Gross Domestic Production (GDP) and Gases Emissions: Are the G7 Rich Countries Contributing to Air Damage?

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Abstract
This paper addresses an important issue: Are increasing levels of gross domestic production related to increasing levels of environmental damage? It aims to analyze this growth-environmental relation focusing on the G7 countries' economic and environmental performances. Theories on growth-cum-environment, sustainable development and the environmental Kuznets' curve hypothesis are presented to support the empirical study. Statistical correlation is the method used and data source is The World Bank (2016). Results show that production levels are negatively related to gases emissions of four types of gases. Exceptions are USA and Japan whose GDP's growths are paired with increasing levels of CO_2 and total greenhouses emissions. Germany, UK and France seem to be fulfilling the environmental Kuznets' curve with decreasing gases emissions pairing intense growth.

Keywords: GDP and Environmental Performances; Gases Emissions; Air Damage. G7 Rich Countries.

Introduction

Economic growth has been a subject of great importance since the first contributions of leading economists, such as Adam Smith's "The Wealth of Nations", published in England in 1776. Throughout the years many other important authors have developed works focusing on production growth, but only in the forties and fifties of the 20th century more elaborated papers on this theme appeared, e.g., the contributions of Domar (1946) and Solow (1956 and 1957). Domar (1946), for instance, emphasized the role of industrial investments in physical capital to prompt production growth, while Solow (1956 and 1957) focused on both the role of technological advances to foster production growth and the way total factor productivity is measured to assure that production growth is obtained via technological progress.

Despite the importance of these seminal contributions on production growth in the forties and fifties, the first works of the modern theories of endogenous growth were published during the 1980s and 1990s, such as Romer (1986) and Lucas (1988) who highlighted the relevance of human capital, education and knowledge to prompt development, and Grossman and Helpman (1990 ; 1991) who brought and treated trade as an important source of endogenous production growth.

A huge change on the prospects of traditional and modern growth theories has occurred since the late eighties, under the influence of the Brundtland Commission (1987), mapping a new direction to target the environment as a key variable to be considered in any attempt of a country to develop. Accordingly, current theories of economic growth have embodied environmental variables into their specifications in a way to analyze the implications to rapid production growth when the environment is taken into account. Important contributions, e.g., Geldrop and Withagen (2000), Palmada (2003), Islan (2005), Charles (2005), Comolli (2006), Bretschger and Smulders (2006), Auty (2007), and Voinov and Farley (2007), have used analytical frames jointly treating production and environmental variables under a single theoretical approach. Daly (2008) contribution on ecological economics and sustainable development is a conceptual work elaborated with no relation to growth-development models, but with important implications to sustainable development strategies. Najam, Runnalls, and Halle (2007) offered propositions for environmental safety under the globalized production processes in course worldwide.

It is obvious that the upgrade of production growth theories to include the environment has had important implications to academic and political issues, as well as to sustainable development policy design and implementation. Thus, sustainable development policy supported by the theoretical contributions presented in section 1 will be discussed. Nations have to be aware of not repeating the mistakes of some today's advanced countries that damaged the environment in their earlier phases of rapid production growth.

Due to the current need for outstanding production performance and sustainable environmental standards, an important question is: Is augmenting Gross Domestic Production (GDP) related to increasing air damage, measured by emissions of pollutant gases? We analyze this issue by evidencing aggregate production performance and standards of gases emissions of the G7 rich countries in the last four decades (1970 - 2012).

In section 1 the relevant theories on production-cum-environment, the concept of sustainable development and the environmental Kuznets' hypothesis are presented to give support to the analysis. In section 2 Graphical analysis and statistical correlation are introduced and arguments on their use appropriateness are elaborated. Section 3 reports the empirical evidence: statistical correlation analysis is applied to evidence the strength of the relationship between GDP paths and trajectories of gases emissions. In general, the evidence shows a significant and negative correlation between GDP and gases emissions for the G7 rich countries, exceptions being USA, Canada and Japan. Production augmentation in USA and Japan are paired with increasing levels of CO_2 and total greenhouses gases, and Canada's GDP increases are correlated to increasing levels of CO_2, methane and total greenhouses gases emissions. Three Europeans countries (Germany, UK and France) performed very well both on production and gases emissions standards, seeming to be under the environmental Kuznets' hypothesis, pairing GDP growth with decreasing levels of gases emissions.

1. Theories on Production Growth with Environment and Sustainable Development

This section presents a set of growth-cum-environment models trying to bridge production and the environment. Following, the Brundtland Commission Report (1987) is referred as a crucial publication that has pioneered and institutionalized the concept of sustainable development. The important environmental Kuznets' U-inverted curve relating advanced stages of development and decreasing environmental damage is presented to end the theoretical section.

1.1. Production-Cum-Environment

Two classes of environmentally-based production growth models are presented: production growth using finite and depletable natural resources; and output growth with pollution as waste generation. The first type of pioneering production-environmental model comes from Anderson (1972), who explores the implications to production growth from explicitly accounting for depletion of a nonreproducible natural resource, such as a fossil fuel reserve. Stiglitz (1974) used a similar construction to model production growth in the presence of exhaustible natural resources. More recently, Amigues, Favard, Gaudet, and Moreaux (1998) and Palmada (2003) formalized optimal allocations of different natural resources, such as air, water and forests, during production phases.

A second class of models was pioneered by Forster (1973 and 1980) who brought an important feature not considered in standard growth models. He presented an optimal physical capital accumulation model taking into account the possibility of waste generation (pollution). Other recent models of pollution generation under optimal environmentally-based output growth are Lyon and Lee (2003); Chakravorty, Moreaux and Tidball (2006); and Chakravorty, Magné, and Moreaux (2006).

In the two classes of pioneering production-cum-environment models mentioned to above the authors follow the standard procedure of considering a one-sector economy, such as in Bretschger and Smulders (2006) analysis of optimal uses of nonrenewable resources, or in Farzin and Akao (2006) and Voinov and Farley (2007) who included renewable natural capital into an output growth model in an one-sector economy.

The most important feature of the pioneer Anderson's (1972) model is that when the nonreproducible stock of natural resources is considered, the main result shows a tendency to postpone capital accumulation and spend time on production growth paths where capital is used less intensively than in models of unconstrained natural resource uses. Therefore, the basic prediction coming from this production growth model accounting for depletable natural resource uses points to a general slowdown trend of production growth. This is so because the environmental constraint poses a limiting restriction on the use of depletable resources, which leads to a reduced rate of physical capital accumulation, driving production downwards. It is optimal to slow down the country's capital accumulation (decreasing production) when depletable natural resources are considered.

