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African Journal of Science, Technology, Innovation and Development
Vol. 3, No. 1, 2011
pp. 65-85

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Abstract

This paper examines the existence of convergence and the importance of education on carbon dioxide growth per capita, over the period 1970-2004 for 85 countries. We use panel data and apply GMM-System estimation. This rigorous approach takes into account the observed and unobserved heterogeneity of countries, and solves the endogeneity problems associated with some variables. Our results suggest a divergence in per capita carbon dioxide emissions around the world, and that education is not a factor in carbon dioxide emissions growth. Contrary to commonly held beliefs based on intuition, we provide evidence that, in developing countries, there is no convergence, and that education is not a factor in carbon dioxide growth. In developed countries, we find a convergence for per capita carbon dioxide emissions. Education was found to be a factor in pollution growth, although its effect is mitigated by the presence of political institutions.

Keywords: Convergence in carbon dioxide; Education; System GMM

JEL Classification: H52, H75, I20.

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1. Introduction

In recent years, the climate change debate has received renewed attention, because climate change associated environmental and socio-economic effects are more evident now than even before. In response, some agreements, such as the Kyoto Protocol, were signed between countries. These agreements establish flexible mechanisms and confirm the commitment of countries to stabilise or reduce greenhouse gas (GHG) emissions over the period 2008-2012. However, these commitments do not include developing countries, such as China or India. Despite this weakness, the Kyoto Protocol remains one of the best instruments of economic policy against pollution at an international level, and should be improved to integrate developing countries. Among many options for including these countries, scientists promote the approach of Contraction and Convergence. This method involves a substantial reduction in carbon dioxide emissions (contraction) and gradual equalisation of per capita carbon dioxide emissions across countries (convergence). The aim of this approach is to allocate commitments to countries, to reduce air pollution from greenhouse gases. Countries can set sustainable emissions budgets, and share this budget on a per capita basis. This scenario is different from the current protocol, where emissions rights are proportional to historical levels. Emissions convergence can facilitate the participation of developing countries in pollution reduction, through adoption of an allocation scheme based on pollution per capita, without involving a substantial transfer of financial resources from developed countries to developing countries. Thus, the analysis of the convergence of air pollution is important in terms of international political policies.

This paper aims to determine the importance of education on air pollution growth, and the existence of convergence. First, based on the available empirical literature on air pollution convergence, we analysed the existence of convergence in per capita carbon dioxide emissions over the period 1970-2004 in 85 developing and developed countries. Other authors have analysed the convergence in per capita carbon dioxide emissions. For example, Strazicich and List (2003) found a beta convergence in carbon dioxide emissions in a sample of 21 industrialised countries over the period 1960-1997. They explain these results by the fact that these countries are on the downward sloping of environmental Kuznets curves, and that their incomes per capita are lower than incomes per capita at the steady state. Thus, pollution reduction would be lower at the transitional stage than after a steady state has been achieved. Nguyen (2005) examined convergence in carbon dioxide emissions for 100 countries from 1966 to 1996, and concluded that the environmental convergence hypothesis is a case of the glass either being half-full or half-empty. More precisely, countries with high initial CO_2 per capita emissions (relatively to sample averages) experienced a decrease in their relative emissions, whereas the relative emissions of low emissions countries remained unchanged during the study period. Stegman (2005) provides weak evidence for convergence in emissions per capita for a set of 97 countries from 1950-1999; and identified weak convergence in countries with very high rates of emissions per capita. Brock and Taylor (2010) examined empirical evidence for the existence of convergence in carbon dioxide emissions per capita for 22 OECD countries from 1960-1998. Based on their research, they developed the green Solow model, by introducing technical progress in the depollution activities sector in the traditional Solow model. This model generates a Kuznets environmental curve, with a balanced growth path of income per capita. Empirically, they found an absence of absolute convergence in emissions per capita for 139 countries, and conditional convergence for OECD countries.

Second, we analyse the role of education in air pollution growth. Contrary to existing literature on economic growth, the environmental economics literature has not explicitly investigated the role of education in air pollution growth. Since the Rio Summit (1992), education is has been considered to be an essential tool for both environmental protection and sustainable development. It is commonly held that educated people are more conscious of environmental problems, and therefore would make behavioural and lifestyle changes in favour of improving the environment. In addition, education is considered to be a driving force behind economic growth, and education fosters environmental protection.

Our results suggest a divergence in per capita carbon dioxide emissions worldwide. In developing countries, we did not find convergence in per capita carbon dioxide emissions and the engine of emissions growth reduction is technical progress. But we did find convergence in carbon dioxide emissions per capita in developed countries, where increased education was associated with increased air pollution growth. However, political institutions appear to be dampening this negative effect of education on air pollution growth.

The remainder of the paper is organized as follows. In Section 2, we address how education can influence environmental quality. In Section 3, an estimating equation is derived and results are shown, while in the last section, brief conclusions are presented along with policy recommendations.

