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Determinants of CO_2 Emission: A Global Evidence

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ABSTRACT

Our article aims to establish a link between carbon dioxide emissions and its various reasons by employing a complex model comprising economic growth, industrial structure, tourist arrivals, foreign direct investment, energy use, trade, and agriculture globally. We have employed GMM models on a panel dataset comprising of 168 countries and 24 years to test our hypotheses. Results confirm the standard environmental Kuznets curve hypotheses together with a positive role of nuclear energy and renewable energy production in reducing CO_2 emissions, while energy from coal increased environmental pollution as expected. Regarding the role of agriculture, estimates showed that while agricultural development reduces, the impact of agricultural land productivity rather stimulates environmental pollution at global level. The extension of international tourism and trade can also enhance environmental degradation by rising CO_2 in the atmosphere. Finally, we found that financial development reduced air pollution.

Keywords: CO_2 Emission, Growth, Tourism, Energy, Agriculture, Trade
JEL Classifications: Q54, Q56

1. INTRODUCTION

The first important international agreement targeting the reduction of environmental pollution was the United Nations Framework Convention on Climate Change, adopted at the Rio Earth Summit in 1992. A few years later, in 1997, the Kyoto Protocol introduced legally a binding emission reduction targets for developed countries.

Since the Paris Agreement signed in 2015, dealing with greenhouse gas emission mitigation, aiming to hold global average temperature growth below 2 °C, climate change and its causes are back on the policy agenda. In addition, the European Environment Agency and the Partnerships in Environmental Management for the Seas of East Asia were founded. These agreements and research institutions highlight the importance of the problem and call the researcher's, decision marker's attention to global environmental concerns.

The carbon dioxide (CO_2) – representing a major component of greenhouse gases (GHG) - is considered as one of the most important causes of increasing global warming and climate change (IPCC, 2014). Moreover, the influence of CO_2 on global warming is expected to continue in the future. Statistics show that the CO_2, more than any other driver, has contributed the most to climate change between 1750 and 2005 (UCS, 2017).

Since the Industrial Revolution, human activities have contributed substantially to climate change by adding CO_2 and other heat-trapping gases to the atmosphere. The emissions of these GHG have increased the greenhouse effect and caused Earth's surface temperature to rise (EPA, 2017). Hence growing industrialisation has worsened the ecological environment and also stimulated the global warming (Adom et al. 2012).

Human activities, such as the burning of fossil fuels and changes in land use, release large amounts of CO_2, causing concentrations in the atmosphere to rise (EPA, 2017). The emissions of carbon dioxide have increased by almost 40% compared with pre-Industrial Revolution times. Consequently, because CO_2 absorbs heat, more CO_2 has increased the amount of the heat in for the Earth's heat balance (Solomon et al., 2007; Stone et al., 2009).

Another problem with CO_2 is that it remains in the atmosphere longer than the other major heat-trapping gases. However, in the case of CO_2, much of today's emissions will be gone in a century, but about 20% will still exist in the atmosphere approximately 800 years from now (Forster et al., 2007). CO_2's long life in the atmosphere provides the clearest possible rationale for reducing the level of CO_2 emissions without delay (UCS, 2017). The highest share of CO_2 emission produced by middle income countries in Asia, more specifically in India and China. Major contributors of the pollution derived from agriculture, energy production, and energy use. Trade is also associated with transport of good, transboundary pollution and relocation of the manufacturing industries indicating the growth of pollution. Foreign direct investment (FDI) and the intensity of tourism industry can also influence level of the global warming and climate change through CO_2 emission.

Although there are a large number of papers dedicated to the topic, the literature seems to have only concentrated on single factors and countries as examples. This paper aims to establish the link between air pollution proxied by carbon dioxide emissions and many segments influenced such as economic growth, tourism arrivals, industrial structure, FDI, energy use, trade and agriculture globally. Consequently, the paper aims to contribute to the existing empirical literature in two ways. First, the impacts of a set of different variables from different industries are investigated to CO_2 emissions instead of single indicators. Second, global analyses are made instead of country level investigations. Furthermore, several environmental hypotheses such as Environmental Kuznets Curve, pollution heaven hypothesis, energy production, agricultural activities, industrial structure, the role of trade and tourism are tested here.

The article is organized as follows. Section 2 summarizes the theoretical framework, outlines the relevant literature while Section 3 discusses the applied data and methodology. The preliminary tests and regression results are presented in Section 4, while Section 5 concludes and it suggests recommendations for decision makers.

2. ANALYTICAL FRAMEWORK

In this section, we outline the most relevant literature relating to the environmental pollution, economic development, agriculture, and trade. Economic development is closely related to CO_2 emissions since more economic development causes more energy consumption, leading to more pollution. However, a more developed economy might also be more efficient in energy terms, leading to less CO_2 emissions. This nexus has largely been discussed and tested in the literature by different variables.

