterior researchers found that Affluence approximated by GDP per capita have a positive impact on emissions level. GDP is represented by GDP per capita in constant 2005 international dollars in our model which is based on purchasing power parity (PPP). Technological change was measured by some researchers such as Grunewald and Martínez-Zarzoso (2011) by industrial activity *(IA)* calculated by the share of the manufacturing industry in total GDP. However, Martínez-Zarzoso (2009) used *industrial activity* (IA) and *energy efficiency* (EE) measured as GDP at constant PPP prices divided by energy use, where energy use refers to apparent consumption (production+imports-exports) as proxies of technological change in the same equation. Present research try to use the two proxies separately and then we will integrate them in the same model. To assess the impact of Kyoto Protocol ratification on CO_2 emissions we created a dummy variable (KyotoRat) following Grunewald and Martínez-Zarzoso (2009). In fact, if a country has ratified the Kyoto Protocol and faces emissions reduction obligations, the variable takes the value of one from the year in which the country has ratified the Kyoto Protocol else it takes the value of zero.

3.2. Data

To accomplish the present study, we use time-series cross-section data from 214 countries for the period ranging from 1980 to 2010. The data comes from the online World Development Indicators (WDI) and those concerning the Kyoto Protocol ratification are from the UNFCCC (2012). In addition, the study apply a decomposition of the sample of countries in different groups according to income levels and geographical regions to consider the heterogeneity of our sample in terms of variability of the estimated coefficients over time and across different groups of countries. The decomposition of the studied sample was considered by a number of studies according to income level such as Fan et al (2006) and Grunewald and Martínez-Zarzoso (2009) that grouped countries into four GDP groups: high, upper-middle, lower-middle and low. However, the present study attempt to decompose countries into three groups: high, middle and low income countries. In addition to a decomposition into geographical regions which isn't conducted to our knowledge by other studies. Studied regions are: East Asia and Pacific, Europe and Central Asia, Latin America & Caribbean, Sub-Saharian Africa, Middle East North Africa, South Asia and North America. The two later groups are omitted from the analysis due to the lack of observations. Geographical and level income decomposition was made according to world development indicators' classification.

4. Empirical results

4.1. Static estimation results

The fixed effects and the random effects regressions are used to estimate the coefficients in each model. Then, the Hausman test was applied in order to choose the most appropriate model. In the present study, the result of the Hausman test indicates that the country effects are correlated with the residuals and therefore only the fixed-effects estimates are consistent. Fixed effects

Panel data models allowing for a unique coefficient for population, affluence and technology for all sample countries are most commonly used in previous studies. Results of fixed effect models estimations are presented in the following tables. In fact, the results of the first model estimations for the whole sample countries and for different geographic regions are presented in table 1.

- The variable population exerts a positive and significant effect for all countries sample and for all geographical groups.
- The variable GDP per capita which represents the proxy of economic growth presents a positive and significant effect on emissions for all countries sample and of all groups of countries except for North America for which the relation isn't significant.
- The variable industrial activity which is a proxy of technology use presents a positive and significant effect for all countries and for East Asia and Pacific, Europe and central Asia, South Asia and North America groups. For other groups the relation isn't significant.
- The variable Kyoto ratification indicates the impact of the ratification of this protocol and consequently the adoption of less pollutant technologies on emission level. Results demonstrate a negative and significant effect for all groups of countries except for East Asia and Pacific[2] and Sub-Saharan Africa for whose the relationship is positive and non significant and for North America for which the ratification of the Kyoto protocol has a negative but none significant effect on emissions.

Table 1.Model (1) static estimation for sample countries grouped in geographic regions

	All countries	East Asia & Pacific	Europe & Cent Asia	Lat Amer & Carib	Sub-Sah Africa	MENA	South Asia	North America
lpop	1.159477	1.153912	1.715477	1.279657	0.8498794	1.283599	1.453061	1.110086
	(36.00)***	(13.55)***	(15.55)***	(20.99)***	(11.50)***	(36.52)***	(10.73)***	(5.03)***
lgpdperc	0.8666475	0.6792375	0.4594912	1.097076	1.180282	0.7822562	1.121894	0.1711788
	(39.10)***	(16.29)***	(14.04)***	(31.57)***	(18.75)***	(18.70)***	(10.74)***	(1.35)
lindva	0.328837	0.3959023	0.5936704	0.0012728	0.0812939	0.0521001	0.9334766	0.2844071
	(13.86)***	(6.70)***	(17.38)***	(0.03)	(1.45)	(1.11)	(8.16)***	(4.16)***
kyoto_ra	-0.086301	0.0274738	-0.1222882	-0.0825224	0.0292888	-0.0773939	-0.145600	-0.022651
	(-6.15)***	(0.92)	(-6.94)***	(-4.42)***	(0.64)	(-3.33)***	(-3.19)***	(-1.40)
cons	-17.41781	-15.78887	-22.87034	-19.9544	-14.88551	-17.14356	-26.92718	-8.768729
	(-34.31)***	(-12.70)***	(-13.28)***	(-22.80)***	(-12.31)***	(-24.13)***	(-13.82)***	(-2.88)***
R^2	0.5657	0.6640	0.4643	0.7936	0.4741	0.8518	0.9227	0.8989
Prob>F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N	4187	655	981	792	1097	410	194	58
Countries	172	26	45	31	42	18	8	2