Recent contributions have shown this result in different contexts. Comolli (2006) by investigating the relation between natural and physical capital during specific production phases concludes that production growth has to slow down as facing the natural capital constraint; and Farzin and Akao (2006) by studying the optimal exhaustion of a nonrenewable resource under different production settings reach the same result.

Following the other pioneering production-cum-environment model, Forster (1973, p. 544) states that "It is naive to think that no wastes are produced and fairly obvious that the free disposal assumption of the neoclassical growth model is not satisfied in the real world". The most relevant prediction coming from this environmentally-sounded production model points out that when pollution is accounted for, the production process tends to a lower physical capital accumulation than when pollution control is not considered, the same prediction coming from the analysis of the depletable natural resource model by Anderson (1972).

These predictions show us that, theoretically, when we consider production-cum-environment models, the growth-environmental damage relation is explicit, a relevant aspect to guide the empirical exercise in section 3, where the economic (GDP) and environmental (gases emissions) performances of the G7 rich countries are analyzed.

1.2. The Concept of Sustainable Development and Sustainability Issues

As stated by Sena (2009, p. 214), "the well known fact that today's economy activities are imposing a heavy burden on the earth's capacity has led to an increasing interest in sustainable development and related issues. It has been emphasized that economic growth depletes the current stock of natural resources and damages the environment and that there are clearly economic limits to rapid growth".

Despite the classical pro-technology optimistic arguments, which pose that technical progress is what is needed to eliminate all constraints on production growth, the approaching exhaustion of many natural resources is a reality. Even in the mining sector, an economic activity that is alleged to be free of its finite mineral resources exhaustion, i. e., where, according to Mudd (2013), the classical pro-technology optimistic arguments are supposed to be applied, is now facing trouble, since evidence on decreasing ore grades, increasing mine waste rock and deeper and larger mines are easy to find.

Current discussions on those issues and attempts to design sound socioeconomic and environmental policy to improve welfare of populations worldwide have had, as a supporting frame, the pioneer definition of sustainable development coming from the Brundtland Commission Report (1987, p. 43): “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” Holmberg and Samdbrook (1992) emphasized that the Brundtland Commission gave geopolitical significance to the sustainable development concept.

Many other definitions have followed, all including economical, social, political, institutional and environmental issues to assure that future generations must have not less than we have today. As taking into account the economic, social and environmental pillars, Environment Canada (2006, p. 2) states that “The integration of environmental sustainability with economic competitiveness and productivity and social equity lies at the core of sustainable development [...] It is an approach that seeks to ensure that in meeting our current needs, we do not jeopardize the ability of future generations to meet their needs.”

Daly (2002, p. 1) defines sustainable development as “dependable on the maintenance of physical throughput over generations […] Natural capital is to be kept intact. The future will be at least well off as the present in terms of its access to biophysical resources and services supplied by the ecosystem.” Gamage and Boyle (2008) offer a review of the concept of sustainable development, including important aspects of consumerism, materialism, and psychological and entrepreneurial aspects, while analyzing the concept in terms of its theoretical advances.

Back to the main focus, and remembering the predictions from the production-cum-environment theoretical models – when constrained by natural resources uses production has to slow down – we ask: is there an inverse relation between production and gases emissions as we consider GDP paths and trajectories of emissions in the G7 rich countries? Are the leader countries in economic (GDP) performance also the leaders in contributing to air degradation? Empirical evidence in section 3 shows the performances of the G7 rich countries on these matters and tries to answer these questions.

1.3. The Environmental Kuznets’ Curve Hypothesis

Kuznets (1955) originally proposes to study the relation between economic growth (augmentation of production-income) and inequality (income distribution). Kuznets (1955, p. 1) opens his seminal paper posing that “The central theme of this paper is the character and causes of long-term changes in the personal distribution of income. Does inequality in the distribution of income increase or decrease in the course of a country's economic growth?” Sarigiannidou and Polivos (2015) offer an interesting modern version of the original Kuznets’ hypothesis, as connecting production growth and income distribution.

In relation to environmental economics, authors have used Kuznets inverted-U relation to study how the environment has been damaged over the different stages of economic growth. Dinda (2004, p. 432), making use of the environmental Kuznets’ curve hypothesis, poses that "[…] environmental quality deteriorates in early stage of economic development/growth and improves in later stage as an economy develops." Stern (2003) referring to the origin of the apparent environmental Kuznets's curve effect affirms that independent of specific phases a country experiences, impacts on the environment will occur depending on the interplay of time and scale effects. For developing and emerging countries experiencing rapid growth, scale effects dominate and pollution increases, while in rich countries facing slower growth paths, time spent in reducing pollution may overcome scale effects.

Considering the empirical record on recent studies about the environmental Kuznets' curve hypothesis, Lau, Choog e Eng (2014), in the context of foreign direct investments and trade, investigate carbon emissions in Malaysia. They found that there is evidence supporting Kuznets' hypothesis. Kennedy and Hutchinson (2014), in a cross-country analysis, study the relationship between pollutant emissions and income growth and conclude that there is a pollutant-spillover effect as income increases. Al-Mulali, Saboori and Ozturk (2015) found a positive relationship between environmental degradation (pollution) and capital accumulation in Vietnam. Katz (2015), on the other hand, finds that the relation between income growth and freshwater uses, as a natural resource, does not match the environmental Kuznets' curve.

As the empirical record shows, there are no unambiguous results concerning the relationship between production growth and environmental damage. As posted by Katz (2015) empirical results are dependent on choice of datasets and statistical techniques.

Combining the main arguments on the environmental Kuznets' curve hypothesis with those of the production-cum-environment models presented before, i.e., that production growth has to be reduce if constraints on natural capital uses are imposed, we can say that even in advanced stages of development, environmental damage could happen if production is free to increase. Thus, in the empirical section these issues will be taken into account in the context of the G7 rich countries economic (production) and environmental (gases emissions) performances in the last four decades (1970-2012).

2. Methods: Cross-Country Graphical Analysis and Statistical Correlation

A graphical presentation of GDP paths (in levels) opens the empirical section 3. We aim to show graphically whether or not increasing production is paired with increasing emissions of four gases: CO_2, methane, nitrous oxide and other greenhouses. Following this analysis, statistical correlation is introduced as a measurement technique used to check if two variables are correlated. For example, consider the variables 'individual disposable income' and 'consumption'. It is expected that the values of these two variables increase or decrease together, i. e., they are related in a way that a positive (negative) change in one variable is paired with a positive (negative) change in the other variable. In this case, we say that 'disposable income' and 'consumption' of an individual are positively correlated. On the other hand, if income-consumption is related to production that to be obtained damages the environment, then 'production' and 'stock of fresh/clean environment' are said to be negatively correlated. Then we say that when 'production' increases, natural capital decreases and vice-versa.