One strand of the literature focuses on the link between environmental pollution and income by applying the well-known environmental Kuznets curve (EKC) hypothesis, generally claiming an inverted U-curve relationship between income and environmental pollution. In other words, environmental damage first increases with income, then stabilizes and eventually declines (Selden and Song, 1994). The investigation of Andersson and Karpestam (2013), for instance, show that economic growth is not responsible for environmental pollution. In this context, the Turkish experience was investigated by Bozkurt and Akan (2014), demonstrating that CO_2 had a negative relationship with economic growth. Tiwari (2011) also found a negative relationship between CO_2 and economic growth by using the impulse response function and the variance decomposition indicator. Oil consumption, carbon dioxide emissions and growth was investigated by Lim et al. (2014). Considering the Philippines experience, the study demonstrates a negative correlation between CO_2 and economic growth in long rung for 1965-2012. Results presented by Ghosh et al. (2014) also showed a negative correlation between CO_2 and economic growth to Bangladesh. The empirical study of Saidi and Hammami (2014) considered the relationship between energy consumption, carbon dioxide emissions and economic growth. The authors used a panel data for the period 1990-2012. By applying a GMM model, their econometric results demonstrated that carbon dioxide emissions were negatively correlated to economic growth. The research of Kais and Mbarek (2015) also showed a negative effect of CO_2 on economic growth in Algeria and Tunisia.

Another part of the literature focuses on the relationship between energy use and environmental pollution. The idea behind is that economic growth is closely related to energy consumption as higher economic development requires more energy consumption.

Transboundary spillovers of pollution make researcher's attention to trade-environment linkages a matter of reality. The most discussed concerns involve emissions of ozone-layer depleting chlorofluorocarbons (CFC) and other GHG, which threaten global climate (Esty, 2001). Ang (2009) analyzed Chinese CO_2 emission and energy consumption data for 1953-2006 and indicated that more energy use, higher income and greater trade openness tended to cause more CO_2 emissions. In a multivariate causality study for China, Zhang and Cheng (2009) found a unidirectional Granger causality running from energy consumption to carbon emissions in the long-run but neither of them contributed to economic growth in their model. Hwang and Yoo (2014) investigated similar relationships in Indonesia on annual data covering the period 1965-2006 and showed that there was a bi-directional causality between energy consumption and CO_2 emissions, implying that an increase in energy consumption directly affects CO_2 emissions and that CO_2 emissions also stimulate further energy consumption. Alshehry and Belloumi (2015) also analyzed energy consumption, carbon dioxide emissions and economic growth linkages in Saudi Arabia and found at least a long-run relationship between energy consumption, energy price, carbon dioxide emissions, and economic growth.

According to many authors, industrial structure is an important determinant of carbon dioxide emissions (Adom et al., 2012; Zhu et al., 2014; Mi et al., 2015). Shifting the industrial structure from energy-intensive to non-energy-intensive sectors helps to ease the CO_2 emissions at an affordable economic cost (Zhu et al., 2014).

Another, though limited, part of the literature is dedicated to interrelationships between agriculture and carbon dioxide emission. Henders et al. (2015) investigated relationships between carbon emission and land use change and found that in the period 2000-2011, the production of beef, soybeans, palm oil, and wood products in the seven countries was responsible for 40% of total tropical deforestation and resulting carbon losses. Similar results were reached by Baccini et al. (2012), suggesting that tropical deforestation caused by agricultural purposes is also a major source of greenhouse gas emissions. In general, however, agriculture was responsible for 7-14% of global carbon dioxide (CO_2) emissions in 2000-2005 (Grace et al., 2014). Foley et al. (2011) goes even further and suggest that agriculture not only uses resources such as petroleum and water but it is reported to contribute 30-35% of global greenhouse gas emissions, mainly with practices associated with tropical deforestation, methane emissions from livestock, emissions from the use of farm machinery and emissions from fertilized soils.

Agricultural trade also has indirect environmental effects, for example larger-scale export agriculture displaces farmers onto marginal lands leading to deforestation and soil erosion. Many developing countries, the structural adjustment policies the area devoted to export crops increases. In some cases, the environmental effects of shifting to export crops can be significant and harmful. Moreover, many products (for example rose) are flown to Europe by jet from different area of the World (e.g. Africa), raising the issue of transportation energy use, but the energy consumed in jet fuel approximately equals the energy needed to produce similar products in Europe (Harris, 2004). In addition, the genetic diversity characteristic of small-scale farming maybe threatened, which could result in the loss of a living seed bank of great importance to world agriculture (Wise, 2007, 2011).