(.) T Student ; ***significative au seuil de 1%, **significative au seuil de 5%, *significative au seuil de 10% ; Prob Test de Hausman < 5% donc le modèle à effets fixes est choisi

Introducing energy efficiency as a proxy of technological change instead of industrial activity in the second model give the following results presented in table 2.

Table 2.Model (2) static estimation for sample countries grouped in geographic regions

	All countries	East Asia & Pacific	Europe & Cent Asia	Lat Amer & Carib	Sub-Sah Africa	MENA	South Asia	North America
lpop	0.9754222	0.9151513	0.4852537	1.530821	0.8273308	0.9652992	2.022478	0.9150411
	(58.38)***	(11.39)***	(6.46)***	(28.46)***	(7.91)***	(25.98)***	(13.46)***	(5.28)***
lgpdperc	1.154895	0.9701032	0.026567	0.9353983	1.950792	0.948135	0.9119437	0.9037082
	(55.83)***	(24.53)***	(43.51)***	(20.24)***	(12.14)***	(24.10)***	(6.06)***	(6.04)***
lgdp_enuse	-0.829927	-0.848715	-1.158688	-0.7080729	-1.05175	-0.5291314	-0. 195981	-1.00027
	(-32.39)***	(-14.57)***	(-43.94)***	(-14.93)***	(-7.08)***	(-13.69)***	(-1.08)	(-7.25)***
kyoto_ra	-0.032123	0.0990917	-0.0698262	-0.0361176	0.0602147	-0.0248186	-0.034067	0.0064584
	(-2.68)**	(3.44)***	(-6.10)***	(-1.92)*	(0.90)	(-1.21)	(-0.67)	(0.50)
cons	-14.36249	-11.64975	-6.012394	-21.48831	-18.31909	-12.48515	632.70434	-10.44121
	(-47.30)***	(-9.67)***	(-5.32)***	(-25.05)***	(-8.57)***	(-19.68)***	(-15.58)***	(-4.30)***
N	3455	474	1056	653	583	477	154	58
R2	0.6167	0.8146	0.7610	0.8377	0.3626	0.8858	0.9135	0.9330
Prob>F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Countries	161	23	48	32	29	20	7	2

(.) Student T; *** significant at 1%, ** significant at 5%, * significant at 10% Prob Test hausman <5% so the fixed effects model is chosen

The relationship between income growth and population on the one hand, and pollution on the other hand still significantly positive for all geographical groups of countries. The negative and significant effect of the ratification of the Kyoto protocol on emission level is observed only for all countries sample, Europe and Central Asia and Latin America and Caribbean. However, this effect is significantly positive for East Asia and Pacific meaning that the ratification of Kyoto Protocol doesn't lead to the reduction of emissions. This result can be explained by the fact that countries belonging to this group are countries that are in a

[2] China, Japan, Indonesia, Malaysia, Islands, Australia…

stage of economic growth such as China, Japan, Malaysia and Indonesia. It's true that economies of these countries are based essentially on services sector but the industrial one is very important and consisting especially in heavy manufacturing and polluting industries. Concerning the energy efficiency, results show that it has a significant and a negative effect on emissions level except south Asia for which energy efficiency is not significant. Consequently, policies promoting energy efficiency have a crucial role in reducing pollution. Then governments have to concentrate their efforts in energy efficient technologies.

The third model introduces the two proxies of technological change in addition to urbanization. Results are presented in table 3.

The relationship between economic growth and population and emission level is positive and statistically significant for all sample countries and for different geographic groups of countries. Energy efficiency exhibits a significantly negative on CO_2. However, the second proxy of technology exerts a positive and significant effect for all groups except for Latin America and Caribbean and MENA groups. Urbanization exerts a negative and significant effect on emission for all countries sample, East Asia & Pacific, Europe & Central Asia and South Asia groups. Yet, this relation is statistically positive Lat America & Caribbean, Sub-Saharan Africa and MENA groups. This result can be explained by the fact that the first group of countries achieved a level of development and consequently urbanization that is very important and that the level of urbanization in last year became low.