According to Choudhury (2009), correlation analysis is about a relationship between variables and gives us two relevant types of information: i) whether the relationship is positive, null or negative; and ii) if the magnitude of the relationship is weak, moderate or strong. Statistical correlation cannot give us information about cause-effect among variables nor can be applied to variables presenting non-linear trajectories.

If endogeneity (loop causation) between two variables is present, statistical correlation has an advantage as compared to cause-effect methods, such as regression analysis. For instance, increasing figures on Foreign Direct Investments (FDI) may cause increasing levels of Gross Domestic Production (GDP) in a certain country. Also, increasing levels of GDP in such a country may cause increasing FDI inflows, characterizing a sort of loop causation. In such cases, it is convenient to use correlation analysis because it is not possible to isolate dependent and independent variables. Correlation could appropriately be applied just to track the paths of the two variables without taking causalities into account.

Let $Y_1, Y_2, \ldots, Y_n$ and $X_1, X_2, \ldots, X_n$ be values of two quantifiable variables, with $i = 1, 2, \ldots, n$ a sample of n observations. Three types of correlation between Y_i and X_i can be derived from the reduced variables V_i and U_i, the standardized values of original variables Y_i and X_i, respectively. If $\sum [V_i.U_i] > 0$, correlation between Y_i and X_i is positive; if $\sum [V_i.U_i] = 0$, null; and if $\sum [V_i.U_i] < 0$, correlation between Y_i and X_i is negative. There is a forth type of correlation called spurious - even with an eventual strong positive correlation, e. g., between a variable 'number of street lights' and variable 'number of born female babies', both annually measured, it makes no sense to study this relationship (even if it is possible that the two series coincidently present a high positive correlation), so it is called 'spurious'. Theory, as relating key-variables in an appropriated and expected way, is the best devise to avoid us using spurious correlation.

The correlation coefficient 'r' is the operator for calculating correlation between two variables. It is obtained dividing $\sum [V_i.U_i]$ by $(n - 1)$. This has to be so since $\sum [V_i.U_i]$ increases as the sample size 'n' increases. Plugging the reduced-standardized variables V_i and U_i given above into 'r', after some algebraic rearranging we get $r = \sum(x_i.y_i) / (\sum x_i^2.\sum y_i^2)^{1/2}$, where x_i and y_i are the deviations of the x_i and y_i values in relation the their means. The values of the correlation coefficient 'r' range from -1 to +1, including zero which is the value for null correlation. The -1 value holds for perfect negative correlation and +1 for perfect positive correlation. For a clear treatment of the applicability of the coefficient of correlation, see Bobko (2001).

We can discuss on the ranges for values of 'r' that correspond to different degrees of strength of the relationship between two variables. According to Choudhury (2009), there is no agreement among scholars on the choice of the interval limits for 'r'. We will consider in the empirical section three closed intervals of the values for r: i) strong strength, with $r = [\pm 0.7 ; \pm 1]$; ii) moderate strength, with $r = [\pm 0.5 ; \pm 0.69]$; and iii) weak strength, with $r = [< \pm 0.5]$.

3. G7 Rich Countries: Empirical Evidence on Production and Gases Emissions

The G7 (Group of Seven) includes the 7 most industrialized countries in the planet: United States, Japan, Germany, United Kingdom, Canada, France, and Italy. They cooperate on economic issues, including the real side (production, investment, budget etc) and the monetary side (inflation, interest rate, exchange rate etc). The G7 rich countries are a subset of the 34 OECD countries.

We start the empirical section clarifying some issues. First, the aggregate production (GDP) is treated here as a variable intentionally chosen to depict a country' production performance. It is an *ex-anti* given indicator that we take without searching for causes to explain successes or failures in production outcomes. The main purpose here is to check the strength of the relationship between production paths and the trajectories of the selected gases emissions, both over the same period of time. We selected data from the World Bank (2016) on GDP, CO_2, methane, nitrous oxide and total greenhouses gases emissions for a 1970-2012 time series. The behavior of GDP paths and trajectories of these gases emissions will be analyzed to investigate whether or not there is a positive relation between GDP production and emissions over the specified period of time.

A brief account of the consequences to the environment from the emissions of harmful gases is needed in order to justify the selection of the indicators. The consequences of CO_2 emissions to the environment are the following: i) rise of sea level leading to "densely settled coastal plains to become uninhabitable …, which would result from melting of the ice caps …; ii) rise of global warming impacting negatively on agriculture, that could have major effects on agricultural productivity; iii) reduction of the ozone layer, since warming would result in increase high cloud cover in winter, giving chemical reactions a platform in the atmosphere, which could result in depletion of the ozone layer; iv) increased extreme weather, changing the climate systems of the earth, meaning there would be more droughts and floods, and more frequent and stronger storms …; v) depletion of ecosystem causing the range of plants and animals to change, with the net effect of most organisms moving towards the North and South Poles." (http://www.carboncalculator.co.uk/effects.php).

Methane emissions contribute to "Earth's greenhouse effects and to warm the atmosphere. Methane is the second most damaging greenhouse gas produced by human activity after carbon dioxide. While methane is a more potent greenhouse gas than CO_2, there is over 200 times more CO_2 in the atmosphere. Hence the amount of warming methane contributes is 28% of the warming CO_2 contributes." (http://www.skepticalscience.com/print.php?r=84).

According to Benton-Short (2014, p. 323), "Globally, about 80 per cent of total nitrogen oxide emissions come from human activities. Nitrous oxide molecules stay in the atmosphere for an average of 120 years before being removed by a sink or destroyed through chemical reactions. The impact of 1 pound of N_2O on warming the atmosphere is over 300 times that of 1 pound of carbon dioxide." "Changes in the atmospheric concentration of N_2O have evoked considerable concern because of its role in regulating stratospheric ozone levels, contributing to the atmospheric greenhouse phenomenon and participating in the acid-rain formation process. The global concentration of N_2O in the atmosphere has been rising since the start of the

Industrial Revolution …"
(http://www.sciencedirect.com/science/article/pii/030626199390018K).