Tourism and environmental pollution is also investigated by a considerable amount of studies. Lee and Brahmasrene (2013) analyzed the influence of tourism on economic growth and carbon emissions in the European Union by using 1988-2009 data and results from panel cointegration techniques and fixed-effects models indicate that a long-run equilibrium relationship exists among these variables, while tourism and FDI incur a high significant negative impact on CO_2 emissions. Solarin (2014) investigated the determinants of carbon dioxide emission with special emphasis on tourism development in Malaysia and by applying cointegration and causality tests on their sample, results suggest long-run relationships between the series and a positive unidirectional long-run causality running from tourist arrivals and the other series to pollution. Scott et al. (2010) examined how global tourism sector can achieve its share in reducing GHG emission. Their analysis reveals that with current high-growth emission trends in tourism, the sector could become a major global source of GHGs in the future if other economic sectors achieve significant emission reductions. Success in achieving emission reductions in tourism is found to be largely dependent on major policy and practice changes in air travel. Moreover, Sharif et al., (2017) also analyzed the impact of tourism on CO_2 emission by applying various co-integration techniques on Pakistani data from 1972 to 2013 and found a uni-directional causality between CO_2 emission and tourist arrivals running from tourist arrival to CO_2 emission. Consequently, the authors noted that policies which moderate the influence of tourism development to emission were necessary for reducing the harmful effect of tourist activities.

Last but not least, some studies focus on the role of foreign business activities in environmental pollution. On the one hand, according to the pollution haven hypothesis companies that choose to physically invest in foreign countries tend to relocate to the countries with the lowest environmental standards or weakest enforcement, thereby 'exporting' pollution. Many studies have tested this hypothesis – an excellent overview on the topic is provided by Millimet and Roy (2015). Alternatively, the technology transfers view suggests that increase of trade openness can accelerate the capital mobility for new technologies, technology transfer and ease the facility of environment-friendly technologies. This circumstances might decrease the environmental degradation and pollution in long term (Akin, 2014). However, Weber et al. (2008), Chebbi et al. (2009), Sharma (2011) as well as Shahbaz and Leitao (2013) found that international trade has positive impact on carbon dioxide emissions.

In sum, studies exploring environment-income-energy-trade linkages usually analyse partially these factors of pollutions. By contrast, the role of economic development, energy use, trade, agricultural productivity, inducing environmental concerns at global perspective is relatively understudied yet. Our purpose is to discover a complex environmental aspect of these factors using various environmental indicators available at the global level.

3. METHODOLOGY AND ECONOMETRIC SPECIFICATIONS

Based on the empirical literature above, the following six hypotheses are tested.

H1: The higher the income growth of a country is, the higher the environmental pollution growth is.

The first hypothesis tests the validity of the EKC curve described in the section of theoretical framework. The use of a quadratic relationship between per capita real GDP and per capita CO_2 emission is necessary to capture the relationship of these variables (Ang, 2007). Income growth is captured via GDP growth, while environmental pollution is measured by CO_2 emission per capita in kiloton. Data are derived from the World Bank World Development Indicators database and a positive relationship is expected. The squared term of GDP expected to be negative because of the U shape of the EKC curve.

H2: The rising share of electricity production from nuclear as well as renewable energy diminish, while energy production from coal increase environmental pollution.

This approach is of interest because the world demand for electricity is increasing with population and economic growth. Electricity can be produced using various natural resources such as oil, coal, natural gas while renewable energy (wind-power, hydro-power, geothermic energy) and nuclear power also produce fewer CO_2 emission during the production of electricity (Zhang and Cheng, 2009; Leitão, 2014).

In contrast, a positive relationship is expected for coal energies (Friedl and Getzner, 2003) increasing air pollution. Data are from the World Bank (2017) World Development indicator (WDI) database.

H3: Agricultural production enhance environmental pollution trough use of farm machinery and emissions from fertilized soils.

The link between agriculture and the environment is twofold but based on empirical evidence discussed above, agriculture positively contributes to environmental pollution (Henders et al., 2015; Baccini et al., 2012; Grace et al., 2014; Foley et al., 2011). Agricultural production is proxied by agricultural value added per hectare and per worker in US dollar. Data are from the World Bank WDI database and a positive relationship is expected.

H4: Number of international tourist arrivals are active contributors to environmental pollution.

The number of tourist arrivals seems to significantly contribute to environmental pollution in the empirical literature (Sharif et al., 2017; Solarin, 2014; Lee and Brahmasrene, 2013; Scott et al., 2010). The biggest problem with the growth of tourism is its high dependency on transportation, energy consumption, which is associated with combusting fossil fuels and a consequential effect of greenhouse gas emissions (Becken et al., 2003). In our model, the number of tourist arrivals is coming from the World Bank WDI database and again, a positive sign is expected.

H5: FDI reduces environmental pollution.

According to the pollution haven hypothesis, companies exporting pollution to third countries. By contrast, many researchers (Liang, 2006, Wang and Yanhong, 2007, Eskeland and Harrison, 2003, Tamazian et al., 2009) did not find evidence for the pollution haven hypothesis and suggested that foreign plants were more energy efficient and used cleaner types of energy than domestic ones. This hypothesis is tested by using FDI, net inflows (% of GDP) from the World Bank WDI database. A negative relationship is expected.

The global trade expansion has raised the topic of the relationship between trade and the environment, therefore, our paper addresses the hypothesis.