Table 3.Model (3) static estimation for sample countries grouped in geographic regions

	All countries	East Asia & Pacific	Europe & Cent Asia	Lat Amer & Carib	Sub-Sah Africa	MENA	South Asia	North America
lpop	0.9703775	0.8782037	0.6799333	1.683786	0.9190107	0.9941717	1.463872	1.28671
	(-28.12)***	(9.19)***	(9.51)***	(29.09)***	(7.78)***	(24.05)***	(9.78)***	(4.36)***
lgpdperc	1.074954	0.8911478	1.076575	0.8447391	1.983037	0.9202757	1.351799	0.769655
	(38.98)***	(22.23)***	(42.49)***	(21.33)***	(11.68)***	(22.55)***	(6.70)***	(4.56)***
lgdp_enuse	-0.760406	-0.764301	-1.005139	-0.7771491	-0.9598144	-0.4611897	-0.512410	-0.961400
	(-24.75)***	(-13.30)***	(-38.13)***	(-14.93)***	(-6.16)***	(-10.55)***	(-2.29)**	(-5.46)***
Lurb_pop	-0.157392	-0.198869	-0.3697923	0.1866131	0.4984378	0.0424424	-0.728621	-0.184185
	(-3.69)***	(-3.45)***	(-5.42)***	(2.02)**	(2.11)**	(-3.74)***	(-4.84)***	(-1.35)
lindva	0.3570319	0.4524235	0.3499218	0.0606255	0.1970434	0.0424424	0.872419	0.179976
	(12.96)***	(6.64)***	(16.26)***	(1.52)	(1.88)*	(1.01)	(7.18)***	(1.71)*
kyoto_ra	-0.026238	0.1005225	-0.0487169	-0.048384	0.0016383	-0.0465591	-0.058496	0.001322
	(-1.89)*	(3.53)***	(-4.48)***	(-3.15)***	(0.02)	(-2.11)**	(-1.45)	(0.10)
cons	-14.47115	-11.38906	-8.673745	-23.80275	-22.5496	-12.35634	-26.09748	-16.0457
	(-23.07)***	(-6.82)***	(-7.54)***	(-21.48)***	(-8.02)***	(-15.56)***	(-13.38)***	(-3.64)***
N	3091	446	963	533	545	397	149	58
R^2	0.6233	0.8388	0.8093	0.8898	0.3654	0.8879	0.9485	0.9367
Prob>F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Countries	151	22	44	30	29	18	6	2

(.) Student T; *** significant at 1%, ** significant at 5%, * significant at 10%; Prob Test hausman <5% so the fixed effects model is chosen

The estimation of the three models after the decomposition of our sample according to income level gives the results presented in table 4.

Table 4. The three models static estimation for the sample countries grouped by income level

	Model (1)			Model (2)			Model (3)		
	Low income	Middle income	High income	Low income	Middle income	High income	Low income	Middle income	High income
lpop	1.04601	1.213072	1.211061	1.342064	0.9592954	0.8314945	1.245479	0.9692534	-6.690145
	(17.60)***	(23.30)***	(23.38)***	(14.46)***	(21.12)***	(24.93)***	(12.78)***	(18.52)***	(19.71)***
lgpdperc	0.8215263	0.9400225	0.7253752	1.711106	1.359868	0.6843067	1.340477	1.363021	0.6754842
	(12.51)***	(28.31)***	(25.25)***	(12.84) ***	(36.36)***	(28.28)***	(9.26)***	(33.07)***	(25.87)***
lgdp_enuse				-0.7783596	-1.116066	-0.6698154	-0.4888183	-1.12541	-0.650078
				(-6.16)***	(-26.70)***	(-24.91)***	(-3.47)***	(-23.85)***	(-21.10)***
Lurb_pop							-0.0195967	0.0979996	-0.1634008
							(-0.11)	(1.31)	(-4.91)***
lindva	0.2140563	0.3185639	0.4703456				0.3975769	0.1865417	0.1334188
	(4.49)***	(8.29)***	(14.10)***				(3.94)***	(4.88)***	(3.41)***
kyoto_rats	-0.077913	-0.0792873	-0.0943505	0.0084746	-0.0063322	-0.0354342	-0.0364539	-0.0146817	-0.027982
	(-2.07)**	(-3.85) ***	(-5.00)***	(0.16)	(-0.33)	(-2.98)***	(-0.65)	(-0.74)	(-2.17)**
cons	-15.95181	-18.69275	-16.90958	-25.21863	-15.28126	-7.685083	-22.54642	-16.4124	-6.690145
	(-15.04)***	(-23.60)***	(-21.54)***	(-14.22)***	(-20.86)***	(-14.92)***	(-10.65)***	(-16.54)***	(-9.15)***
N	732	2335	1120	319	1970	1166	292	1796	1003
R^2	0.5286	0.5494	0.6865	0.6727	0.6487	0.7413	0.6929	0.6461	0.7158