"The consequences of greenhouses gas emissions to the air and the environment are to warm the Earth's surface and the lower atmosphere... Human activities, primarily the burning of fossil fuels and deforestation, have intensified the greenhouse effect, causing global warming… The main effect of increases in atmospheric greenhouse gas concentrations is global warming. Increases in the different greenhouse gases have other effects apart from global warming including ocean acidification, smog pollution, ozone depletion, and plant growth reduction." (http://whatsyourimpact.org/effects-increased-greenhouse-gas-levels).

3.1. Pairing GDP Paths and Trajectories of Gases Emissions

We start analyzing the absolute GDP graphs for the G7 rich countries from 1970 to 2015. The data set was taken from The World Bank (2016), The Development Indicators. In Figure 1a we see that GDP levels are growing fast in USA for the whole period (from US$1 billion in 1970 to US$18 billion in 2015) and in Japan and Germany at slower paces (both from around US$0.2 billion in 1970 to around US$4 billion in 2015). On average, these three countries are the best GDP performers among the G7 economies in the investigated decades. Even during the hard years of the world financial crisis (2008-2009), the USA and Germany had just a slight downward change in their GDP levels. Japan's GDP slowdown starts a little after the crisis, in 2012.

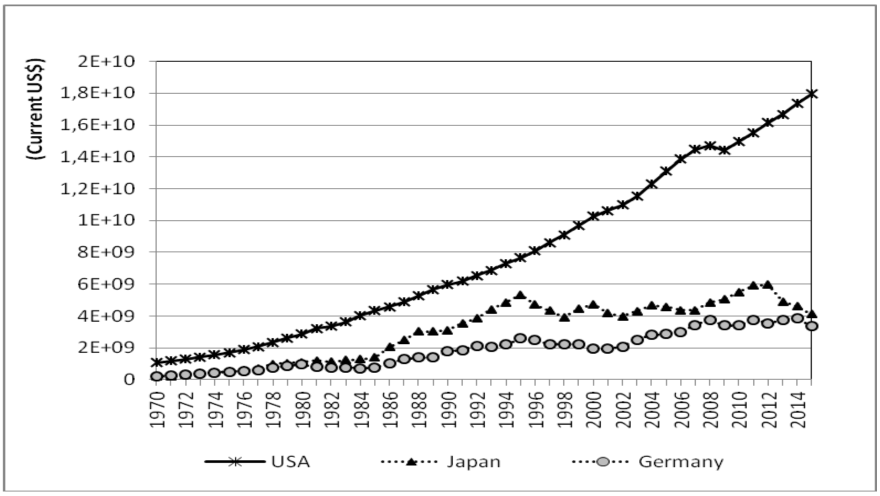

Figure 1a: GDP Levels of the Top 3 G7 Rich Countries - 1970-2015

Comparing the slopes of the tendency line of the three countries, the USA is by far the leader in speeding up its GDP levels over time. Japan and Germany's long run GDP trends are similar, with that of Japan steeper than Germany's.

Figure 1b shows that UK, France, Italy and Canada present GDP graphs growing fast but at lower levels as compared to the top three G7 rich countries in Figure 1a (UK from around US$100 million in 1970 to US$2.8 billion in 2015; and France from around US$100 million to US$2.4 billion). All four countries experienced more intensively the negative effects of the financial crisis by 2008-2009. Italy and Canada grow at the lowest paces among the G7 countries; the slopes of their trend lines are less steep than those of UK and France, as seen in Figure 1b.

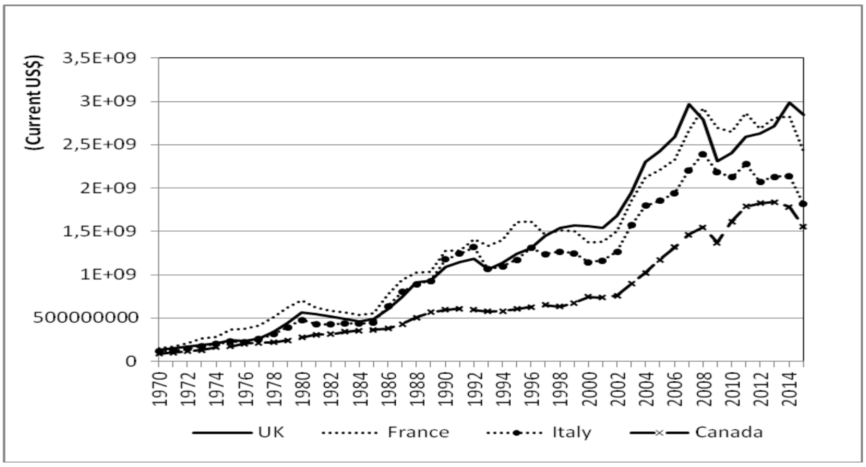

Figure 1b: GDP Levels of the Other Four G7 Rich Countries - 1970-2015

Overall, the GDP levels are increasing in all G7 countries for the whole 1970-2015 period, mainly in the 2000s when the slopes of the tendency lines are steeper. The top seven richest countries in the world did so well in speeding up aggregate production.

3.1.1. CO_2 Emissions

To pair the outstanding production performances of the G7 rich countries with their CO_2 emissions, Figure 2a shows that the top 3 performers in GDP levels were exactly the same countries leaders in CO_2 level emissions: USA, Japan and Germany are the leaders in CO_2 emissions as they are GDP performers. USA is by far both the champion in GDP (Figure 1a) and in emitting CO_2 gas to the atmosphere, with levels in between around 4.3 million and 5.1 million of tons in the 1970-2013.

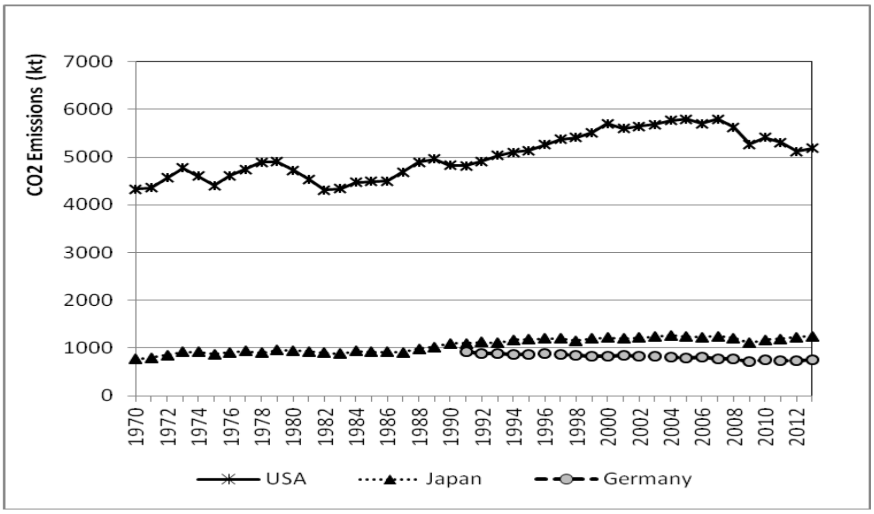

Figure 2a: CO2 Emissions – USA, Japan and Germany / 1970-2013

Japan and Germany performed as mid CO_2 emissors; Japan oscillating a little above and Germany slightly below 1 million tons of emissions (data for Germany emissions are only from 1991 to 2013). Note that Germany is the only, among the three, to present a long run downward trend of its CO_2 emissions.