H6: Trade openness causes higher CO_2 emission.

However, Jayanthakumaran et al. (2012) suggests that in the short-run international trade tends to reduce CO_2 emissions, trade openness seems to cause higher CO_2 emission as far as many other studies suggest (Nakano et al., 2009; Chebbi et al., 2009, Yan and Yang, 2010, Sharma, 2011, Shahbaz and Leitao, 2013). Trade openness is proxied by total trade as the percentage of GDP. A positive sign is expected.

Finally, industrial structure is also tested, represented by variable measuring country's industrial value added in percent of GDP (Adom el al., 2012). The positive effect is expected.

H7: Highly industrialized countries produce more CO_2.

In these paper, we employ representative panel sample of world countries for the last two decades. General panel tests (unit root, serial correlation and cross sectional dependency) are also applied in order to ensure the robustness of our results.

First, we start our regression estimation with a baseline model including only the variables of EKC hypothesis. After we add the different group of explanatory variables representing fossil and renewable energy use, agricultural activity, tourism, industrial structure trade and FDI. The logarithmic version for our extended estimation model can be written as follows:

$$\ln CO_{2it} = \alpha + \beta_1 \ln GDPPC_{it} + \beta_2 \ln (GDPPC_{it})^2 + \beta_3 NUC_{it} + \beta_4 \ln ENRG_{it} + \beta_5 RENW_{it} + \beta_6 \ln AgrVApw_{it} + \beta_7 \ln AgrVApha_{it} + \beta_8 Trade_{it} + \beta_9 FDI_{it} + \beta_{10} \ln Tourism_{it} + \beta_{11} Industr_{ti} + \varepsilon$$

Where

$lnCO_{2it}$ is the per capita CO_2 emission (metric tons per capita) as dependent variables, representing the level of air pollution

$GDPPC_{it}$ Per Capita Gross Domestic Product (GDP per capita, in current USD)

NUC_{it} is the electricity production from the nuclear source (% of total)

$ENRG_{it}$ Electricity production from coal (% of total)

$RENW_{it}$ Renewable electricity output (% of total electricity output)

$lnAgrVApha_{it}$ represents land productivity – Agricultural value added per hectare (current USD per hectare)

$lnAgrVApw_{it}$ represents labour productivity – Agricultural value added per worker (current USD per worker)

FDI - Financial development proxied by FDI, net inflows (% of GDP)

$lnTourism_{it}$ - International tourism, number of arrivals

$Trade_{it}$ - Trade is a country's the total trade as the percentage of GDP

$Industr_{ti}$ - Industry, value added (% of GDP).

In this paper, we focus on a panel data analysis of 168 countries (Appendix) from 6 continents of the World (The 7th continent Antarctica is omitted because of the lack of permanent human population and energy use). The selected 168 countries illustrating a representative sample of the whole World (86% of world total countries) for a period of 1990 and 2013. Our panel variables are derived from World Bank (2017) World Development Indicator's database. The description of the variables can be found in Table 1. However, our dependent variable is strongly balanced, the explanatory variables used are only available with missing values for the entire period.

4. DESCRIPTIVE STATISTICS

According to IPCC (2014) data, 65% of global greenhouse gas (GHG) emissions was coming from CO_2 emissions in 2010, originating from fossil fuel use. The same report suggests that electricity and heat production as well as agriculture were together responsible for half of global GHG emissions.

However, the world has experienced different CO_2 emission growth rates during the past decades (Figure 1). CO_2 emission were quite stable for high and low income countries, while middle income countries seem to have doubled their respective emission (from 9.3 to 20.8 million kiloton - kt) from 1990 to 2013. Note that CO_2 emission growth have started to significantly raise after 2002 in middle income countries and even the economic crisis has not changed its pace.

By analyzing CO_2 emission by region, further trends become observable (Figure 2). The Asia & Pacific region was the engine of global CO_2 emission growth, due to their fast economic growth in the period analyzed, indicated by GDP growth (World Bank, 2017). Note that role of China and India in this regard where CO_2 emissions have reached extraordinary levels.

The sharp upward trend of middle income countries can be explained by fact that the world's richest countries are progressively outsourcing their carbon emission to China and other developing countries, that produce goods for US and European consumers (The Guardian, 2017a) known as pollution heaven hypothesis in environmental economics. In addition, about 80% of Chinese electricity derived from coal (Zhang and Cheng 2009, The Guardian, 2017b). All the other regions seem to have maintained their previous CO_2 emission rates. Figures 1 and 2 clearly show that the dynamics of CO_2 emission differ significantly across country groups during the sample period.

Figure 3 illustrates the classical relationship between per capita CO_2 emission and per capita GDP. It appears that the two indicators have both increased from 1990 to 2008 after which CO_2 emission have started to decline in line with world economic crisis, while GDP per capita has continued to grow. On the global level, there are many signs of an increased decoupling of CO_2 emissions and GDP growth, reflecting structural changes in the global economy, such as improvements in energy efficiency and the energy mix of global players (Olivier et al., 2016). However, further mitigation of coal use will be needed to meet the goals of the Paris Agreement.