Prob>F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Countries	29	99	44	16	97	48	15	94	42

(.) Student T; *** significant at 1%, ** significant at 5%, * significant at 10% Prob Test hausman <5% so the fixed effects model is chosen

The variables population level and economic growth has a significant positive impact for the different estimated models and for the different level of income. Concerning energy efficiency, it exerts a significant and negative effect on emissions level for the models (2) and (3) for different income levels. Furthermore, Industrial activity has a significantly positive effect on emissions. Urbanization introduced in the third model is negatively significant only for high income countries meaning that these countries have achieved a level of urbanization that permit the decrease of emission levels. The effect of Kyoto protocol ratification variable is significantly negative for the first model. The introduction of energy efficiency in the two others models makes the protocol ratification significant only for high income countries. This can be explained by the fact that high income countries are countries concerned with emissions reductions obligations. However, the significance of this variable in the first model is due to the non existence of energy efficiency as explanatory variable.

Results are in accordance with Dietz and Rosa (1997) and Grunewald and Martínez-Zarzoso (2011) suggested that population and economic growth intensify GHG emissions. Concerning industrial activity, our findings are in line with York et al (2003) that found that industrialization increases CO_2 emissions. However, our results concerning energy efficiency are in dissonance with Hiroki and Keisuke (2010)'s findings. The negative and significant relationship between Kyoto protocol ratification and CO_2 emissions was supported by Martínez-Zarzoso (2009). Furthermore, studying the northern EU country group, Mazzanti and Musolesi (2009) find an effect of the Kyoto Protocol on CO_2 emissions. Comparison with other researches concerning geographical group is not conducted since there is no research that performed this decomposition. The increasing effect of urbanization on emissions level was supported by Zhu et al (2012). However, the negative effect for high income countries is in line with Martínez-Zarzoso (2009)'s results.

4.2. Dynamic estimation results

The dynamic approach assumes that CO_2 emissions of the last year have an impact on this year's emissions. However, dynamic models suffer from a bias, which is caused by the endogeneity of the lagged dependent variable. Since $lnCO_2$ is a function of v_{it}, then $lnCO_{2t-1}$ will be a function of v_{it} as well and therefore endogenous. The endogeneity problem can be solved by Anderson Hsiao (AH) estimator by using instruments for the lag endogenous variable ($lnCO_{2t-1}$). The efficiency of this estimator was criticized by a number of authors since other instrumental variable estimators such as the Arellano Bond and Blundell Bond estimator use more instruments and are more efficient. For this we use the Arellano Bond estimator in the present paper. Estimation results of the first model with the GMM method proposed by Blundell and Bond (1998) are presented in table 5.

Table 5. Model (1) dynamic estimation for countries grouped in geographic regions

	All countries	East Asia & Pacific	Europe & Cent Asia	Latin Amer & Carib	Sub-Sah Africa	MENA
lCO_2(t-1)	0.7256033	0.6801799	0.6702608	0.5727142	0.7090386	0.4985918
	(763.05)***	(9.57)***	(36.57)***	(27.01)***	(33.31)***	(1.75)*
lpop	0.3430552	0.3455252	0.3116438	0.6291212	0.314365	0.7664782
	(52.07)***	(1.75)*	(1.87)*	(9.85)***	(12.49)***	(1.52)
lgpdperc	0.2636021	0.2972293	0.2104636	0.4383992	0.4061668	0.2389229
	(136.25)***	(3.72)***	(15.68)***	(9.73)***	(9.71)***	(1.93)*
lindva	0.0346112	-0.030282	0 .1471797	0.0608423	-0.0071669	0.0619643
	(18.10)***	(-0.33)	(11.19)***	(1.01)	(-0.32)	(1.43)
kyoto_ra	-0.0385867	-0.012423	-0.0360211	-0.0603946	-0.0190733	-0.0158493
	(-41.00)***	(-1.09)	(-11.96)***	(-9.02)***	(-3.16)***	(-0.33)
cons	-5.179398	-4.797716	-3.878951	-9.62957	-5.69364	-9.312878
	(-51.53)***	(-1.96)**	(-1.52)	(-15.80)***	(-14.40)***	(-1.65)*
Sargan test	168.3486	23.19206	42.39572	25.32982	38.04655	15.55509
	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)	(1.0000)
Arellano-Bond test AR(1)	-4.7705	-2.7794	-3.6123	-1.9179	-3.219	-1.9154
	(0.0000)	(0.0054)	(0.0003)	(0.0551)	(0.0013)	(0.0554)
Arellano-Bond test AR(2)	0.15693	-0.7054	0.2874	1.115	0.01214	0.86093
	(0.8753)	(0.4806)	(0.7738)	(0.2648)	(0.9903)	(0.3893)
Observations	3883	613	895	740	1021	379
Countries	172	26	45	31	42	18