2. Literature Review

Different approaches drawn from the literature on economic growth have been used to study convergence in air pollution. In this section, we present these methods and survey the empirical literature related to air pollution convergence.

Convergence in air pollution emissions

The concept of convergence in air pollution can be explored by employing several approaches adapted from the literature on economic growth. The first approach is sigma (σ) convergence. According to Sala-i-Martin (1990), sigma convergence is defined as the reduction in the spread or dispersion of air pollution emissions over time: usually measured using coefficient variation (cv) or standard deviation. The second approach is beta-convergence. Beta convergence refers to the existence of a negative relationship between the growth rate of air pollution per capita and the initial level of pollution per capita. Beta convergence occurs when countries with high initial levels of per capita CO_2 emissions have lower emission growth rates than countries with lower initial per capita CO_2 emissions. In addition, there is convergence when cross country differences in air pollution are declining. The third approach, the dynamic distributional approach to convergence analysis proposed by Quah (1995a, 1995b, 1996, 1997, 2000), examines the distribution dynamics of air pollution emissions. According to Quah, estimation of beta convergence using the method of cross sectional regression analysis yields "only average behavior", and does not produce relevant information on distribution dynamics, because it only captures representative economic dynamics. The dynamic distributional approach to convergence enables analysis and comparison of the distribution of a variable of interest at different dates. Finally, the last approach, stochastic convergence, is based on univariate time-series analysis, and was inspired by Carlino and Mills (1996). This method employs unit root specifications with a constant, and with or without a linear trend, for testing if shocks in air pollution per capita relative to the average for a country are temporary or tend to vanish over time. In other words, the time series approach to convergence analysis is based on the assumption that forecasts of variable differences converge to zero as the forecast horizon becomes arbitrarily long. If the differences between the countries' variable levels contain either a non-zero mean or a unit root, then the convergence condition is violated (Bernard and Durlauf, 1995, 1996).

Education and environmental quality

In this section, we examine and explore theoretical arguments concerning the relationship between education and environmental quality. In particular, two groups of articles are discussed.

The first group deals with the civic externalities of education. Nelson and Phelps (1966) consider that education enhances one's ability to receive, decode, and understand information; and that both information processing and interpretation impact learning and behavioural change. In recent years, education has been proposed as a vehicle for sustainable development, and by extension, the fight against pollution. Education is a permanent learning process that contributes to the training of citizens whose goal is the acquisition of knowledge, soft skills, know-how and good manners. It enables them to get involved in individual and collective actions, based on the principles of interdependence and solidarity. This will help coordinate person-society-environment relationships and support the emergence of sustainable societies that are socio-politically and economically fair, here and elsewhere, now and for future generations.

According to Farzin and Bond (2006), the predicted positive effects of education on environmental quality can be channelled in three ways. First, educated people are expected to be more conscious of environmental problems, and therefore would display behaviours and lifestyles in favour of environmental improvement. In addition, educated people have better access to information about environmental damage, and may consequently change their behaviour. In support of this, Bimonte (2002) has shown that increased education is often accompanied by higher levels of environmental protection.

Second, educated people have a higher capacity or ability to use existing means and channels to express their environmental preferences. For example, they can organize into pressure groups or lobbies, to push for and achieve implementation of environmental public policies. Dasgupta and Wheeler (1997) analysed factors encouraging people to complain about environmental damage in China. They found that Chinese provinces with relatively low education levels displayed a lower marginal propensity to complain about environmental damage. Without education, people have little information about the harmful risks or the long-term effects of environmental damage, and are only aware of the obvious impact. Furthermore, less educated people have little confidence in their own capacity to influence authorities. In support of this, empirical studies from the World Bank (Wheeler *et al.*, 1993) have shown that in the absence of effective government policies, communities with higher education levels take favourable actions to control or reduce pollution emissions.

Third, Farzin and Bond (2006) consider that educated people are "more likely to generate an environmentally progressive civil service, and therefore have democratically-minded public policymakers and organizations that are more receptive to public demands for environmental quality".

The second group focuses on the effect of education with respect to labour productivity and income. Specifically, according to the Environmental Kuznets Curve, environmental quality is initially reduced with rising incomes and development. At a given level, income rises are then associated with improvements in the environment. This effect is explained by fact that increased income levels generate the resources necessary for pollution abatement. In support of this, Jorgenson (2003) found that education has a positive effect on the ecological footprint. However, educated people have more income and purchasing power, and are encouraged to over-consume material goods. Indeed, they apparently fulfil a desire to live well by accumulating material goods, without caring about the consequences of this happiness: instead following the ideological model of "consume more to be happier" (Princen *et al.*, 2001) conveyed by advertising and the media, leading to even greater consumption of material goods. Therefore, because overconsumption of goods is a factor in the over-exploitation of natural resources, educated people directly contribute to environmental degradation (pollution of air, soil, and water). These empirical results reveal a positive and significant effect of enrolment in school on the ecological footprint per capita.