The indicators of millennium development goals also confirms that the main contributors of total GHG emissions were China, United States, European Union, India, Russia, Japan and Germany in 2011 (UN, 2017). It indicates that behind the most populated Asian countries, the western world is another major contributor of air pollution.

5. RESULTS AND DISCUSSION

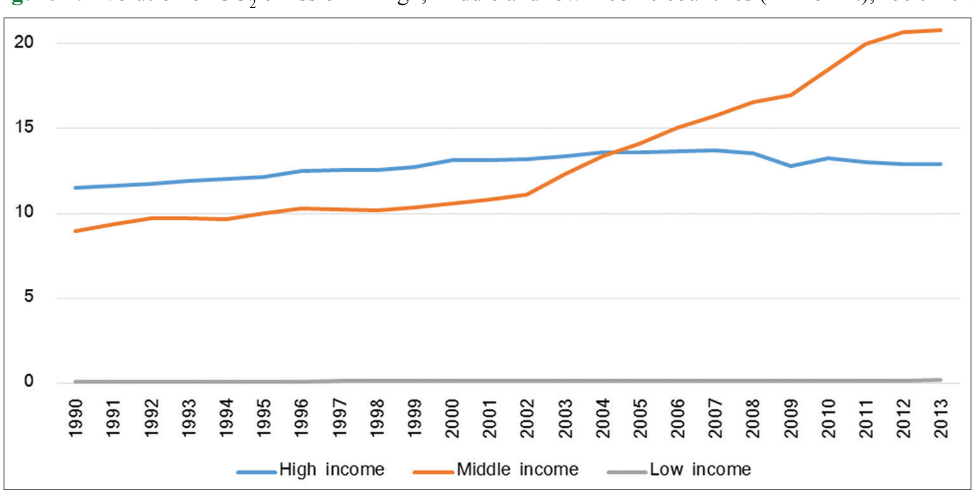
Before estimating the EKC regression for CO_2, dependent variables were pre-tested for unit root test, autocorrelation and cross-sectional dependence (Pesaran, 2004).

Table 1: Description of variables

Variable	Denomination	Source	Expected sign
$lnCO_2$	The per capita CO_2 emission (metric tons per capita)	World Development Indicator	
GDPPC	$GDPPC_{it}$ Gross Domestic Product (GDP per capita, current US $)	World Development Indicator	+
$GDPPC^2$	Squared $GDPPC_{it}$ Gross Domestic Product (GDP per capita, current US $)	calculated from *GDPPC*	-
NUC	Electricity production from the nuclear source (% of total)	World Development Indicator	-
ENRG	Electricity production from coal (% of total)	World Development Indicator	+
RENW	Renewable electricity output (% of total electricity output)	World Development Indicator	-
lnAgrVApha	Agricultural value added per hectare (in current USD per hectare)	World Development Indicator	+
lnAgrVApw	Agricultural value added per worker (in current USD per worker)	World Development Indicator	-
FDI	Foreign direct investment, net inflows (% of GDP)	World Development Indicator	-
lnTourism	International tourism, number of arrivals	World Development Indicator	+
Trade	Total trade as the percentage of GDP	World Development Indicator	+
Industr	Industrial structure, industry, value added (% of GDP)	World Development Indicator	+

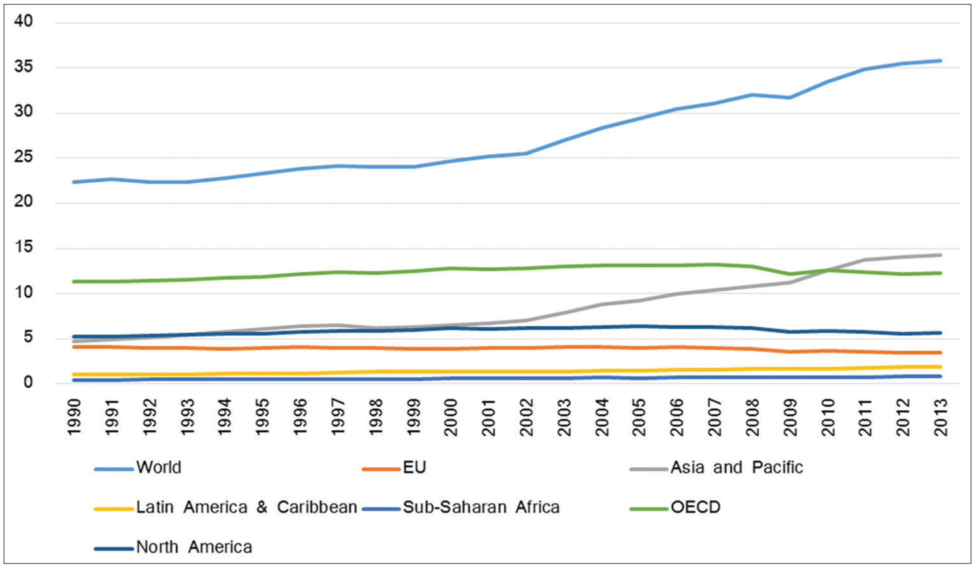
Source: Own composition

Figure 1: Evolution of CO_2 emission in high, middle and low income countries (million kt), 1990-2013



