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The dynamic intensity of CO_2 emissions: empirical evidence for the 20th century

A intensidade dinâmica das emissões de CO_2: evidências empíricas para o século XX

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RESUMO: A relação entre crescimento econômico e degradação ambiental (poluição) tem sido amplamente investigada por acadêmicos, principalmente, em virtude da constatação de que fatores antrópicos podem influir no clima global. O mecanismo pelo qual isso acontece, o dito efeito estufa, está diretamente relacionado ao acúmulo de certos gases na atmosfera, sendo o principal deles o dióxido de carbono, oriundos da atividade produtiva. Assim, o presente trabalho pretende estimar a taxa a qual a intensidade de emissão, razão entre o nível de emissões de CO_2 e o PIB, vem crescendo desde o início do século XX para um grupo de 24 países. Os resultados mostraram que Inglaterra e Estados Unidos possuem tendência negativa da intensidade de emissão, ao contrário do que foi observado para a Índia. Testou-se também a presença de mudanças estruturais, que se mostraram presentes coincidindo com a Primeira Guerra Mundial (1914 a 1918), a Grande Depressão dos anos 1930 e os Choques do Petróleo da década de 1970. A partir das análises dos resultados, pode-se dizer que os países desenvolvidos são menos intensivos em emissão, ou seja, é evidente o papel da tecnologia como instrumento de redução da intensidade de emissão global.
PALAVRAS-CHAVE: Intensidade de emissão; dióxido de carbono; aquecimento global.

ABSTRACT: The debate around the economic growth and environmental degradation is the hot topic among academics. However, up to a point, all of them embrace the uncontroversial view that tells us that anthropic factors have leverage on global climate. It happens that the so-called *greenhouse effect* is closely related to the accumulation of certain gases in the atmosphere, e.g., carbon dioxide, whose original source comes from productive sectors. Thus, our purpose in this article is to estimate the rate of emission intensity – here we mean the ratio between CO_2 emissions and GDP – which has increased since the early part of the 20th century. To support that idea, this study reports on data from 24 different countries. In terms of $C0_2$ emission, the results undoubtedly show that United Kingdom and the United

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States highlight a negative picture, particularly when both are compared to India. It should be noted the presence of structural changes, which coincide with three major historical events: the World War I (1914-1918), the Great Depression in the 1930s, and finally the Oil-price shocks in the 1970s. As the result of the analysis demonstrates, the amount of emission produced by developing countries is surprisingly low. That the technology reveals its relative merit for reducing the overall emission intensity is transparently obvious.
KEYWORDS: Emission intensity; carbon dioxide; global warming.
Jel Classification: K32.

INTRODUCTION

Even if the projections could all be mistaken, it has been a hardly deeply disturbing fact that economic externalities cause problems for the environment. Given that climate change is directly and necessarily influenced by human affairs, climate researchers have been concerned about the predicted bad effects of climate change without sacrificing the prosperity on the part of presently existing people. All this can be recognized but the tricky point is how one may properly produce while minimize environmental impact.

In fact, in the early 21st century empirical data were presented by the Intergovernmental Panel on Climate Change (2000, 2001, 2003). Examinations pointed out with increasing knowledge of the global temperature that CO_2 emissions are quite significantly.

Despite the current gain visibility, that issue was early on discussed by D'Arge in the 1970s. He primarily started by taking a Malthusian scenario, bolstered by the relationship between growth in population and environmental concern and came to the conclusion that population growth, material flows, etc. produce large amounts of pollution, deteriorating progressively the natural resources. This would be, of course, in the long run unacceptable. In practical terms, what is astonishing is that the exceeding of CO_2 emission occurs regarding one is stuck with the inevitable use of energy, as an indispensable input for the production – principal sources of energy are directly related to the burning of fossil fuels, having CO_2 emission as a by-product. Despite existing natural resources less damageable, coal and oil have been altogether the most familiar ones, at least since the second industrial revolution (Mauro, 1973).

A matter of ongoing concern is the extent to which CO_2 emission can or should affect, on grounds of efficiency, the production to a given economy. To make things simpler, an indicator that allows us to compare the efficiency between distinct economies will be required, one disposed by the ratios of CO_2 emission/GDP here called emission intensity (henceforth EI).

To explain this kind of problem, one must be able to build aspectual representations of the rate of EI. The theoretical framework in which we will estimate serial trends is that of the econometry, which can be regarded on the other hand as an extension of other views[1]. Granted this well-established framework comes to complement them, we still need to supply two congenial findings provided by Perron and Yabu (2009a, 2009b): the first estimates deterministic point placed in a context in which the signal-to-noise component can be integrated or stationary; the second admits equal properties of error, but is further dedicated to test the existence of structural change in the growth rate of EI.