Second, education facilitates the development and adoption of new technologies that are more productive in a closed economy (Bartel and Lichtenberg (1987)); and according to Wells (1972), educated people adopt innovation sooner than less educated people. In fact, marketing literature shows that early (consumers) purchasers of new products are more educated. Nelson and Phelps (1966, page 70) concluded that a "better educated farmer is quicker to adopt profitable new processes and products since for him, the expected payoff from innovation is likely to be greater and the risk likely to be smaller; for he is better able to discriminate between promising and unpromising ideas, and hence less likely to make mistakes. The less educated farmer, for whom the information in technical journals means less, is prudent to delay the introduction of a new technique".

Education also stimulates the creation of knowledge; resulting in innovation as a function of research and the dissemination of knowledge from research centres and institutions, and promoting new ideas. These institutions can train many engineers and scientists and develop a research sector that is favourable to pollution abatement. Formal Research and Development (R&D) spending is concentrated in OECD countries, and developing countries spend relatively less on basic science and innovations. Thus, developing countries rely even more on the international diffusion of technology. Interestingly, Eaton and Kortum (1999) concluded that international technology transfers are the major source of technical progress for both developed and developing countries; while Keller (2004) argues that technology comes more often from abroad (90% or more) than from inside the country. The important question remains: Is human capital also important for international technology adoption and diffusion? Empirical and theoretical articles suggest that this story has gained support. For example, Caselli and Coleman (2001) have shown that inward technology diffusion increases with a country's human capital. Other major determinants of international technology diffusion are research and development expenditures, trade through intermediate input imports, learning-by-exporting experience, foreign direct investment (FDI) and communication.

Finally, education can change the structure of exports, which can become relatively less polluting, increasing the capacity to implement environmental policies. If an economy grows initially with the accumulation of polluting physical capital, and later with the accumulation of non-polluting human capital, then pollution can appear in the shape of a reversed U-curve.

3. Empirical analysis

(a) Econometric specification

The econometric approach of our paper is to analyze the role of education on the growth of air pollution and the existence of convergence. For this purpose, we estimate the growth of carbon dioxide emissions per capita on the level of education and a set of control variables. We write the baseline model as follows:

$$log\ \left({e_{i,t}}/{e_{i,t-1}}\right) = \beta_1 log\ \left(e_{i,t-1}\right) + \ \beta_2 \log\left(h_{i,t}\right) + \delta X_{i,t} + \alpha_i + \gamma_t + \varepsilon_{i,t} \ (1)$$

with $e_{i,t}$ the average quantity of carbon dioxide per capita (in metric ton) in a country i in a year t, $h_{i,t}$ is education, $\varepsilon_{i,t}$ is the error term, γ_t is time effect, α_i is country specific effect and $x_{i,t}$ is control variables. These variables are investments, population growth rate, trade openness, political institutions and technical progress. The period ranges from 1970 to 2004 and data are compiled in five-year averages. Our sample is taken from 85 countries including 22 developed countries and 63 developing countries (See Appendices).

Firstly, we analyse the existence of air pollution convergence (β_1). If it is negative and significant we can conclude that countries with low carbon dioxide per capita emissions catch up countries with high carbon dioxide per capita emissions. In other words, convergence occurs when countries with high initial level of per capita CO2 emissions have lower emission growth rate than countries with low initial level of per capita CO2 emissions. Secondly, we evaluate the effect of education on air pollution growth ($h_{i,t}$).

(b) Estimation method

In order to estimate this model we use adequate econometric techniques. The panel data take into account transversal and temporal dimensions and the unobserved heterogeneity (for example influence of economic specificities and environmental policies, etc.). We can run estimations using OLS (Ordinary Least Square) or Fixed Effects (FE). These are inadequate because the former (OLS) doesn't take into account unobserved heterogeneity of countries and the latter (FE) is inadequate for dynamic models. We then take into account country and time fixed effects and use the System GMM (Generalized Method of Moment). The first–differenced generalized method of moments estimators applied to panel data models addresses the problem of the potential endogeneity of some explanatory variables, measurement errors and omitted variables. The idea of the first–differenced GMM is "to take first differences to remove unobserved time invariant country specific effects, and then instrument the right–hand-side variables in the first-differenced equations using levels of the series lagged one period or more, under the assumption that the time varying disturbances in the original levels equations are not serially correlated" (Bond, Hoeffler and Temple, 2001). The System GMM estimator combines the previous set of equations in first differences with suitable lagged levels as instruments, with an additional set of equations in levels with suitably lagged first differences as instruments. Blundell and Bond (1998) provide evidence with Monte Carlo simulations that System GMM performs better than first-differenced GMM, the latter being seriously biased in small samples when the instruments are weak. To test the validity of the lagged variables as instruments, we use the standard Hansen test of over-identifying restrictions, where the null hypothesis is that the instrumental variables are not correlated with the residual, and the serial correlation test, where the null hypothesis is that the errors exhibit no second-order serial correlation. In our regressions, none of the tests on the statistics allows us to reject the validity of the lagged variables as instruments as well as the lack of second order autocorrelation.