Figure 2b shows that UK emitted around 0.66 million tons of CO_2 in 1970, decreasing its emissions to 0.47 million in 2013. France followed the same trend, at a lower level, decreasing its CO_2 emissions from 0.44 million in 1970 to 0.34 million tons in 2013.

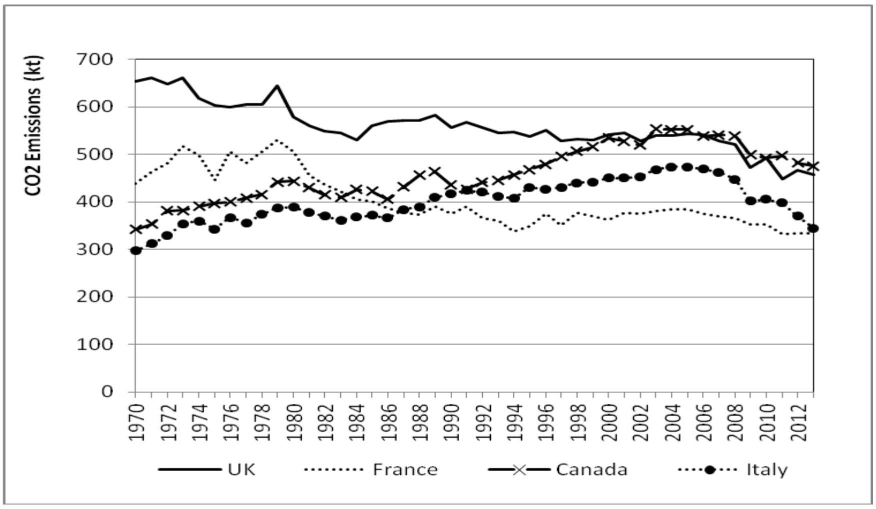

Figure 2b: CO2 Emissions – UK, France, Canada and Italy / 1970-2013

On the other hand, Canada and Italy show increasing long run trends in their CO_2 emissions, mainly from 1970 to 2004, reversing them only by the mid-2000s. It is worth to note that three European countries – Germany (Figure 2a), UK and France (Figure 2b) – had long run decreasing trajectories of CO_2 emissions over 1970-2013.

3.1.2. Methane Emissions

Figure 3a shows that the top 3 performers in GDP levels were also the same countries leaders in methane level emissions: USA, Japan and Germany were leaders in methane emissions as they were as GDP performers.

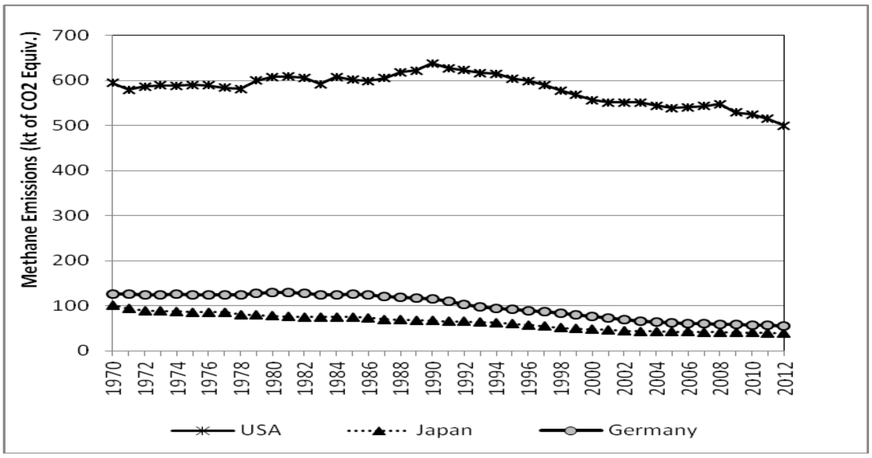

Figure 3a: Methane Emissions – USA, Japan and Germany / 1970-2012

The USA again are both the champion in GDP growth (Figure 1a) and in emitting methane gas, with levels in between 0.5 million and 0.6 million of tons of CO_2 equivalent in the 1970-2012 period. Japan and Germany performed as mid methane emissors; Japan oscillating a little below and Germany slightly above 100 thousand tons of methane emissions from 1970 to 1990 and around 50 thousand tons afterwards. Note that all the 3 top performers in GDP (Figure 1a) present a long run downward trend of its methane emissions, an evidence hopefully leading to reducing levels of emissions of this gas in the future.

Figure 3b shows that UK emitted around 120 thousand of methane tons of CO_2 equivalents in 1970, decreasing its emissions to 60 thousand tons by 2012. France followed a constant trend, emissions oscillating around the order of 80 thousand of methane tons of CO_2 equivalent over the whole period; and Italy showed a similar constant long run trend, but with methane emissions oscillating at a lower level, around 40 thousand tons.

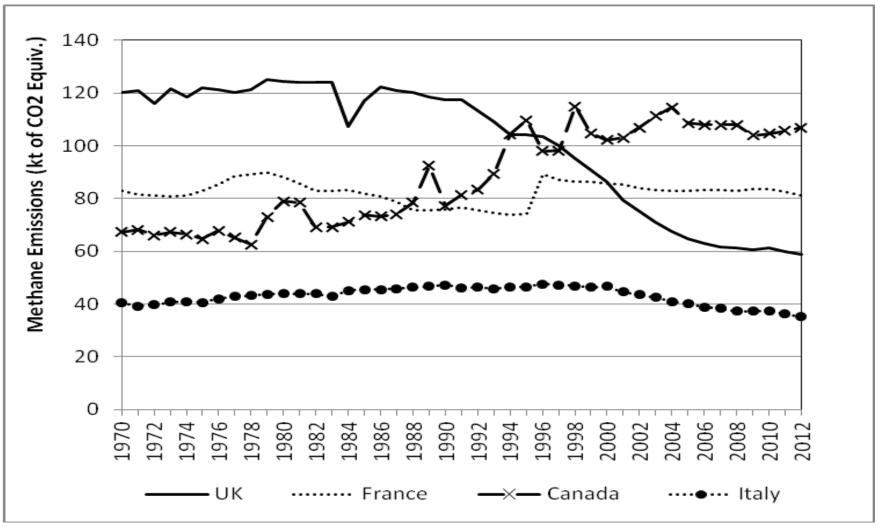

Figure 3b: Methane Emissions – UK, France, Canada and Italy / 1970-2012

Canada is the only country having an increasing long run trend, starting its methane emissions at a level around 70 and ending with 110 thousand tons of CO_2 equivalent in 2012. It is worth to note that UK shows a sharp long run decrease in its methane emissions over 1970-2012.