The novelty here that reinforces the value of the contribution to the field is considerable: not only because this approach is clearly "econometric" comparatively to what we have done somewhere[2], rather, our enquiry into the logic of EI, namely, carried out with a bearing on its historic-serial principles, will be capable of generalization over a domain extending from 1901 to 2010, and this should in turn move us a long way toward establishing meaningful benchmarks in the field of environmental economics.

Using long-run data is by the way very useful in exploring if technological progress – which is generally meant to have a positive contribution to the GDP –, can somehow afford a reduction of CO_2. Based on the results, we evaluate if growth rate in EI is positive, negative or constant over the base period, and if we can gesture policy implications paying attention to the effects of greenhouse gases concentration, similarly tending to tackle the effects of climate change.

The rest of this paper is structured as follows. Second section will describe the database, e.g., source and temporal dimension, as well as the descriptive analysis of the time series. Third section presents the strategy of estimating the growth rate in CO_2 emission, that is to say, the alleged view engendered by Perron and Yabu (2009a, 2009b). The analysis and further discussion of the results make up fourth section, followed by a few final commentaries.

METHOD AND DATA

$C0_2$ emission – the source

The key to providing the intended calculation for EI (encompassing 24 developed countries 1901-2010 and equivalent amount of one thousand metric ton of carbon dioxide) resides in the ratio between CO_2 emission and GDP. In turn, as for the former, we make use of its data officially published by the Carbon Dioxide Information Center (CDIAC) but whose elaboration is due to Boden, Marland and Andres (2011). Such emissions come primarily from various resources, though the authors take into account the burning of fossil fuels, cement manufacture and flue gas. Additionally, as

[1] We are referring to the works of Nielsson (1993), Goldemberg (1996), Mielnik and Goldemberg (1999), Ang (1999), Roca and Alcántara (2001). The authors rely their views on visual inspection and descriptive statistics.

[2] Cf. Irffi (2011).

for the latter, we take data, with respect per capita GDP (for 1990 and estimated in 1990 international dollar) and population, engendered by Bolt and Zanden (2013) from the *Maddison Project*.

Be they rich, developed or developing, the choice of the following countries was determined by availability and access of data sets. They are: Europe – Austria, Belgium, Denmark, Finland, France, Greece, The Netherlands, Italy, Norway, Sweden, Switzerland, United Kingdom, Portugal and Spain; Oceania – Australia and New Zealand; North America – Canada and the United States; Latin America – Argentina, Brazil, Chile, Mexico, Peru; Asia – India.

Box 1: Variables description

Variable	Description	Measured value	Source
Pc GDP	Per capita GDP	1990 dollars	Madisson Project
Local residents	Local residentes	1.000 people	Madisson Project
GDP	Gross domestic product [Per capita GDP vs. Local residents]	1990 dollars	Calculated
CO_2	Emission of carbon dioxide	1.000 metric ton of CO_2	CDIAC
Intensity	Pollution originated for each dollar/a unit of wealth [(CO_2/GDP) x 1.000]	Kg. of CO_2 per 1990 dollars	Calculated

Source: Elaborated by the authors themselves.

Descriptive Analysis of Results

Having presented the variables, now we are *ipso facto* concerned with the behavior of the series along the base period. As for CO_2 emission and GDP, Graphs 1 and 2 indicate, in an aggregated way, the time evolution, namely, the sum of both variables bearing in mind the aforementioned 24 countries. Graph 3 highlights evolution of the global average of EI. Going a step further, we supply the analysis by pointing out the countries and the related chiefs elements which corroborate our view: the average yearly GDP growth, CO_2 emission and EI all along the base period.

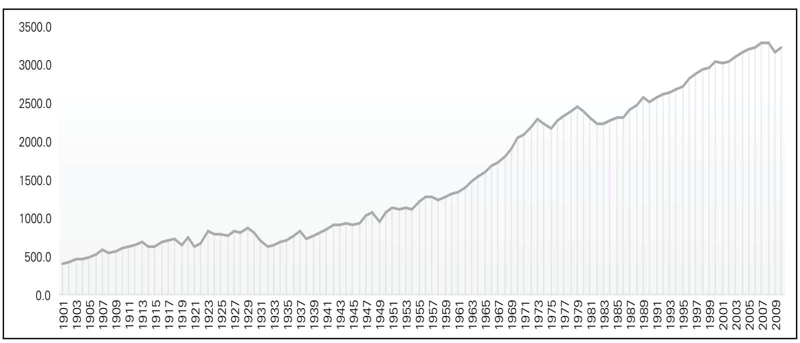
That a kind of evolutionary path towards an aggregated CO_2 emission outlines a positive trend is shown in Graph 1. However, in a few years, notably 1930 and 1970 decades, there seem to have been interruptions in that path, probably due to the Great Depression and the Oil-shocks. A rather notable point concerns an increase in emissions during the 1960s, given the average yearly growth rate of emissions doubled in comparison with previous decade. Finally, the level of emission varies consistently, though it has been subtle variations since the 1980s, the latter coinciding with the global financial crisis of 2007.