(c) Descriptive analysis of data

The data on carbon dioxide emissions per capita, the investment rate, the trade openness and the population growth rate are from the World Development Indicators (World Bank, 2005). The data on education and political institutions come respectively from Barro and Lee (2000) and Polity IV (2010).

The emissions of carbon dioxide per capita are measured in metric ton per capita and are estimated from the combustion of fossil energies and cement industries in the liquid, solid or gas form. Trade openness and investment respectively correspond to the share of the sum of exports and imports and investments in gross domestic product (GDP). As political institutions variable, we chose the index of polity (2), which is a score obtained by differentiating the index of democracy and the index of autocracy on a scale going from +10 (democracy) to -10 (autocracy). The indicator of democracy is characterized by the effective existence of institutional rules framing of the power and the presence of institutions enabling citizens to express their expectations and to choose political elites. Autocracy is characterized by the absence or the restriction of political competition, economic planning and control. The exercise of power is slightly constrained by institutions and the leaders are only selected within a "political elite". The data on education resulting from Barro and Lee (2000) correspond to the average schooling years in the total population.

Table 1: Descriptive statistics of emissions of dioxide carbon and education

	Mean	Std. Dev.	Min	Max
World				
Growth of emissions per capita	0.08	0.35	-4.44	2.76
Emissions per capita	4.56	7.91	0.001	78.61
Education	4.67	2.06	0.042	12.21
Developed countries				
Growth of emissions per capita	0.04	0.29	-1.03	2.76
Emissions per capita	12.26	12.11	1.72	78.61
Education	7.93	2.05	2.44	12.21
Developing countries				
Growth of emissions per capita	0.09	0.37	-4.44	2.59
Emissions per capita	2.17	3.55	0.001	29.10
Education	3.41	2.19	0.04	10.27

Notes: the total sample is composed of developed and developing countries over the period 1970 -2004

Source: Author

Table 1 presents descriptive statistics of education, carbon dioxide emissions level and growth rate. It shows a high growth rate of carbon dioxide emissions per capita in the world (8.23%). This can be explained by the pollution growth rate in developing countries (9.4%) indicating their importance in the pollution phenomenon, contrary to developed countries (4.3%). We also noticed that countries (Developed countries) with high carbon dioxide emissions are relatively more educated and have low carbon dioxide growth rate.

4. Results

Table 2 presents results obtained using the System Generalized Method of Moments (System GMM). Column (1) shows the absence of conditional convergence in carbon dioxide emissions per capita in the world, because the coefficient is insignificant and equals (- 0.003). Note that this coefficient is between the fixed effects (FE) estimator (-0.595) and OLS estimator (-0.0008), which (Table 7 in Appendices) are biased downward and upward in the dynamic panel (for a small time period) (Bond, 2002). This result is consistent with previous studies (Westerlund and Basher, 2008; Aldy, 2007), which found an absence of convergence in air pollution at the international level. Since countries develop pollution behaviours according to their economic development, we analysed the convergence in carbon dioxide per capita according to the level of development (i.e. developing countries and developed countries).

Air pollution convergence according to economic development

Columns 2 and 3 of Table 2 show results when the sample is restricted to developing countries and developed countries. We found conditional convergence in carbon dioxide emissions per capita for developed countries, and divergence for developing countries. Our results are similar to Strazicich and List (2003) and Brock and Taylor (2010), who reported convergence in air pollution for OECD countries. Indeed these results confirm the hypothesis of convergence among the 23 member countries of the Organization for Economic Cooperation and Development (OECD) between 1960-1997 and 1960-1998.

Interestingly, we also observed that the effects of education and political institutions on pollution growth were significantly different, depending on the level of development. In fact, education favours pollution growth in developed countries, in contrast with developing countries where education was not associated with decreased pollution growth. Political institutions contribute to pollution growth in developing countries and attenuate pollution growth in developed countries.

The role of institutions and human capital as fundamental sources of differences in economic development, as highlighted by the economic literature, suggests the possibility that the effect of education on the environment could differ according to the quality of institutions in a given country.