3.1.3. Nitrous Oxide Emissions

Figure 4a shows that USA levels of nitrous oxide emissions are huge, compared to Japan and Germany's. From 1970 to 1997-98, USA and Japan, the top 2 GDP performers, increased their emissions of nitrous oxide into the atmosphere; and Germany presented a more or less constant trend. But, starting in the late 1990s, all three reduced their nitrous oxide gas emissions.

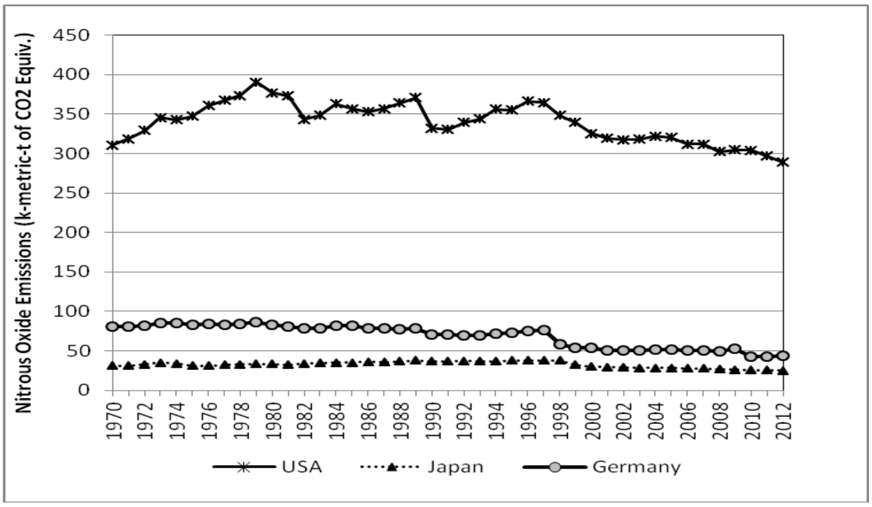

Figure 4a: Nitrous Oxide Emissions – USA, Japan and Germany / 1970-2012

The USA levels of emissions ranged in between around 290 and 370 thousand metric tons of CO_2 equivalents from 1997 to 2012. Germany, at higher levels, paired Japan's downward trend during the 2000s, Japan emitting around 48 thousand metric tons and Germany 50 thousand metric tons of CO_2 equivalents of nitrous oxide.

Figure 4b shows that France and UK present similar downward trends, France emitting around 65 thousand nitrous oxide metric tons of CO_2 equivalents in 1970, decreasing its emissions to 37 thousand metric tons by 2012. UK emissions are cut in half, decreasing from 50 thousand nitrous oxide metric tons of CO_2 equivalent in 1970 to 25 thousand metric tons in 2012. These two countries, following the top 3 GDP performers (USA, Japan and Germany in Figure 1a), rank high as outstanding GDP performers (Figure 1b). Despite their decreasing trends, they score relatively high in terms of levels of nitrous oxide emissions until the mid-1990s.

Italy showed also a long run decreasing trend, with nitrous oxide emissions ranging from 30 to 20 thousand of metric tons. Canada presented a sharp increasing trend until the mid-1990s, from 30 thousand in 1970 to 70 thousand of nitrous oxide metric tons of CO_2 equivalent in 1995, reversing its emissions since then. By the late 1990s until 2012, all countries in Figure 4b experienced a strong downward tendency at their levels of nitrous oxide emissions, a trend hopefully leading to reducing this gas in the future.

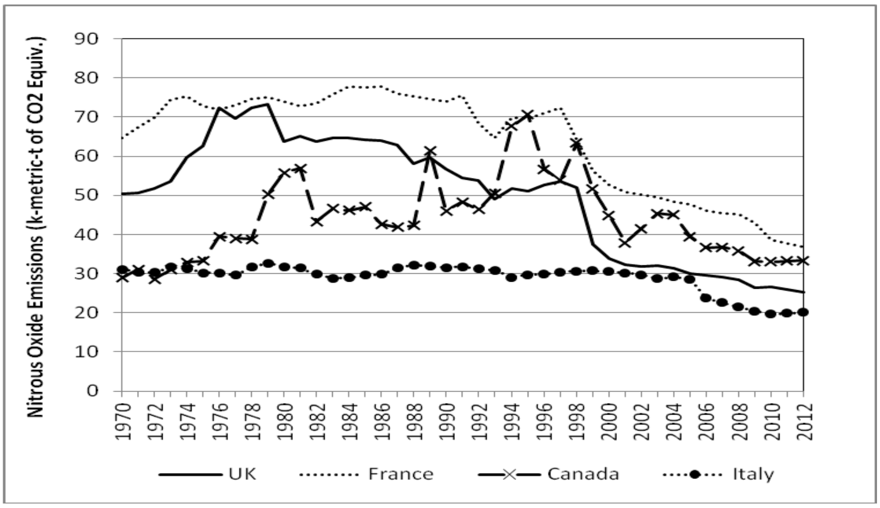

Figure 4b: Nitrous Oxide Emissions – UK, France, Canada and Italy / 1970-2012

Summing up, evidence in Figures 4a and 4b shows that the leader countries in GDP performances are also the leaders in nitrous oxide emissions. But, in the long run considering the whole period, the trajectories of nitrous oxide emissions in all G7 countries present decreasing trends, again a sound result presumably leading to reduced levels of nitrous oxide emissions in the future.

3.1.4. Total Greenhouses Emissions

As in the evidence showed for CO_2, methane and nitrous oxide emissions, Figure 5a shows that the top 3 GDP performers are also the leaders in level emissions of the total greenhouses gas.