By those lights, note that it is straightforward to see how global CO_2 emissions did increased during 20th century. In addition, there have been nearly no decreases whatsoever, especially in the last 50 years, when there has been a strong increase, significantly leading to the global warming and climate change.

Like CO_2 emissions, any large-scale production of goods and services (measured by GDP) turned out a vertiginous growth last century. Note that during this period, the path is meant to get an exponential picture. Therefore, the positive tendency is a crystal clear example of this, since there is practically no period of persistent decline in global-scale production.

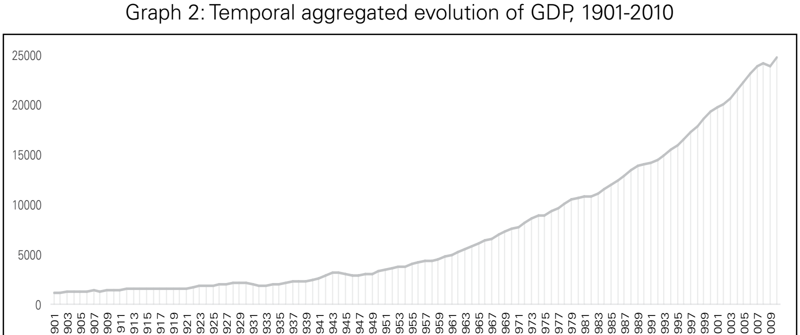
In Graphs 1 and 2 it can be “read off” that both CO_2 emissions and GDP outline a positive tendency. However, the former does not exhibit much shifts as for the latter, and the growth rate of the latter appears to be much less than that of the former, so much that time-path average of EI, as seen in Graph 3, has the tendency to decrease with strong shifts related to problematic historical happenings, namely, the two world wars. Since the intensity is given by the ratio between emissions and GDP, its decreasing path indicates a greater GDP growth as for the diffusion of CO_2.

Graph 1: Temporal aggregated evolution of EI, 1901-2010



Source: Elaborated by the authors themselves.

Graph 2: Temporal aggregated evolution of GDP, 1901-2010



Source: Elaborated by the authors themselves.

With respect the analysis of the aggregated series, as it can be seen, emissions and global production increased all along 20th century, but they were accompanied by a decrease in EI. Each country in our sample is individually reported in the Table 1, their growth rates (on average and in abolute terms) regarding CO_2 emission/GDP/EI over a 109-year period.

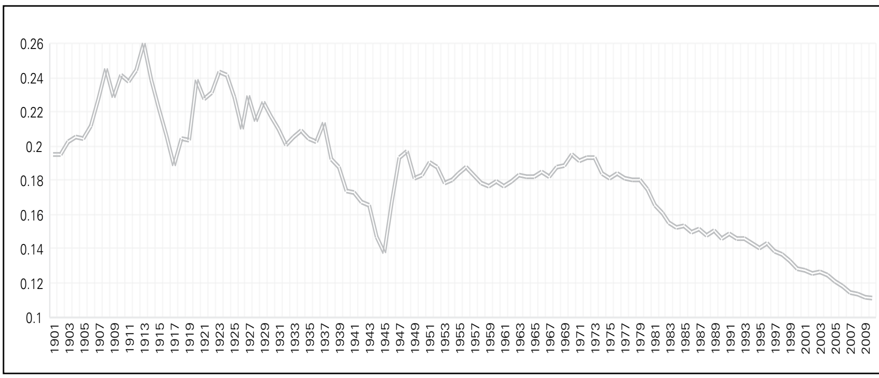
Table 1: Emission growth rate of CO_2-GDP/CO_2-GDP, 1901-2010