Table 2: Effect of education on the growth of carbon dioxide per capita (System GMM)

	All countries (1)	Developing countries (2)	Developed countries(3)	Developing countries(4)	Developed countries(5)
Log of initial carbon dioxide per capita	-0.003 (-0.18)	0.008 (0.05)	-0.305 (-2.17)**	-0.009 (-0.72)	-0.201 (-2.14)**
Log of investment	0.326 (2.50)**	0.315 (2.40)**	0.549 (3.19)**	0.401 (3.29)**	0.337 (2.85)**
Log of trade openness	0.086 (0.93)	0.203 (1.51)	0.027 (0.48)	0.151 (1.32)	0.017 (0.43)
Democratic Institutions	0.036 (1.73)	0.043 (2.07)**	-0.049 (10.56)***	0.034 (1.75)**	-0.035 (1.36)
Growth of population	-0.034 (0.30)	-0.160 (1.43)	-0.104 (2.47)**	-0.15 (1.37)	-0.026 (1.84)**
Education	0.253 (0.83)	-0.219 (0.96)	0.445 (3.76)***	-0.047 (0.27)	0.545 (12.45)***
Education* Democratic Institutions				-0.008 (0.94)	-0.035 (2.91)***
Constant	-1.293 (1.84)*	-1.329 (1.90)*	-0.294 (1.91)*	-1.562 (2.32)*	-1.269 (2.51)**
Observations	229	182	47	182	47
Countries	85	63	22	63	22
AR (1) /AR(2) p value	0.82/0.21	0.57/0.75	0.52/0.40	0.70/0.36	0.07/0.18
Hansen Test p value	0.40	0.69	0.91	0.82	0.62
Number of Instruments	17	17	14	17	14

Note: *significant at 10%; ** at 5%; *** at 1%. Temporal dummy variables are included. The period is 1970 -2004 and data are compiled in five-year averages (70-74, 75-79, etc).

Interaction between education and institutions

When considered to be a public good, improvements in the quality of the environment are not directly determined by individual preferences, but rather indirectly through political institutions. In other words, the interaction between education and political institutions could affect environmental protection. Mahon (2002) hypothesised that the effect of education on the quality of the environment could be significantly greater in the presence of stable political institutions that are considered to be a channel of expression for the people. Inclusion of an interactive variable between education and institutions in our equation suggests that the effect of education on pollution growth is conditional on political institutions.

Columns (4) and (5) confirm that the growth rate of carbon dioxide per capita positively and significantly depends on the investment rate. This variable is an important determinant of air pollution in developing countries. In these countries, people are not very concerned about environment problems; and are more worried about development problems (e.g. low and unstable growth, unemployment). These investments can also reduce poverty because they are a driving force of economic growth. Foreign and domestic investments allow countries to access international markets, trade, and develop new technologies and competences. However, these opportunities differ with the level of development in the country.

In some countries, investments are directed toward buildings, services and manufacturing sectors. In other countries, they are directed toward the natural resource sector: in particular oil firms and wood companies, which are big energy consumers, and thus pollutants. For example, in Africa, 65% of direct foreign investments go to the natural resources sector. The expected effects are a rise in employment, taxes, state revenues, and a reduction of poverty. As such, these countries can also be less sensitive to environmental problems. In the same way, infrastructure weaknesses, particularly roads, strongly increases the use of energy and the consumption of polluting resources.

Political institutions have a significant and opposite effect, based on the level of development. In developing countries, the positive effect can be explained by free rider behaviour (Carlsson and Lundström, 2003), where political leaders consider pollution to be a public good and have no willingness to fight it. In contrast, in developed countries, political institutions reduce carbon dioxide per capita growth; an effect which is more significant with education. Columns (3) and (5) demonstrate that the effect of the quality of institutions on pollution growth is conditioned by the level of education.

Education also seems to be a factor in air pollution in developed countries, although its effect is slightly mitigated by the presence of political institutions. In the absence of political institutions, education increases pollution. Our results are similar to Jorgenson's (2003). As mentioned in the literature review, a possible explanation is that educated people have higher incomes and are encouraged to over-consume. They also fulfil their desire to live well by accumulating material goods without caring about the consequences of this happiness: following the ideological model of "consume more to be happier" (Princen *et al.*, 2001). However, political institutions mitigate this negative effect of education. In addition, although they pollute, educated people are also more conscious of environmental problems. Thus, their increased education level will increase their preferences for higher levels of environmental protection, which they will reflect through political institutions.

In developing countries, education and its interactive variable have no effect on the growth of carbon dioxide emissions per capita. Low education levels and the relative weakness of political institutions might explain the absence of an effect of education in developing countries. The combination of these factors strongly reduces the ability of people to express their preferences for a better environment. Therefore, the average effect of education on emissions growth is negligible. Furthermore, less educated people (relative to those in developed countries) are also poor and consume less material goods, which is a factor in environmental degradation.

While technical progress has no impact on pollution growth in developed countries, it is the key driving force behind depollution in developing countries. These results are not surprising. In developed countries, high education levels are also factors in the advancement of knowledge and technical progress; in contrast, developing countries produce little technical progress and require technology transfers. Because the level of technical progress is relatively low and their technological needs are so enormous, an increase in technical progress (e.g. new technology transfers) has only a high marginal effect on pollution reduction. In other words, technical progress is more effective in countries that are weakly endowed with such progress.