USA, Japan and Germany are top in emitting total greenhouses gases (HFC, PFC and SF6) into the atmosphere. USA is by far the champion, with a very high level and an increasing trend of emissions over the four decades. Their levels of total greenhouse gas emissions increase from around 5.4 million to around 6.2 million tons of CO_2 equivalents in the investigated period.

Japan and Germany, as mid-emissors of total greenhouse gases, present similar trends, with Germany leading emissions around 1 million until 1990, and Japan taking the lead from then on. It is worth to note that Germany is the only, among the three top other greenhouses emissors, evidencing a steady long run downward tendency in its emissions of other greenhouses gases into the air from 1970 to 2012.

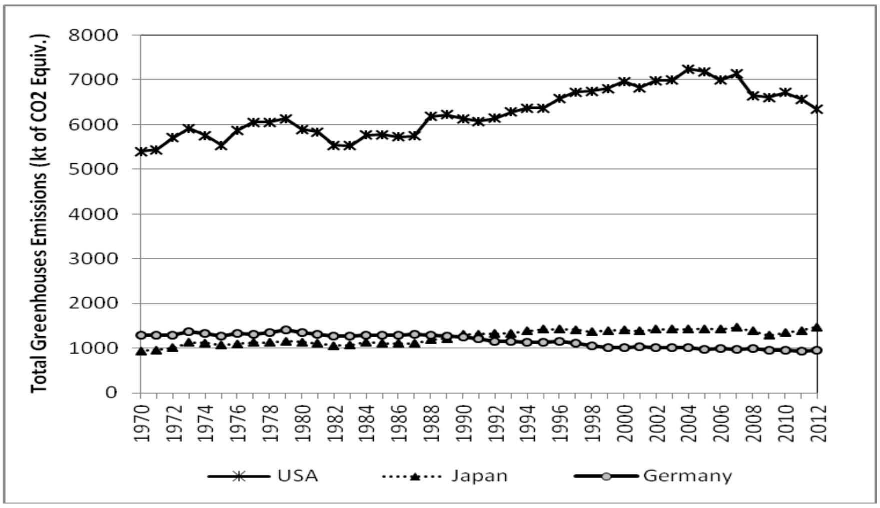

Figure 5a: Total Greenhouses Emissions – USA, Japan and Germany / 1970-2012

Figure 5b shows very similar evidence on the trends of total greenhouses emissions when compared to the emissions of nitrous oxide gas (Figure 4b). Except for Italy's increasing long run trend, both UK and France present downward long run tendency lines - UK emitting around 8.5 million total greenhouses tons of CO_2 equivalents in 1970, decreasing its emissions to 6 million tons by 2012. France emissions are cut from 6 million to 5 million of total greenhouses tons of CO_2 equivalents over 1970-2012. Otherwise, Canada and Italy present upward trends, with Canada showing a steeper slope of its long run tendency line.

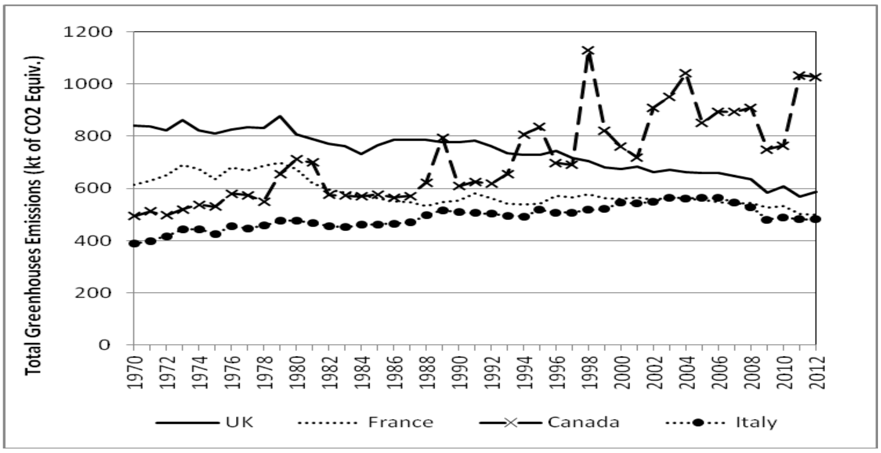

Figure 5b: Total Greenhouses Emissions – UK, France, Canada and Italy / 1970-2012

To sum up, evidence in Figures 5a and 5b show that USA, Japan and Germany, the leader in GDP performances, are also leaders in levels of total greenhouse gas emissions. Looking at the long run trends, a problematic environmental concern for today and into the future is that the trajectories of HFC, PFC and SF6 gases emissions, mainly in USA, Japan, Canada and Italy, presented increasing trends, a risk to the current air conditions.

3.1.5. A Word on GDP and Gases Emission Levels

In terms of GDP and emissions of the four air pollutant gases (in levels), Table 1 shows that the rankings of the top three GDP performers – USA, Japan and Germany

– are exactly the same as those of the leading emissors of CO_2 and total greenhouses. In Table 1, calculated annual averages for the period from 1970 to 2012 evidence that USA are by far the champions in contributing to accumulated levels of emissions of all four gases. Its high average level of production (US$7.8 billion) is tied to its high levels of emissions of CO_2, (5 million tons), total greenhouses gases (6.2 million tons), methane (581 thousand tons of CO_2 equivalent) and nitrous oxide (340 thousand metric tons of CO2 equivalent). These numbers compared to those of the countries ranked 2nd and 3rd places in GDP performance and gas emissions average levels – Japan and Germany – are huge. Thus, in terms of average levels of pollutant gas emissions, we prize USA with the 'red light' award. Japan is ranked 2nd as a GDP performer (annual average of US$3.1 billion) and also 2nd in CO_2 (around 1.1 million tons) and total greenhouses (around 1.2 million tons) emissions.

Table 1: GDP (billion US$) and Gases Emissions (million tons) Level Averages – 1970-2012

G7	**GDP**	**CO_2**	**Total Greenhouses**
USA	7,82	5,02	6,27
Japan	3,08	1,06	1,26
Germany	1,87	0,82	1,17
G7	**Methane**		
USA	0,581		
UK	0,101		
Germany	0,992		
G7	**Nitrous Oxide**		
USA	0,340		
Germany	0,072		
France	0,063		

Source: Word Bank (2016). Elaborated by the authors.

To conclude, we say that in terms of average levels, countries with high GDP figures, mainly the USA, are also the countries that present the highest levels of gas emissions in the four decades investigated, contributing thus for the accumulation of Earth's air damage. An alert: USA and Japan have to keep their eyes opened to fight against level emissions of CO_2 and total greenhouses (HFC, PFC and SF6) gases emissions.