Countries	Emission of CO_2				GDP				Intensity of CO_2 emission			
	Growth (on average)	Rank.	Growth (in absolute terms)	Rank.	Growth (on average)	Rank.	Growth (in absolute terms)	Rank.	Growth (on average)	Rank.	Growth (in absolute terms)	Rank.
ARG	5,25	8	72,39	7	3,32	8	30,21	8	1,86	8	2,40	6
AUS	3,51	17	32,59	9	3,44	7	37,79	5	0,08	17	0,86	12
AUT	5,64	7	2,36	22	2,71	19	11,45	21	2,63	6	0,21	23
BEL	1,53	23	2,33	23	2,21	23	9,71	23	-0,73	21	0,24	21
BRA	6,10	6	199,42	4	4,42	1	103,05	1	1,59	9	1,94	7
CAN	3,16	18	20,92	13	3,76	3	49,11	3	-0,52	20	0,43	18
CHE	4,25	11	7,47	19	2,25	22	10,14	22	1,48	10	0,74	13
CHL	4,13	13	46,04	8	3,62	6	34,94	6	0,80	13	1,32	9
DNK	2,68	19	8,63	17	2,67	20	16,11	19	0,02	18	0,54	15
ESP	4,18	12	22,82	11	2,98	15	22,02	16	1,06	12	1,04	10
FIN	12,67	2	146,65	5	3,22	11	28,05	9	8,26	2	5,23	4
FRA	1,55	22	2,89	21	2,61	21	12,11	20	-1,02	23	0,24	22
GBR	0,71	24	1,20	24	1,98	24	8,02	24	-1,29	24	0,15	24
GRC	21,14	1	207,44	3	3,76	4	26,64	11	18,04	1	7,79	1
IND	4,79	9	139,43	6	3,02	14	22,74	13	1,91	7	6,13	3
ITA	7,12	3	30,03	10	2,83	18	17,62	18	3,12	4	1,70	8
MEX	6,70	5	337,96	1	3,63	5	44,57	4	3,13	3	7,58	2
NLD	3,65	16	12,71	15	3,21	12	22,71	14	0,25	16	0,56	14
NOR	3,95	14	14,67	14	3,26	9	30,51	7	0,49	15	0,48	17
NZL	2,55	20	11,50	16	3,04	13	23,08	12	-0,35	19	0,50	16
PER	6,80	4	241,57	2	3,99	2	62,75	2	2,65	5	3,85	5
PRT	3,76	15	21,90	12	2,98	16	22,17	15	0,75	14	0,99	11
SWE	4,56	10	6,16	20	2,88	17	20,84	17	1,31	11	0,30	19
USA	2,15	21	7,52	18	3,23	10	27,21	10	-0,99	22	0,28	20

Source: Elaborated by the authors themselves.

Note the existence of heterogeneity between average rates of growth of CO_2 emissions, while developed countries such as England, Belgium and France present an average annual emission growth rate around 1,5%, occupying the lowest positions – leading nations are Greece, Finland and Italy, the former having an average growth over 20% per annum. Regarding the evolution of emissions growth in absolute terms, Mexico turned out to have the largest increase in CO_2 emissions; in 2010, for instance, 337 times its emission than 1901, while England observed the lowest one, a little higher (20%) in 2010 than 1901.

Graph 3: Temporal Evolution of Average Emission Intensity, 1901 to 2010

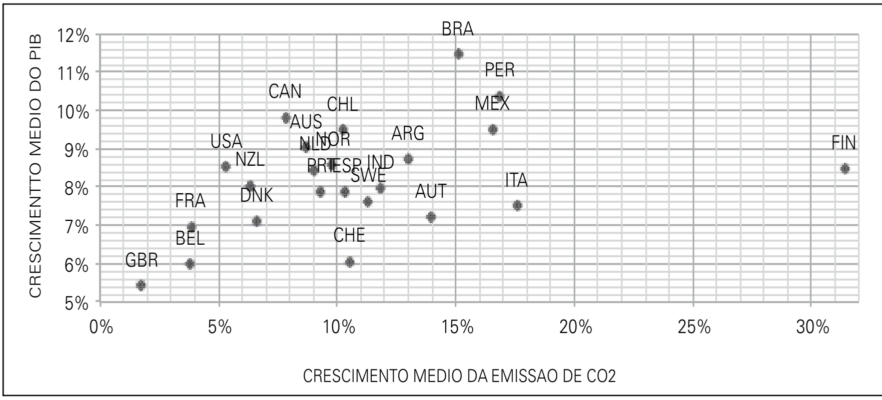


Source: Elaborated by the authors themselves.

Unlike emissions of CO_2, GDP growth rate varied slightly within the countries, ranging from 4,42% in Brazil to 1,98% in England. By the way, Brazil achieved the highest absolute growth; in 2010 the economy of Brazil turned out to be 100 times greater than a century earlier. As for the growth rate of emissions, England had the lowest one in absolute terms, having its economy multiplied by 8 since 1901.