4. Robustness checks

To analyse the strength of our results, we considered eight other educational measures. These are: the average of years of schooling in general for individuals over 25 years old; the average of years of higher level schooling for individuals over 15 years old; the average of years of higher level schooling for individuals over 25 years old; the average of years of secondary level for individuals over 15 years old; the average of years of secondary level for individuals over 25 years old; the percentage of the population who completed some form of higher education; the percentage of the population who completed secondary school; and the percentage of the population who completed primary school. As suggested by Tables 3 and 4, our results remain stable in spite of the use of eight alternative variables. Thus, the average primary, secondary and higher school years in the population have similar effects on the growth of carbon dioxide emissions per capita, and these effects are different according to the country's level of development.

Second, we checked if the effect of education on the growth of emissions per capita was simply due to omission of the income variable (GDP per capita). From the point that education contributes to a rise in income and economic growth, education increases the use of environmental resources. It is thus a source of air pollution growth through increased income per capita. Our results may also be simply explained by omission of income (GDP/capita). Thus, to control for the relevance/accuracy of our results, we included income per capita. Columns 1 and 4 of Table 5 show that income per capita does not have a significant effect on the growth of emissions per capita. Results are stable, coherent and valid.

In recent years, the debate on climate change has been renewed because environmental and socio-economic effects are now more evident. In response, several international agreements were signed between countries. To take into account the effect of international agreements, we included The United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. The UNFCCC is an international environmental treaty produced at the Earth Summit in Rio de Janeiro (1992). The objective of the Treaty was to encourage stabilization of the concentration of greenhouse gases at a level that would prevent dangerous anthropogenic interference with the climate system. The Kyoto protocol establishes flexible mechanisms and commitments on the part of countries to stabilise or reduce the emissions of greenhouse gases (GHGs) by 5.3% over the period 2008-2012. Thus, we were very interested in testing the impact of the Kyoto Protocol and UNFCCC on the growth of carbon dioxide per capita. In Table 5 (columns 2, 3, 5, 6 and 7), we include "Kyoto" and "UNFCCC" variables. The dummy takes a value of one if a country has ratified the Kyoto Protocol or the UNFCCC treaty, and faces emissions reduction obligations; otherwise it takes a value of zero. Our results show that the Kyoto Protocol and the UNFCCC have no direct impact on the growth of carbon dioxide per capita. Two arguments can explain these results. First, it is still very early to verify the effects of the Kyoto protocol commitments on air pollution growth, because our analysis covers the period 1970-2004, and many countries only ratified it in 2002. Second, countries are not prompted to respect their international agreements.

Table 3: Effect of alternative education variables on the growth of carbon dioxide per capita (GMM-System) in developed countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log of initial carbon dioxide per capita	-0.16 (-2.05)**	-0.15 (-2.98)***	-0.14 (-2.89)***	-0.24 (-2.64)***	-0.16 (-2.02)**	-0.13 (-2.71)***	-0.14 (-2.28)**	-0.30 (-2.30)**
Educ1	0.539 (12.52)***							
PolityEduc1	-0.040 (3.89)***							
Educ2		0.447 (13.27)***						
PolityEduc1		-0.038 (6.68)***						
Educ3			0.439 (13.62)***					
PolityEduc3			-0.039 (7.22)***					
Educ4				0.588 (10.91)***				
PolityEduc4				-0.039 (4.37)***				
Educ5					0.487 (10.46)***			
PolityEduc5					-0.044 (10.02)***			
Educ6						0.442 (11.70)***		
PolityEduc6						-0.038 (8.53)***		
Educ7							0.522 (9.76)***	
PolityEduc7							-0.048 (11.79)***	
Educ8								0.551 (10.49)***
PolityEduc8								-0.043 (8.72)***
Number of countries	22	22	22	22	22	22	22	22

Notes: *significant at 10%; ** at 5%; *** at 1%. The period is 1970 to 2004 and data are compiled in five-year averages. Variables Educ1,… Educ8 correspond respectively to the logarithm of: the average schooling years in general for individuals over 25 years old, 15 years old; the average schooling years at a higher level for individuals over 25 years old; the average schooling years at a secondary level for individuals over 15 years old; the average schooling years at a secondary level for individuals over 25 years old; the percentage of the population having completed higher education; the percentage of the population having completed secondary school;and the percentage of the population having completed primary school.