3.2. Correlation Analysis: G7 Rich Countries' GDP Versus Gases Emissions

To evaluate the strength of relationship between production paths and the trajectories of the four gases emissions, Table 2 shows the relevant coefficients of correlations. All of them are statistically significant at the 5% level, except the GDP x Methane correlation for France and GDP x Nitrous Oxide correlation for Canada.

Table 2: Correlations between GDP and Gases Emissions of the G7 Rich Countries - 1970-2012

	GDP x CO2	GDP x Methane	GDP x Nitrous Oxide	GDP x Total Greenhouses
* USA	0,83	-0,76	-0,70	0,84
* Japan	0,93	-0,93	-0,29	0,93
** Germany	-0,86	-0,94	-0,89	-0,91
* UK	-0,81	-0,95	-0,88	-0,93
* France	-0,76	-0,05 [i]	-0,85	-0,74
* Canada	0,73	0,79	-0,16 [i]	0,76
* Italy	0,66	-0,34	-0,75	0,73

Source: Elaborated by the authors (2016). All coefficients significant at 5%. [i] Insignificant at 5%. * 1970-2013 for GDP x CO_2. ** 1991-2013 for GDP x CO_2.

The evidence in Table 2 shows that the magnitudes of correlations of GDP x CO_2 are strong in all G7 countries, except in Italy that presents a moderate correlation [$| r | = 0.66 < 0.7$]. We prize the three Europeans, Germany, UK and France with a 'green light' – strong negative GDP x CO_2 correlations [$| r | \geq 0.76$], meaning that there exist a significant inverse relation between GDP paths and CO_2 emissions in these countries. 'Red lights' winners USA, Japan and Canada present strong positive GDP x CO_2 correlations [$| r | \geq 0.73$], meaning that increased CO_2 emissions are paired with increasing levels of aggregate production.

Regarding GDP x Methane and GDP x Nitrous Oxide correlations, Table 2 shows a dominance of negative signals, evidence that for these two gases there is lesser concern in terms of expecting increasing emissions. Only Canada presented a strong positive GDP x Methane correlation [$| r | = 0.79$], winning a 'red light' for its methane emissions.

Increasing GDP levels are strongly related to decreasing levels of methane emissions in Japan, USA, Germany and UK, the top four G7 countries leaders as GDP performers. The same holds for the GDP x Nitrous Oxide correlation figures, except for Japan with a significant but weak negative correlation [$| r | = 0.29$] and Canada with an insignificant coefficient [$| r | = 0.16$].

From Table 2, evidence on correlation coefficients involving total greenhouses gas emissions is a concern: 'red lights' to USA, Japan, Canada and Italy, all with correlations coefficients $r \geq 0.73$. Increasing paces of rapid production are very strong and positively related to increasing levels of HFC, PFC and SF6 gases emissions. Note that the three Europeans, Germany, UK and France, showed consistently strong and negative correlations [$| r | \geq 0.74$]. Again, all three countries are winners of 'green light' prizes.

Considering the three Europeans 'green light' winners, a relevant issue to be brought in the analysis is if these countries have been already facing high stages of economic development since the 1970s, and thus, the environmental Kuznets' curve hypothesis is under way – as higher stages of economic growth/development are being attained, environmental damage is prompted to reduce. As we know, Germany, UK and France have attained an economic stage of maturity since the mid-1950s, differently from Japan and Canada, for example, where higher stages of economic prosperity is a more recent phenomenon. This is an important issue to be discussed, but it is out of the scope of the present study.

To answer the question posed in the title of the paper (Are the G7 Rich Countries Contributing to Air Damage?) we use the empirical evidence presented to argue that in terms of levels, countries with high GDP figures are also the countries that presented the highest levels of gases emissions in the four decades investigated. This is evidence that the G7 rich countries are contributing to the accumulating levels of air damage via emissions of pollutant gases.

But, in terms of relational tendencies, i.e., using correlation analysis, increasing paths of GDP levels over time in the G7 rich countries are significantly related to decreasing levels of methane and nitrous oxide emissions. The villain are CO_2 and total greenhouses gases emissions – USA, Japan, Canada and Italy presented strong and positive correlations on GDP x CO_2 and GDP x Total Greenhouses over the long run of the four decades investigated. Alleviating evidence comes from the three Europeans: Germany, UK and France have been experiencing production growth and, at the same time, facing decreasing levels of all four gases emissions.

Conclusion

Taking into account the current need for nations adhering to environmental standards, a relevant issue is investigated: are augmenting levels of Gross Domestic Production (GDP) tied to increasing levels of air damage? This paper aims to analyze this production-environmental relation focusing on the G7 rich countries' economic (production) and environmental (gases emissions) performances in the four decade 1970-2012 period.

Graphical and statistical correlation analyses are the methods used to evidence that the relationships between GDP paths and trajectories of gases emission are, in general, significant, negative and strong. The source of the data set used is World Bank (2016), The Development Indicators. Results show that increasing GDP levels in the G7 countries are negatively related to methane and nitrous oxide gases emissions. Otherwise, the USA, Japan, Canada and Italy's DGP growth paths are paired with increasing levels of both CO_2 and total greenhouses gases emissions - they are winners of the 'red light' prizes, a concern to be taken into account if air safety is a priority.

To answer the question posed in the title of the paper, empirical evidence shows that, in terms of levels, countries with high GDP figures are also countries that present the highest levels of gases emissions in the four decades investigated, contributing thus to Earth's air damage. An alert: in terms of levels, USA and Japan have to keep their eyes opened to fight against emissions of CO_2 and total greenhouses (HFC, PFC and SF6) gases.

But, in terms of tendencies, correlation analysis brings a set of sound evidences: increasing trajectories for GDP levels over time in three European countries –

Germany, UK and France – were significantly related to decreasing levels of CO_2, methane, nitrous oxide and total greenhouses emissions. Another alert is needed: in terms of trends, USA, Japan, Canada and Italy have to keep their eyes opened to fight against CO_2 and total greenhouses (HFC, PFC and SF6) gases emissions.

Considering the three Europeans 'green light' winners, a relevant issue is if these countries have been already facing high stages of economic development since the 1970s, and thus, the environmental Kuznets' curve hypothesis is under way – for a country, as higher stages of economic growth/development are being attained, environmental damage is prompted to reduce. As we know, Germany, UK and France have attained economic stages of maturity since the mid-1950s, differently from Japan and Canada, for example, where higher attainment of high stages of economic prosperity are a more recent phenomenon. This is an important issue to be discussed in a future work; it is out of the scope of the present study.

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