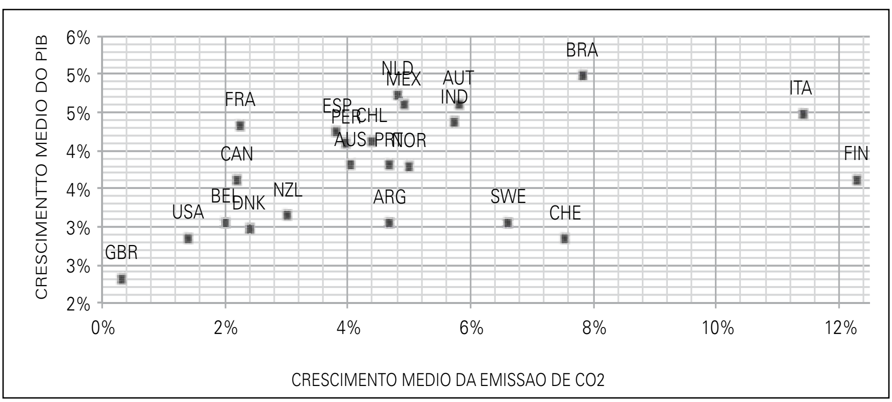
Due to the accuracy, in environmental studies, many economists make use of data from 1950 onwards. Thus, in order to differentiate the dynamic traditionally observed from that available by means of historical data, the period was split into two: the first from 1901 until 1945; the second from 1945 onwards. Both are seen in Graphs 4 and 5 which further deal with average yearly GDP growth rates vs. average yearly growth rate of CO_2 emissions. It is clearly indicated that economic growth in the first half of the twentieth century is accompanied by low growth rates of emissions, whereas this relationship seems to be stressed from 1956 onwards.

Graph 4: Growth GDP vis-à-vis average yearly growth of CO_2 emission, 1901-1945



Source: Elaborated by the authors themselves.

Graph 5: Growth GDP vis-à-vis average yearly growth of CO_2 emission, 1946-2010

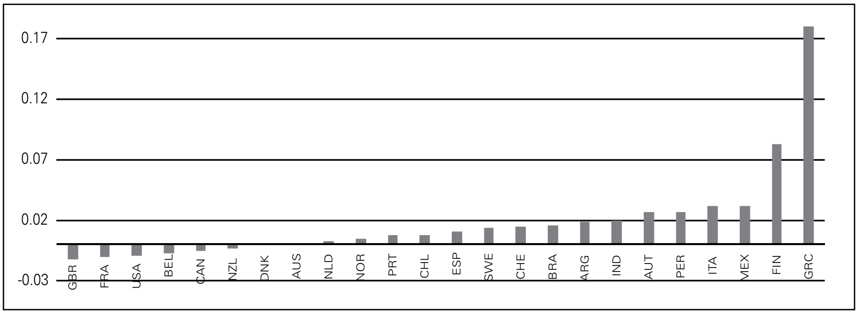


Source: Elaborated by the authors themselves.

For the sake of completeness, Graph 6 shows the ranking of countries regarding the growth averaged rate relatively to the EI. Note that developing nations (including Mediterranean countries), with the exclusion of France, outline the highest growth averaged rate. England, France and the United States instead outline rather the lowest levels. In absolute terms, Greece, which leads the ranking, had its intensity multiplied by 7 between the years 1901 and 2010; England, at the same period, reduced its EI to 15% from what it was a century before. A possible other reason for roughly explaining the dynamism in EI lies at the variety of economies, whilst including the application of less pollution-intensive technologies.

There are clear-cut evidences to support the existence of a positive relationship between economic growth and increase of CO_2 emissions, as well as a negative move in terms of EI. All that we are saying has a very direct and vital bearing upon growth rate of CO_2 emission, with (perhaps) unexpected structural breaks in the series.

Graph 6: Average yearly growth of CO_2 emission, 1901-2010



Source: Elaborated by the authors themselves.

Estimation results

To identify the trend of any time series may at first glance appear to be something relatively simple. Moreover, even by simpler process of visual inspection or the accurate statistics description may be misleading hinging on the properties of the series in question. We happen to know Canjels and Watson (1997), Vogelsang (1998) efforts in testing the existence of deterministic trend in macroeconomics series.

In addition, there is something to be learned from the classical framework of environmental economics, because, after all, Fomby and Vogelsang (2002), Vogelsang and Franses (2005), Coggin (2010) works are all glimpsing into the underlying hypothetical linear move of average growth temperature.

The increase in the global average temperature, about 0.5° every 100 years, is a remarkable result purposed in Vogelsang-Fomby 2002 paper. Further, it is worth noting that a positive trend in monthly temperatures during the winter is explicitly stated in Vogelsang-Franses (2005). Coggin (2010), in turn, applies a series of econometric tests to global and hemispheric surface temperature data. The author concludes that the tests are consistent regarding the warming pattern in recent years (post-1975).

Following Irffi 2011 paper, this study estimates the existence of any trend in **EI**:

$$y_t = \propto + \beta t + u_t \qquad (1)$$

Where y_t denotes the EI logarithm, then β catches the deterministic trend, u_t is the error term, subscript t meaning time, measured in years, $t = 1, \ldots, T$.