T-students are provided in parentheses: ***, ** and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Sargan statistic is a Sargan-Hansen test of over identifying restrictions. AR (k) is the test for k-th order autocorrelation. Estimation are made using two-step System GMM. We note that there is no second-order autocorrelation of errors for difference equation, because the test of second order autocorrelation AR (2) does not allow rejecting the hypothesis of absence of second-order autocorrelation. The instruments used in our regressions are valid, because Hansen test does not reject the hypothesis of validity of lagged variables in levels and in difference as instruments.

Results show that for the different models estimated, the coefficient of the lagged endogenous variable is positive and strongly significant. Consequently, last year's emissions have a strong impact on today's ones. The integration of several explanatory variables in the basic model gives the following results:

- The variable population exerts a significant positive effect for all countries sample and for all groups except MENA group;

• Income growth exhibits a positive impact on emissions meaning that economic growth leads to environmental degradation;

• The variable industrial activity presents a positive and significant effect only for all countries and for Europe and central Asia group. Meaning that industrial activity increases emissions level;

• The variable Kyoto ratification indicates the impact of the ratification of this protocol and consequently the adoption of less pollutant technologies on emission level. Results demonstrate a negative and significant effect for all groups of countries except the East Asia & Pacific and MENA group. In fact, for all countries sample, a country with emission reduction obligations emits on average around 4 percent less CO_2 which is almost the same result found by Hiroki and Keisuke (2010). Table 6 presents estimation results of the 2nd model where energy efficiency was integrated as a proxy of technological changes.

Results show that the elasticity of this variable is negative and significant for all sample countries and all geographical groups. Income growth approximated by GDP per capita still has a positive and statistically significant impact for all groups of countries. The impact of population is positively significant on emissions except for East Asia & Pacific for which this impact isn't significant and for Europe & Central Asia whose population exhibits a significant negative effect on CO_2 emissions. This result can be explained by the fact that European countries exhibit a decreasing number of inhabitants. However, the Kyoto ratification presents a negative and significant effect except for East Asia & Pacific and MENA groups on the endogenous variable. The negative sign of the Kyoto protocol ratification and emission levels indicates that these groups attempt to reduce their emissions and meat their quantified engagements.

Table 6. Model (2) dynamic estimation for countries grouped in geographic regions

	All countries	East Asia & Pacific	Europe & Centr Asia	Latin Amer & Carib	Sub-Sah Africa	MENA
lCO_2(t-1)	0.7053663	0.615504	0.441933	0.5567771	0.7381439	0.5081452
	(687.75)***	(11.58)***	(28.72)***	(27.62)***	(20.33)***	(5.31)***
lpop	0.1420076	0 .1620568	-0.3761161	0.6737836	0.2735716	0.5329614
	(29.74)***	(0.47)	(-3.65)***	(32.70)***	(5.39)***	(4.61)***
lgpdperc	0.5654581	0.4209583	0.7827296	0.5285678	0.7484547	0.3077089
	(330.26)***	(5.29)***	(20.15)***	(14.01)***	(42.99)***	(2.07)**
lgdp_enuse	-0.5436957	-0.279122	-0.7780011	-0.3700217	-0.5605283	-0.3352268
	(-368.23)***	(-3.32)***	(-19.29)***	(-7.90)***	(-7.63)***	(-4.06)***
kyoto_ra	-0.0126348	-0.0386629	-0.0213561	-0.0540382	-0.0183703	0.0050786
	(-27.52)***	(-0.74)	(-8.97)***	(-2.61)***	(-8.60)***	(0.44)
cons	-3.377739	-1.81534	5.891979	-10.2593	-7.044737	-5.462081
	(-45.07)***	(-0.40)	(3.82)***	(-26.36)***	(-11.47)***	(-6.30)***
Sargan test	158.4986	17.44634	-0.05068	25.32571	24.02861	13.2974
	(1.0000)	(1.0000)	(0.9596)	(1.0000)	(1.0000)	(1.0000)
Arellano-Bond test AR(1)	-4.0791	-2.1709	-3.1711	-2.6273	-2.5025	-3.0222
	(0.0000)	(0.0299)	(0.0015)	(0.0086)	(0.0123)	(0.0025)
Arellano-Bond test AR(2)	-0.95629	-1.764	-0.05068	0.46683	-1.1205	0.79231
	(0.3389)	(0.0777)	(0.9596)	(0.6406)	(0.2625)	(0.4282)
Observations	3154	432	964	590	532	441
Countries	161	23	48	32	29	20