Table 4: Effect of alternative education variables on the growth of carbon dioxide per capita (GMM-System) in developing countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log of initial carbon dioxide per capita	-0.11 (-0.28)	0.05 (-0.10)	-0.16 (-0.42)	-0.47 (0.69)	-1.15 (-0.67)	-0.03 (-0.08)	0.42 (0.52)	-0.41 (0.74)
Educ1	-0.204 (0.37)							
PolityEduc1	-0.001 (0.09)							
Educ2		-0.114 (0.30)						
PolityEduc1		-0.002 (0.34)						
Educ3			0.074 (0.31)					
PolityEduc3			-0.001 (0.28)					
Educ4				-0.531 (0.89)				
PolityEduc4				-0.013 (0.85)				
Educ5					-0.429 (0.62)			
PolityEduc5					0.001 (0.05)			
Educ6						-0.047 (0.15)		
PolityEduc6						-0.002 (0.35)		
Educ7							1.102 (0.65)	
PolityEduc7							0.016 (0.54)	
Educ8								-0.619 (0.83)
PolityEduc8								-0.009 (0.69)
Number of countries	65	63	65	63	65	63	63	63

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%. The period is 1970-2004. Variables Educ1,… Educ8 correspond respectively to the logarithm of: the average schooling years in general for individuals over (25 years old;15 years old); the average schooling years at a higher level for individuals over 25 years old; the average schooling years at a secondary level for individuals over 15 years old; the average schooling years at a secondary level for individuals over 25 years old; the percentage of the population having completed higher education; the percentage of the population having completed secondary school; and the percentage of the population having completed primary school

Table 5: Effect of education on the growth of carbon dioxide per capita, including international agreements and income

Growth of carbon dioxide per capita (GMM-system)	(1)	Developed countries (2)	(3)	(4)	Developing countries (5)	(6)	(7)
Log of initial carbon dioxide per capita	-0.19 (-2.14)**	0.19 (3.16)***	0.19 (2.92)***	-0.084 (-0.61)	0.11 (0.99)	0.19 (1.30)	0.15 (0.52)
Log of investment	0.340 (2.80)**	0.330 (1.39)***	0.328 (1.37)***	0.402 (3.30)***	0.388 (3.21)***	0.489 (3.52)***	0.39 (2.69)***
Log of trade openness	0.026 (0.51)	0.025 (0.46)	0.024 (0.43)	0.147 (1.30)	0.068 (0.50)	0.044 (0.36)	0.013 (0.11)
Technical progress	0.031 (1.04)	0.046 (0.43)	0.047 (0.70)	-0.178 (2.16)**	-0.104 (2.01)**	-0.091 (1.71)*	-0.04 (1.85)*
Political institutions	0.035 (1.45)	0.943 (0.22)	0.717 (0.12)	0.034 (1.76)*	0.036 (1.89)*	0.033 (2.24)**	0.043 (2.24)**
Population rate	-0.029 (1.69)	-0.093 (1.69)	-0.096 (1.66)	-0.140 (1.27)	-0.100 (0.81)	-0.075 (0.69)	0.004 (0.13)
Education	0.542 (12.63)***	18.015 (2.32)**	13.918 (2.25)**	0.005 (0.02)	0.084 (0.56)	0.212 (1.07)	-0.008 (0.04)
Education* Political Institutions	-0.036 (3.14)***	-1.787 (2.32)**	-1.377 (2.24)**	-0.009 (0.95)	-0.010 (0.90)	-0.004 (0.49)	-0.02 (1.04)
Log of income per capita	0.006 (0.42)			0.004 (0.33)			
UNFCCC		0.090 (1.54)			-0.018 (0.06)		
Kyoto			0.081 (1.14)			-0.134 (1.15)	
CDM							0.21 (1.19)
Constant	-1.407 (2.55)**	-10.193 (2.25)**	-7.913 (2.16)**	-1.61 (2.46)**	-0.877 (1.84)*	-1.232 (2.27)**	1.48 (2.17)*
Observations	47	47	47	161	170	170	170
Number of countries	22	22	22	63	63	63	63
AR (1)	0.22	0.071	0.06	0.51	0.32	0.35	0.52
AR(2)	0.72	0.24	0.17	0.81	0.45	0.47	0.40
Hansen Test	0.83	0.75	0.69	0.72	0.72	0.48	0.90
Number Instruments	14	15	15	17	27	27	27

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%. The period is 1970 to 2004 and data are compiled in five-year averages (70-74, 75-79, etc). Temporal dummies are taken into account.

5. Conclusion

This study examined convergence in air pollution and the effect of education on the growth of air pollution over the period 1970-2004 in 85 countries. Our results show a divergence in carbon dioxide per capita at a global level during the period 1970-2004. For developing countries, there is a divergence in carbon dioxide per capita.

Our results also suggest that education has no impact on the growth of air pollution in the total sample (85 countries). However, this effect is heterogeneous between the countries according to their level of development. Indeed, while its effect remains insignificant in the developing countries sub-sample, education does matter for pollution growth in the developed countries. More interestingly, when controlled for the quality of democratic institutions, the positive effect of education on air pollution growth is mitigated in developed countries, while it is insignificant in developing countries.

Technical progress contributes to a reduction in air pollution growth. Investment, which is the driving force behind economic growth, is an important source of pollution in both developing and developed countries.