In such structure, to verify the presence of EI trend is equivalent to test H_0: β

= 0 vis-à-vis H_1: $\beta \neq 0$. If the null hypothesis is rejected, the sign of β indicates the trend direction. For $\beta > 0$, it is inferred that GDP growth is accompanied by an increase in CO_2 emissions. If $\beta < 0$, the country instead reversed the trend emission. Finally, if the null hypothesis is not rejected, the emission is statistically constant. To estimate its growth rate (namely, β), the *Feasible Quasi-generalized Least Squares* method developed by Perron and Yabu (2009a) is taken into account. Here the trend slope is mean to be unknown pattern, that is, it can be stationary or contain a unit root. This method allows us to make inference about the slope parameter by assuming the standard normal distribution.

Time series lack structural changes and this may invalidate the results of statistical test if they are not properly modeled. Perron-Yabu test (2009b) nonetheless captures the existence of structural changes within EI trend. This test is an inspiration of Perron-Yabu (2009a).

Given structural changes, the break date is obtained by inserting a dummy into the regression for minimizing the sum of squared error, as follows:

$$y_t = \propto + \beta_1 t + \beta_2 DT + e_t, \text{ where: } T = \left(t > TB\right)\left(t - TB\right) \qquad (1)$$

Being *D* a variable that captures structural change, *TB* assures shift date. The test statistic is part of *Feasible Quasi-generalized Least Squares* carrying a super-efficient estimator with known break dates from the Wald test (asymptotically distributed as a qui-square random variable). On the other hand, as for unknown break dates, there are constraints, since the test statistic still hinges on the twofold aspect of the series, namely, I (0) and I (1). Moreover, the date of structural change is estimated endogenously. Further, asymptotic critical values are very close at all levels of significance, thus allowing a very asymptotical procedure as for I (0) and I (1). In addition, the simulations performed by Perron-Yabu (2009a, 2009b) show greater robustness than the existing tests.

ANALYTICAL DISCUSSION OF RESULTS

We begin our analysis in this section by presenting results. All emission intensities measured in the manner of Perron-Yabu (2009a) are initially reported, because its advantages at present are huge, especially as for CO_2 emission trend, by dismissing hopelessly inadequate talk of its stationarity. Subsequently, the results are estimated in the light of Perron-Yabu (2009b) machinery, whose aim lies in detecting the presence of structural changes (these are very common to longer time series).

Statistically speaking, the first result, as seen in Table 2, suggests that for the most countries EI is constant, as they do not reject the null hypothesis, being the trend coefficient equal to zero forming 95% confidence interval. The exceptions are the United States, UK and India – outlining a negative trend in the two former cases, whereas in the latter a positive one. In view of this picture, it can be inferred that the two developed countries, in contrast with India, are remarkably more efficient in terms of emission per product generated, as India.

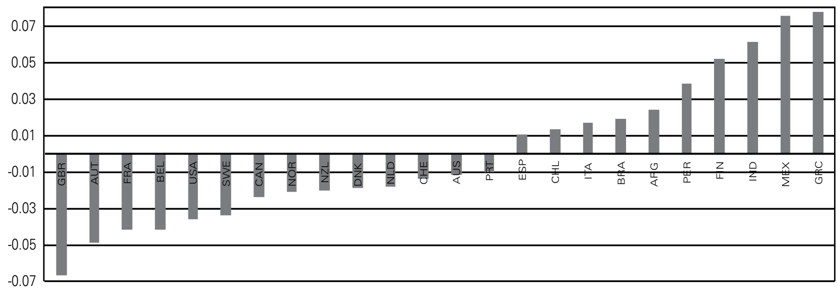
Table 2: Trend Estimation of CO_2/GDP, Perron-Yabu (2009a)

Countries	Intercept	Trend Coefficient	Lower Limit IC (95%)	Upper limit IC (95%)
AUT	0,4512	-0,0033	-0,0091	0,0025
BEL	0,5075	-0,0035	-0,0088	0,0018
DNK	0,1825	-0,0008	-0,0033	0,0017
FIN	0,0253	0,001	-0,0027	0,0048
FRA	0,2991	-0,0021	-0,0045	0,0004
ITA	0,0574	0,0004	-0,0018	0,0026
NLD	0,2183	-0,0009	-0,003	0,0013
NOR	0,249	-0,0012	-0,0047	0,0023
SWE	0,2125	-0,0014	-0,0053	0,0026
CHE	0,0753	-0,0002	-0,0012	0,0008
GBR	**0,6111**	**-0,0047**	**-0,0069**	**-0,0026**
PRT	0,0943	0,0000	-0,0012	0,0012
ESP	0,0908	0,0000	-0,0019	0,002
AUS	0,2146	-0,0003	-0,0025	0,0019
NZL	0,2159	-0,001	-0,0032	0,0012
CAN	0,3816	-0,002	-0,0058	0,0018
USA	**0,5701**	**-0,0038**	**-0,0068**	**-0,0007**
ARG	0,0478	0,0006	-0,0012	0,0024
BRA	0,0424	0,0004	-0,0008	0,0015
CHL	0,0641	0,0002	-0,0013	0,0017
MEX	0,0173	0,0011	-0,0096	0,0118
PER	0,0238	0,0006	-0,0017	0,003
IND	**0,0215**	**0,0011**	**0,0001**	**0,002**
GRC	0,018	0,0012	-0,0008	0,0032

Source: Elaborated by the authors themselves.