T-students are provided in parentheses: ***, ** and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Sargan statistic is a Sargan-Hansen test of over identifying restrictions. AR (k) is the test for k-th order autocorrelation. Estimation are made using two-step System GMM. We note that there is no second-order autocorrelation of errors for difference equation, because the test of second order autocorrelation AR (2) does not allow rejecting the hypothesis of absence of second-order autocorrelation. The instruments used in our regressions are valid, because Hansen test does not reject the hypothesis of validity of lagged variables in levels and in difference as instruments.

The dynamic estimation results of the third model are presented in table 7.

Table 7. Model (3) dynamic estimation for countries grouped in geographic regions

	All countries	East Asia & Pacific	Europe & Centr Asia	Lat Amer & Carib	Sub-Saharan Africa	MENA
CO_2 (t-1)	0.677495	0.6279886	0.379821	0.5307351	0.8191581	0.147903
	(466.33)***	(13.99)***	(18.17)***	(8.28)***	(17.35)***	(0.58)
lpop	0.1429838	0.4352753	-0.1529535	0.7118609	0.5622146	1.77166
	(21.01)***	(0.86)	(-0.38)	(4.16)***	(5.06)***	(2.56)***
lgpdperc	0.5773768	0.4225074	0.792874	0.4872919	0.5872562	0.0139186
	(246.77)***	(4.72)***	(25.64)***	(11.53)***	(3.54)***	(0.05)
lgdp_energyuse	-0.5521717	-0.2964214	-0.7871759	-0.3711262	-0.4293567	0.1556738
	(-174.25)***	(-3.23)***	(-12.57)***	(-6.39)***	(-1.94)*	(0.66)
Lurb_pop	-0.0685487	0.4924046	0.076824	0.1988152	1.877854	0.728032
	(-14.24)***	(0.66)	(0.16)	(0.47)	(2.11)**	(0.95)
lindva	0.0622293	0.127167	0 .1442708	0.0099449	-0.2379768	0 .0644876
	(28.46)***	(1.14)	(2.82)***	(0.20)	(-2.16)**	(0.81)
kyoto_ra	-0.0131627	0.0142138	-0.0113094	-0.0313248	-0.0741157	-0.0237137
	(-27.92)***	(1.07)	(-2.94)***	(-4.25)***	(-2.27)**	(-1.59)
cons	-3.176854	-8.553868	2.134257	-10.97913	-16.98416	-22.21856
	(-30.86)***	(-0.82)	(0.28)	(-3.12)***	(-3.89)***	(-2.41)**

Sargan test	143.4228 (1.0000)	14.45228 (1.0000)	39.57619 (1.0000)	20.33032 (1.0000)	18.73294 (1.0000)	10.68392 (1.0000)
Arellano-Bond test AR(1)	-3.5462 (0.0004)	-2.0554 (0.0398)	-2.9059 (0.0037)	-2.9631 (0.0030)	-2.7756 (0.0055)	-1.1357 (0.2561)
Arellano-Bond test AR(2)	-1.4665 (0.1425)	-1.6681 (0.0953)	0.00233 (0.9981)	-1.9045 (0.0568)	-1.4905 (0.1361)	0.85171 (0.3944)
Observations	2821	407	879	482	496	365
Countries	150	22	44	30	28	18

T-students are provided in parentheses: ***, ** and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Sargan statistic is a Sargan-Hansen test of over identifying restrictions. AR (k) is the test for k-th order autocorrelation. Estimation are made using two-step System GMM. We note that there is no second-order autocorrelation of errors for difference equation, because the test of second order autocorrelation AR (2) does not allow rejecting the hypothesis of absence of second-order autocorrelation. The instruments used in our regressions are valid, because Hansen test does not reject the hypothesis of validity of lagged variables in levels and in difference as instruments.

Results show that the lagged endogenous variable is statistically significant and positive for all studied groups except MENA group. Consequently, last year's emissions have a strong impact on today's ones. Results for the variable population are the same for the second model. The impact of economic growth still positive except for the MENA group for which GDP per capita become non significant. The impact of population and Kyoto ratification is the same of the second model estimation. Concerning the two proxies of technological changes: the elasticity of energy efficiency relative to emissions is negative and significant for all sample countries and all geographical groups as the second estimated equation except for MENA groups for which the impact is insignificant and positive, however, industrial activity presents a positive and significant effect only for all countries and for Europe and central Asia group. The same result is noticed as regards Kyoto ratification.