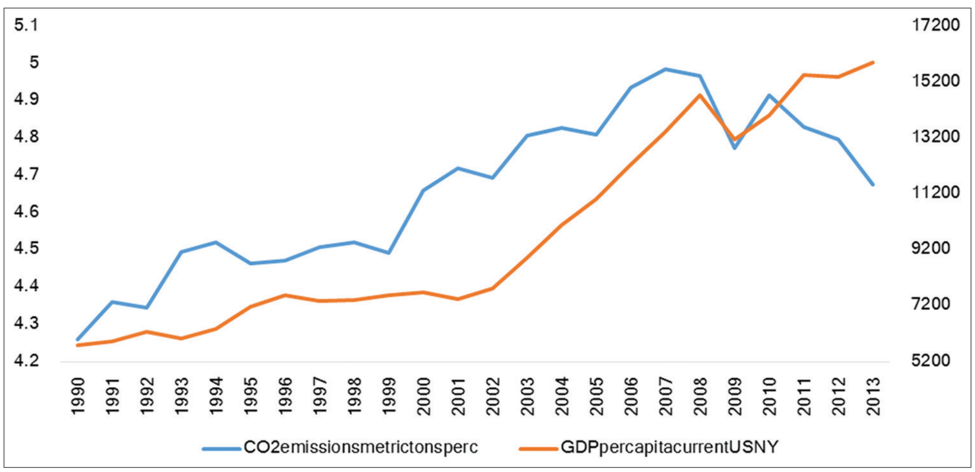
Source: Own composition based on World Bank (2017) data

Figure 2: Evolution of global CO_2 emission by region (million kt), 1990-2013



Source: Own composition based on World Bank (2017) data

Figure 3: Evolution of per capita CO_2 emission and per capita GDP of sample countries over year



Source: Own composition based on World Bank (2017) data

During the recent decade, many panel unit root test have been developed in order to investigate the hypothesis of convergence or stationary (Baltagi, 2008). Unit root tests have divided into first or second generation type test. The advanced second generation unit root tests (Maddala and Wu, 1999; Pesaran, 2007) take into consideration the existence of cross-sectional dependence as well. The Pesaran (2004) CD test reveals cross-sectional dependence in per capita CO_2 variable and the first-order autocorrelation cannot be rejected (Table 2).

Since the pre-estimation test results showed the presence of CD, we used a second generation panel unit root test following Pesaran (2007), Maddala and Wu (1999), employing 0-4 time lags. Test results allow us to reject the hypothesis of non-stationary of CO_2 emission variables for 0-1 lags, although independent variables are unbalanced therefore stationarity criteria of explanatory variables cannot be tested. As Pesaran test (2004) revealed cross-section dependence, Pesaran (2007) CIPS test is more reliable. Because CO_2 variables are stationary, models were estimated without using panel cointegration techniques (Table 3).

Table 2: Pesaran (2004) CD and Wooldridge (2002) tests

Variable	Pesaran (2004) test		Wooldridge (2002) test	
	CD-test	P-value	F-test	P-value
$lnCO_2pc$	78.17	0.000	140.416	0.0000

Pesaran test H_0: Cross-section independence CD~N(0,1); Wooldridge test H_0: No first-order autocorrelation, Source: Own composition based on World Bank (2017) data

In our data, Wooldridge (2002) test confirms the existence of first order serial correlation (P = 0.000). Leitao (2012) suggest using dynamic panel framework to solve problems of serial correlation, heteroscedasticity and endogeneity of some explanatory variables. These econometric problems were solved by Arellano and Bover (1995) and Blundell and Bond (1998) who developed the first-differenced GMM (GMM-DIF) estimator and the GMM system (GMM-SYS) estimator.

Table 3: Panel unit root tests

Maddala and Wu (1999) MW test						Pesaran (2007) CIPS	
Specification without trend				Specification with trend		Specification without trend	
Variable	lags	χ^2	P-value	χ^2	P-value	Zt-bar	P-value
lnCO2pc	0	560.517	0.000	520.466	0.000	−5.896	0.000
lnCO2pc	1	360.895	0.168	419.998	0.001	−2.392	0.008
lnCO2pc	2	291.359	0.962	282.019	0.985	1.689	0.954
lnCO2pc	3	349.608	0.293	320.916	0.714	1.151	0.875
lnCO2pc	4	393.402	0.017	295.067	0.948	6.544	1.000

Null for tests: Series is I (1). MW test assumes cross-section independence. CIPS test assumes cross-section dependence is in form of a single unobserved common factor. Source: Own composition based on World Bank (2017) data

Linear dynamic panel-data models exist that include p lags of the dependent variable as covariates and contain unobserved panel-level effects, fixed or random. By construction, the unobserved panel-level effects are correlated with the lagged dependent variables, making standard estimators inconsistent. Arellano and Bond (1991) derived a consistent generalized method of moments (GMM) estimator for the parameters of this model; in Stata xtabond command implements this estimator.