Yet it should be noted that, although the series earlier analyzed (see Graph 3) highlight a kind of downward moving trend as for emission intensity, Table 3 rather reports that in most countries there is no trend which be in turn statistically significant. Graphs 7 and 8 report the deterministic trend coefficients as well as the 95% estimated confidence interval. Once again, the United States and UK have negative growth rates, being their absolute values remarkably observed. As extreme case, India is the unique country that showed a positive trend regarding the base period, whose economic growth is clearly intensive in EI.

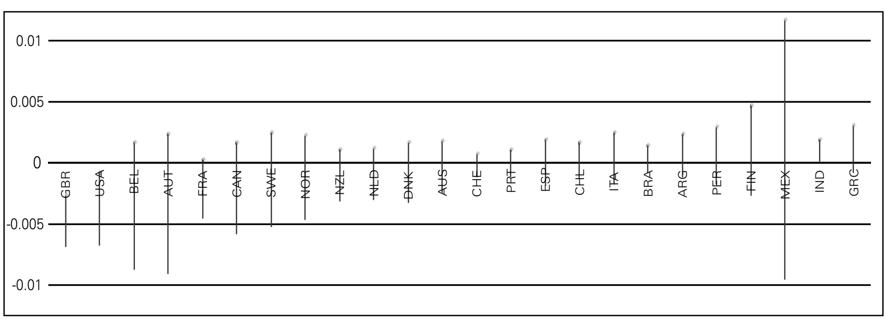
Graph 7: Growth rate of EI



Source: Elaborated by the authors themselves.

So far, we have only reported results with no break, thus we will also include the possibility of structural change. Regarding trend estimations, Table 3 contemplates pre(post)-structural change as well as its date and the statistical test. Further, among the 24 countries, eight of them presented structural change over the base period.

Graph 8: 95% confidence interval of CO_2 intensity trend



Source: Elaborated by the authors themselves.

The break dates indicate periods of *changement,* which in turn acknowledge occurrences in the dynamic relationship between economic growth and emission of $CO_{2.}$ For example, chronologically, the United States is a very young nation compared to most other nations of the world. However, North Americans have developed a strong sense of pride in many areas. For example, in the 1910s, North Americans got into rival disputes with several Central American countries, because they wanted to get rid of Panama's Canal under German influence.

As it were, US economy is highly protectionist, so as North Americans were obligated to provide primary material to their allies. Mauro (1973) suggests that the production of coal was the most affected activity by such official control. At that time, coal turned out to be a domestic product, which should be rationed since then. Details about this can be seen in Graph 9 below.

Table 3: Structural shift and estimations-tests trend of CO_2/GDP, Perron-Yabu (2009b)

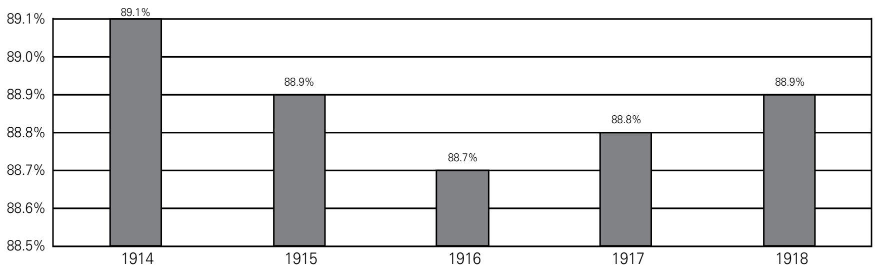
Country	Break date	Intercept	Pre-break trend	Statistical test	Post-break trend
BEL	1930	0,4875	0,0021	5,5468	-0,0079
DNK	1971	0,1844	0,0007	25,0660	-0,0044
FRA	1930	0,2918	0,0011	8,8267	-0,0045
NLD	1975	0,2356	-0,0001	5,9551	-0,0035
CAN	1916	0,3685	0,0111	7,3599	-0,0152
USA	1916	0,5548	0,0116	4,4781	-0,0178
PER	1925	0,0185	0,006	2,8474	-0,0068
IND	1993	0,0209	0,0017	2,0490	-0,0041

Source: The critical value for structural break test at the 5% level counts 1.67.