Our results are important for economic policy development. Initially, they highlight the importance of education in environmental protection. The current accumulation of knowledge is a factor in both economic growth and pollution growth. We are not recommending questioning education policies, whose intrinsic values are obvious. On the contrary, there is a need for introducing a changed perception of the role of education, in favour of the environment. This should be very urgently implemented in developing countries, because the realisation of the Millennium Development Goals (MDG) regarding education will be followed by environmental pollution. Then, there is the free rider phenomenon practised by some countries in the fight against climate change. In addition, because investments are a key factor in economic growth and a determinant of pollution, reduction of these effects should be necessarily followed by the establishment of ecologically appropriate investments. Finally, the divergence of air pollution at an international and developing countries levels requires transformation of the Kyoto protocol, which should include agreements for technology transfers and the promotion of ecological development.

This paper opens several avenues for future research. Indeed, our results highlight the convergence and divergence in air pollution for developed and developing countries, respectively. It will therefore be interesting to analyse deeper determinants of air pollution convergence with respect to economic development.

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Appendices

List of countries included in the sample

Australia, Austria, Belgium, Canada Denmark, France, Finland, Germany, Greece, Holland, Israel, Italy, Japan, Luxemburg, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, The USA. Algeria, South Africa, Burundi, Benin, Bangladesh, Bahrain, Bolivia, Brazil, Botswana, Central Africa, Chilie, China, Cameroun, Congo, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, Fiji, Ghana, Guatemala, Honduras, Haiti, Hungary , Indonesia, India, Iran, Jamaica, Jordan, Kenya, Mexico, Mali, Mauritania, Malawi, Malaysia, Niger, Nicaragua, Nepal, Pakistan, Peru, Philippines, New Guinea, Guinea, Poland, Paraguay, Rwanda, Senegal, Sri Lanka, Sierra Leone, El Salvador, Syria,Togo, Thailand, Trinidad and Tobago, Tunisia, Turkey , Uganda,Uruguay, Zambia.

Table 6: Definition and source of variables

Variables	Definitions	Data Source
Carbon dioxide per capita	Carbon dioxide per capita (metric ton per capita)	World Development Indicators (2005)
Emissions per capita initial	Carbon dioxide per capita at the beginning of each period	
Investment rate	Investment/GDP	
Trade openess rate	(Exports+Imports) / GDP	
Population growth rate	Population growth rate	
Political institutions	Combined score of democracy and autocracy on a scale going from -10 to 10. (- 10) large represents a big autocracy and 10, large democracy	Polity IV
Education	Average schooling years in the total population	Barro and Lee (2000)

Table 7: Effect of education on the growth of carbon dioxide pe capita with Fixed effects (FE) and (Ordinary Least Square)

	All countries		Developed countries			
	F E	OLS	FE	OLS	FE	OLS
Log of initial carbon dioxide capita	-0.595***	-0.0008***	-0.346***	-0.158***	-0.237**	-0.175***
	(-15.26)	(-4.810)	(-4.993)	(-4.507)	(-2.696)	(-4.591)
Log of investment	0.244***	0.408***	0.129	0.322***	0.0272	0.249***
	(3.302)	(7.197)	(1.261)	(3.686)	(0.241)	(2.983)
Log of trade	0.216***	-0.0104	-0.228**	-0.0225	-0.188*	-0.0409
	(3.233)	(-0.399)	(-2.059)	(-0.940)	(-1.725)	(-1.609)
Technical progress	-0.00697	0.00317	0.00366	0.0100	-0.00244	0.00748
	(-0.455)	(0.211)	(0.187)	(0.676)	(-0.127)	(0.499)
Political institutions	0.00177	0.00157	-0.00799	-0.000782	0.0141	0.0224
	(1.080)	(1.017)	(-1.193)	(-0.146)	(1.068)	(1.265)
Education	0.0462	0.0572***	0.122**	0.0160	0.277***	0.133*
	(1.098)	(3.212)	(2.164)	(0.695)	(2.843)	(1.836)
Political institutions*education					-0.0176*	-0.0117
					(-1.918)	(-1.621)
Constant	-1.507***	-0.955***	1.148*	-0.382	0.951	-0.286
	(-5.741)	(-4.471)	(1.886)	(-1.229)	(1.592)	(-0.994)
Observations	292	292	73	73	73	73
R-squared	0.642	0.331	0.852	0.807	0.865	0.821
Countries	88		23		23	

Note: *significant at 10%; ** at 5%; *** at 1%. Temporal dummy variables are included. The period is 1970 -2004 and data are compiled in five-year averages (70-74, 75-79, etc)

Table 8: Descriptive statistic

Variables	Mean	Std. Dev.	Min	Max
Log of initial per capita dioxide carbon	4.56	0.35	0.0015	78.61
Growth rate of dioxide carbon per capita	0.08	7.91	-4.44	2.76
Investment rate	21.42	7.39	2.53	86.79
Trade openess rate	71.14	41.51	5.71	297.33
Political institutions	0.49	7.47	-10	+10
Population growth rate	1.97	1.61	-20.36	16.17
Education	4.67	2.95	0.042	12.21

Source: WDI (2005), Polity IV, Barro and Lee (2000)