Table 8 presents results for the different estimated models for different groups of countries decomposed according to the level of income.

Table 8. The three models dynamic estimation for the sample countries grouped by income level

	Model (1)			**Model (2)**			**Model (3)**		
	Low income	**Middle income**	**High income**	**Low income**	**Middle income**	**High income**	**Low income**	**Middle income**	**High income**
lCO_2(t-1)	0.5586238 (9.26)***	0.7234318 (242.10)***	0.6582507 (32.22)***	0.6109706 (8.32)***	0.6817232 (361.83)***	0.5861227 (64.36)***	0.1133814 (0.41)	0.674148 (187.56)***	0.5560301 (38.28)***
lpop	0.5046914 (5.84)***	0.3827157 (35.40)***	0.3959427 (8.12)***	0.333939 (0.97)	0.1922618 (37.84)***	0.3271729 (12.43)***	0.7503256 (1.38)	0.2162763 (10.46)***	0.3712442 (9.13)***
lgpdperc	0.3646471 (3.83)***	0.2441391 (78.45)***	0.310295 (13.09)***	0.8490308 (3.41)***	0.7213998 (150.32)***	0.3237195 (23.87)***	1.124825 (1.64)	0.7404889 (89.64)***	0.3229815 (14.23)***
gdp_eneuse				-1.275544 (-2.48)**	-0.6895097 (-146.87)***	-0.4055221 (-27.27)***	-0.2044353 (-0.76)	-0.7204565 (-80.66)***	-0.365573 (-20.80)***
Lurb_pop							-3.83678 (-0.84)	0.1695532 (3.21)***	-0.033907 (-0.34)
lindva	0.089421 (1.18)	0.0694611 (11.92)***	0.1090576 (3.22)***				-0.1582853 (-0.55)	0.0447108 (22.11)***	0.047822 (2.42)**
kyoto_ra	-0.04490 (-1.92)	-0.02699 (-21.14)***	-0.0485805 (-16.03)***	0.0028294 (0.15)	-0.019266 (-18.67)***	-0.005795 (-3.58)***	-0.526953 (-2.15)**	-0.024421 (50.11)***	-0.00841 (-4.20)***
cons	-7.71329 (-6.17)***	-5.684006 (-38.20)***	-5.95281 (-7.13)***	-6.803054 (-1.53)	-4.847515 (-80.41)***	-3.086551 (-11.47)***	0.9863989 (0.04)	-5.985256 (-13.26)***	-3.56595 (-5.33)***
Sargan test	22.75529 (1.0000)	93.04615 (1.0000)	37.3205 (1.0000)	6.876083 (1.0000)	92.43417 (1.0000)	43.99464 (1.0000)	3.199619 (1.0000)	89.3367 (1.0000)	34.11241 (1.0000)
Arellano-Bond test AR(1)	-2.2038 (0.0275)	-3.9294 (0.0001)	-1.6614 (0.0966)	-1.9785 (0.0479)	-3.1813 (0.0015)	-3.6427 (0.0003)	-0.09704 (0.9227)	-2.7919 (0.0052)	-3.3819 (0.0007)
Arellano-Bond test AR(2)	-1.139 (0.2547)	-0.88791 (0.3746)	1.0348 (0.3007)	-0.43308 (0.6650)	-0.74957 (0.4535)	-0.63653 (0.5244)	-0.10972 (0.9126)	-1.1407 (0.2540)	-0.65314 (0.5137)
Observ	680	2165	1038	291	1789	1074	266	1632	923
Countries	29	99	44	16	97	48	14	94	42

T-students are provided in parentheses: ***, ** and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Sargan statistic is a Sargan-Hansen test of over identifying restrictions. AR (k) is the test for k-th order autocorrelation. Estimation are made using two-step System GMM. We note that there is no second-order autocorrelation of errors for difference equation, because the test of second order autocorrelation AR (2) does not allow rejecting the hypothesis of absence of second-order autocorrelation. The instruments used in our regressions are valid, because Hansen test does not reject the hypothesis of validity of lagged variables in levels and in difference as instruments.

Concerning the first model, population, GDP per capita and industrial activities exert a positive and significant impact on CO_2 emissions, except low income countries for which industrial activity isn't significant. This result can be explained by the fact that the industry in low income countries isn't enough developed so that it affects environment. However, Kyoto ratification exhibits a negative and significant effect except for low income countries.

With respect to the second model, GDP per capita and population still have the same effect as in the first model except for low income countries for which population impact isn't statistically significant, the variable energetic efficiency has a significant and negative effect on emissions for all groups of countries. Concerning Kyoto protocol ratification we can remark that its effect in the same as the first equation.