Occasionally, North Americans began to engage in environmental policies, especially the ones envisaged to protect forests and archaeological sites. Then they decided to build, in 1916, the National Park Service (Robertson, 1967). And, of course, this reflects a social worry about the conservation of natural resources, as Dinda (2004) points out, responsible for regulating certain sectors and so leading to a reduction of CO_2 emissions.

In the light of structural change machinery, the data suggest a kind of reverse trend motived simultaneously by the fall in production of North American coal (in part due to the First World War), and the increase of environmental regulation – which restrained the intensive use of wood as source of energy.

Graph 9: Proportion of Emissions from Solid Fuels, USA, 1914 to 1918



Source: Elaborated by the authors themselves.

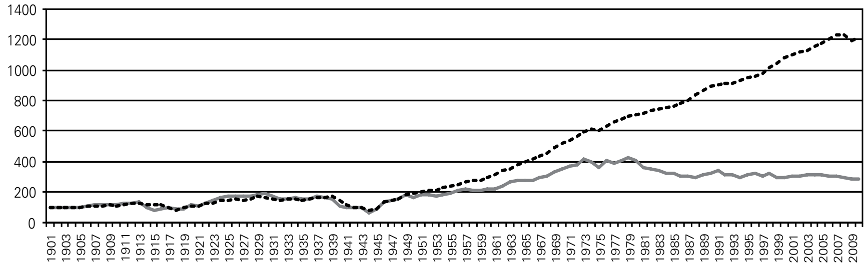
The interwar period, also known as the Great Depression, shakes profoundly the world markets, in particular by reducing both production and international trade. In the European context, the countries – which were still recovering from the disasters of the First World War – faced credit shortages immediately after the fall of New York Stock Exchange, plunged into crisis once again (Mauro, 1973).

In France, for example, that picture rendered indeed grave in virtue of party clashes and popular unrest. The fifteen years that followed the crisis of 1929, until the end of the Second World War, were stagnant for the French economy. It is no coincidence at all that in the same period the EI has fallen. However, the post-war period began a race for European reconstruction with a strong GDP recovery, but it was not accompanied by the increase in emissions. This is most readily seen in Graph 10.

Furthermore, oil shocks in the 1970s meant increases in commodity prices within OPEC members. These events highlighted global fuel trade weakness – a highly concentrated sector – and so encourage the search for alternative sources of energy (Farias and Sellitto, 2011). Since then, there was a great deal in news ways of human production, consequently, less pollution-intensive.

Unlike other dates, which mark worldwide events, the structural change underlined India data occurs in a peaceful (prosperous) period. This local phenomenon can be explained according to Barbosa (2008) by the profound economic reforms made in the early 1990s, when liberalization and trade liberalization policies were adopted. These reforms assured a significant growth to the Indian economy with the installation of a productive sector focused on manufactured goods exportation. In Beckerman's view (1992), India seems to be following the more natural way to reduce EI, and as consequence, will become a more developed country.

Graph 10: Change in GDP and CO_2 Emissions for France, 1901 to 2010



Source: Elaborated by the authors themselves.

CONCLUDING REMARKS

The foregoing sections have followed up the hazards of pollution in the domain of the society. We should supplement this now by calling Acemoglu et al. (2012) disturbing words concerning the most pressing challenges of environmental economics, though our argument lies outside the range of this controversy. We were engaged in estimating the emission intensity of CO_2 having a set of 24 countries.

Admittedly, as the results showed, the most development economies, namely, the United States and United Kingdom outline altogether a consistent gain in efficiency. What has been said of them, however, does not apply equally to India, whose production of CO_2 emission is quite high. This corresponds with its process of commercial *ouverture* since 1993.

Such reduction teaches us that richer countries are in line with Environmental Kuznets Curve thought by Grossman and Krueger (1991, 1995). This finding establishes that post-industrial economies tend to embrace lower levels of pollution, regarding the wealth generation is altogether related to service sector. Such sector admittedly minimizes the discharge of pollutants and produces cleaner technology.

The clear conclusion emerging from these data sets is that the EI path change had different origins within the countries under analysis. In addition, these changes appear to be tied to the changes in international scenario, such as wars or supply shocks, which require a reasonable way of using natural resources, in particular, energy resources. Bearing in mind the developed countries, changes in international scenario encourage the development of more efficient means of production, thus causing a reduction in emission intensity.

Finally, as suggestion for reducing global emissions of CO_2, one should take into account particular economics traits between developing and developed countries, not only by imposing them goals on increasing emissions, such proposed by Kyoto Protocol, but creating means of disseminating less emission-intensive technologies.

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