The standard GMM system estimator is consistent if there is no second-order serial correlation in the residuals (AB2 statistics). The Arellano-Bond test confirms the hypothesis of autocorrelation in first-differenced errors, while second order autocorrelation cannot be rejected (Table 4). The models present consistent estimates, with no serial correlation in case of AB2 statistics (except Model 2). Furthermore, the Sargan tests (Table 4) confirm that there are no problems with the validity of time lags as instruments used.

The first specification (1) of our dynamic panel Arellano and Bond (xtabond) model tested and confirmed the EKC hypothesis for per capita CO_2 emission employing 2 lags (H1). Results are positive and significant for per capita GDP but negative for per capita squared GDP, in line with previous findings of the literature (Selden and Song, 1994; Andersson and Karpestam, 2013).

In conclusion, after countries reaching a given level of economic growth, CO_2 emission have started to drop. Our second model specification (2) estimated the effect of energy production form nuclear, coal and renewable energy. Results confirmed the positive role of nuclear energy and renewable energy production while energy from coal contributed to environmental pollution as expected (H2). This is also in line with the majority of the literature (Zhang and Cheng, 2009; Leitão, 2014; Friedl and Getzner, 2003) and the scientific fact that cleaner energy production reduces air pollution.

Our third model included agriculture-related factors such as land and labour productivity. The significance level of coefficient confirmed that agricultural development reduces air pollution (negative coefficient of lnAgrVAperwork), while the impact of agricultural land productivity (lnAgrVAperhectar) was ambiguous (Models 3 and 5). Conversely, the unrestricted Model (5) confirm that agricultural land productivity increase CO_2 emission that seems to be true.

Our fourth hypothesis was also confirmed, suggesting that financial development reduces pollution, rejecting pollution heaven hypothesis. Moreover, international tourist arrivals are found to be one of the major causes of CO_2 emissions (H5), in line with the literature (Sharif et al., 2017; Solarin, 2014; Lee and Brahmasrene, 2013; Scott et al., 2010). However, tourism is an important sector in many countries, attracting more and more tourists to a given country, also implying higher ecological degradation as the example of Malaysia suggests (Solarin, 2014).

Our extended Model (5) could confirm the positive impact of international trade on carbon dioxide emissions too (H6). More specifically, the augmentation of relative share of trade to GDP produces bigger environmental pollution. Finally, higher share of industry in total economy produces more CO_2 confirming H7. These findings are consistent with the literature such as Weber et al. (2008), Chebbi et al. (2009), Sharma (2011), Shahbaz and Leitao (2013). This result is also in line with the findings of OECD (2017), emphasizing that international trade has negative impacts on the environment through trading and transport of goods or through the movement of production to areas with lower environmental standards (OECD 2017).

6. CONCLUSIONS AND POLICY IMPLICATIONS

This article analyzed the various possible reasons behind CO_2 emissions globally. Although there are a large number of studies dedicated to measuring the determinants of CO_2 emission, the literature seems to have only concentrated on a few factors and limited number of countries as examples. Our paper aims to establish the link between carbon dioxide emissions employing a complex model comprising economic growth, tourism sector, financial development, energy use, trade and agriculture globally, employing GMM models on a panel dataset comprising of 168 countries and 24 years. In doing so, the article has reached a number of findings.

Regression results were positive and significant for per capita GDP and negative for per capita squared GDP, confirming the standard EKC hypotheses. A positive role of nuclear energy and renewable energy production were also revealed while energy from coal increased environmental pollution as expected.

Moreover, the size of industrial sector in total economy significantly stimulates environmental pollution. Regarding the role of agriculture, estimates showed that while agricultural development reduces, the impact of agricultural land productivity