Regarding the third model, all explanatory variables aren't statistically significant for low income countries except Kyoto protocol ratification that has a negative and significant impact on emissions. However, for middle and high income countries, the sign and the significance of the variables remain the same as in the second model. Industrial activity exhibits a positive and significant effect which is the same result as the first model. Kyoto protocol ratification has a negative and significant impact on emissions. It is very important to note that the negative impact on emissions is more important in middle income than in high income countries. The variable urbanization causes environmental degradation only for middle income countries. This can be explained by the fact that the level of economic growth in these countries requires investments in infrastructure and urbanization process causing energy use and environmental destruction.

Comparing the results of the present research with the literature, we can note that results concerning the lagged endogenous variable, population, economic growth, industrial activity are in accordance with Grunewald and Martínez-Zarzoso (2009), Martínez-Zarzoso (2009), Hiroki and Keisuke (2010) and Grunewald and Martínez-Zarzoso (2009). The negative sign of the relation between Energy efficiency is in accordance with the findings of Martínez-Zarzoso (2009) who studied 121 countries during the period 1975-2003, However, Hiroki and Keisuke (2010) found a negative one. This difference can be due the sample of countries and the period studied by these authors which is composed from 119 countries. Results concerning the negative effect of Kyoto protocol ratification are in accordance with those found by Grunewald and Martínez-Zarzoso (2009) and Hiroki and Keisuke (2010) how studied different GHG in addition to CO_2. Comparison with other researches concerning geographical group is not conducted since there is no research that performed this decomposition.

5. Conclusion

Anthropogenic climate change which is the consequence of greenhouse gas emissions has serious negative effects over generations. For this, their reduction is very important in order to achieve sustainable development. Aiming to reduce these emissions, Kyoto Protocol had been adopted in 1997 and ratified by an important number of countries, most of which are developed countries, except the United States. In this paper we developed the theoretical and the analytical framework of STIRPAT model to analyze the determinants of carbon dioxide emissions and to investigate the effects of the Kyoto Protocol's quantified emission reduction, using three model specifications. Via time-series cross-section data from 214 countries for the period ranging from 1980 to 2010, we tried to study the effect of affluence, population and technology on emissions and consequently their effect on damaging the environment for different income and geographical groups of countries.

In this perspective, we analyzed five main hypotheses. First, we studied the role of population in environmental degradation. Results from static and dynamic models showed that population contributes to the increase of dioxide carbon emissions and this is true for all countries sample and almost all geographical and different income groups. Second, we investigated the responsibility of economic growth on environmental degradation. The analysis shows that growing GDP per capita conduct to growing emission level. However, we could rather conceive to develop better technology to overcome the rise of emissions due to economic growth than slowing down growth to reduce environmental problems. Hence the third hypothesis that tended to test the damaging effect of the adopted technology using two different proxies namely industrial activity measured by the weight of industrial activity in the GDP and energy efficiency measured as GDP divided by energy use. Industrial activity contributes to carbon dioxide emissions especially for developed countries which possesses an important growth rate. As regards energy efficiency, it contributes to emissions reduction and this for almost all geographical and income groups. Consequently, using more efficient technology may overcome the effects of economic growth that causes environmental degradation. Fourth, we appealed to verify the effect of urbanization on CO_2 emissions. Results are different according to income level. The elasticity is negative for high income countries with static model estimation and positive for middle income countries with dynamic one. These result leads to a very important finding stipulating that when urbanization achieve a certain level of development it will contribute to reducing emissions. Finally, we tried to verify the effect of Kyoto Protocol ratification on emissions. In fact, this variable exhibits a negative effect for all countries sample. This result is in accordance with Grunewald and Martinez-Zarzoso (2009), Hiroki and Keisuke (2010) and Mazzanti and Musolesi (2009) for northern EU countries. Decomposing the sample in geographical groups, we can remark that when estimating the static model the ratification of this protocol doesn't affect emissions level mainly for North America and sub-Saharan Africa. This can be explained by the fact that United States signed but haven't ratified the protocol and sub-Saharan Africa group isn't concerned with quantified obligations of this protocol. Studying countries grouped according to income level, we concluded that Kyoto protocol ratification has a negative impact mainly for high income countries when estimating the static model and for middle and high income countries while estimating the dynamic one. This paper tried to detect the impact of Kyoto protocol on emissions level. A very important issue to be examined in further researches is the impact of the flexible mechanisms of this protocol that is: joint implementation, clean development mechanism and tradable emission permits. These mechanisms allow countries having quantified obligations to reduce their emissions in other countries while reducing their costs of realization.

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