Table 4: The determinants of CO2 emission

Estimation method	(1)	(2)	(3)	(4)	(5)	(6)
	xtabond	xtabond	xtabond	xtabond	xtabond	xtabond
Variables	$lnCO_2pc$	$lnCO_2pc$	$lnCO_2pc$	$lnCO_2pc$	$lnCO_2pc$	$lnCO_2pc$
$L.lnCO_2pc$	0.671***	0.515***	0.555***	0.558***	0.454***	0.447***
	(0.00182)	(0.00395)	(0.00813)	(0.00948)	(0.00849)	(0.0100)
$L2.lnCO_2pc$	0.0834***	0.0584***	0.0606***	0.0806***	0.0662***	0.0724***
	(0.000336)	(0.00144)	(0.00120)	(0.00272)	(0.00425)	(0.00593)
lnGDPPC	0.398***	0.421***	0.478***	0.470***	0.494***	0.438***
	(0.00723)	(0.00860)	(0.0112)	(0.00785)	(0.0230)	(0.0195)
lnGDPPCsq	−0.0206***	−0.0209***	−0.0221***	−0.0238***	−0.0225***	−0.0199***
	(0.000414)	(0.000518)	(0.000709)	(0.000436)	(0.00135)	(0.00111)
ElectricityNuc		−0.00643***	−0.00532***	−0.00669***	−0.00779***	−0.00838***
		(0.000718)	(0.000669)	(0.000952)	(0.000854)	(0.00113)
ElectricityCoal		0.00220***	0.00122***		0.00154***	0.00243***
		(0.000134)	(0.000121)		(0.000191)	(0.000247)
Renewable		−0.00356***	−0.00397***		−0.00521***	−0.00519***
		(8.32e-05)	(0.000137)		(0.000111)	(0.000126)
lnAgrVAperwork			−0.0575***	−0.106***	−0.175***	−0.134***
			(0.00705)	(0.00521)	(0.00980)	(0.00822)
lnAgrVAperhectar			−0.0737***		0.0317***	0.0339***
			(0.00597)		(0.00917)	(0.00738)
lntourist				0.0300***	0.0396***	0.0289***
				(0.00213)	(0.00369)	(0.00433)
TradeofGDP				0.000757***	0.000443***	0.000257***
				(6.14e-05)	(5.97e-05)	(7.06e-05)
FDI					−0.000177***	−0.000204***
					(2.86e-05)	(3.08e-05)
Industr						0.00599***
						(0.000148)
Constant	−1.685***	−1.512***	−0.857***	−1.446***	−1.259***	−1.356***
	(0.0291)	(0.0382)	(0.0674)	(0.0322)	(0.0953)	(0.0694)
Observations	3,362	2,119	1,796	1,589	1,414	1,370
Number of country id	165	109	98	101	97	93
AB1 (P-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AB2 (P-value)	0.9641	0.0271	0.1051	0.1064	0.0982	0.0941
Sargan test (P-value)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Standard errors in parentheses, ***P<0.01, **P<0.05, *P<0.1, Arellano-Bond (AB) test for zero autocorrelation in first-differenced errors. H0: no autocorrelation, Sargan test of overidentifying restrictions H0: overidentifying restrictions are valid, Source: Own composition based on World Bank (2017) data

rather stimulates environmental pollution at a global level. The extension of international tourism and trade can also enhance environmental degradation by rising CO_2 in the atmosphere. Finally, we found that financial development reduces air pollution.

Paper suggests that environmentalist, decision makers should focus on nuclear or renewable energy in order to reduce global air pollution and satisfy the requirements of Paris Agreement. Moreover, behind fossil energy production, trade and agriculture can be considered as major contributors to world CO_2 emission. Therefore, reduce long-distance trade and using biofuel or renewable energy in agriculture would be also an important issue for scientist. Finally, financial development can stimulate the adoption of environmental friendly technologies to less developed countries at world level.

It should be mentioned that our study has several limitation and restriction that influenced our results. First, only CO_2 emission was tested as dependent variable while other GHG indicators also exist such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), chlorofluorocarbons (CFC). The explanatory variables of the model are not balanced therefore panel unit root tests were not applied to these variables.

Future research might want to test our hypothesis to different countries/regions or add new dependent variables to our models.

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APPENDIX

List of sample countries (168)

Afghanistan, Albania, Algeria, Angola, Antigua and Barbuda, Argentina, Aruba, Australia, Austria, Bahamas, Bahrain, Bangladesh, Barbados, Belgium, Belize, Benin, Bermuda, Bhutan, Bolivia, Botswana, Brazil, British Virgin Islands, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, Canada, Caribbean small states, Cayman Islands, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo, Dem. Rep., Congo, Rep., Costa Rica, Cote d'Ivoire, Cuba, Cyprus, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, Arab Rep., El Salvador, Equatorial Guinea, Ethiopia, Faroe Islands, Fiji, Finland, France, French Polynesia, Gabon, Gambia, The, Ghana, Gibraltar, Greece, Greenland, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hong Kong SAR, China, Hungary, Iceland, India, Indonesia, Iran Islamic Rep., Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Kiribati, Korea Rep., Lao PDR, Lebanon, Liberia, Libya, Luxembourg, Macao SAR, China, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Marshall Islands, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nauru, Nepal, Netherlands, New Caledonia, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Rwanda, Samoa, Sao Tome and Principe, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Singapore, Solomon Islands, South Africa, Spain, Sri Lanka, St. Kitts and Nevis, St. Lucia, Vincent and the Grenadines, Sudan, Suriname, Swaziland, Sweden, Switzerland, Syrian Arab Republic, Tanzania, Thailand, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Uganda, United Arab Emirates, United Kingdom, United States, Uruguay, Vanuatu, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe.