Does Education matter for convergence in carbon dioxide per capita emissions?

KINDA Somlanaré Romuald

Ph-D candidate at CERDI[1], Université d'Auvergne

Abstract

Recent papers have debated the existence of convergence in carbon dioxide per capita. This paper improves on existing work and examines the importance of education on the convergence in carbon dioxide per capita emissions over the period 1970-2004 for 85 countries. We use panel data and apply GMM-System. This rigorous approach takes into account observed and unobserved heterogeneity of countries and solves the endogeneity of some variables.

Our results suggest a divergence in carbon dioxide per capita emissions and education doesn't matter. Contrary to common intuition, in developing countries there is no convergence and education doesn't matter for carbon dioxide growth. In developed countries, education favours convergence in carbon dioxide per capita only if it interacts with good political institutions. Without interaction to political institutions, education increases carbon dioxide per capita growth and handicaps carbon dioxide per capita convergence.

Key words: Convergence; carbon dioxide; Human capital; GMM-System

[1] CERDI : Centre d'Etude et de Recherche sur le Développement International, Université d'Auvergne, Clermont Ferrand

1. Introduction

In recent years, the climate change debate has been renewed attention because these environmental and socio-economic effects are now more evident than even before. In response, some agreements including the Kyoto Protocol were signed between countries. It establishes flexible mechanisms and commitments of countries to stabilize or reduce emissions of greenhouse gases (GHGs) over the period 2008-2012. However, these commitments do not include developing countries and its application is subject to criticisms. Despite these uncertainties, the Kyoto Protocol remains the only instrument of economic policy against pollution at the international level and should be improved to integrate developing countries.

Analyze the convergence of greenhouse gases (GHGs) can affect the political economy of multilateral negotiations on climate. It could encourage countries with high emissions per capita (developed countries) to make additional effort to mitigate climate change compared to countries with low emissions per capita (developing countries). In few years pollution in developing countries will exceed emissions in developed countries. So, some analysts want to encourage the participation of countries in globally carbon emissions permits regime based on per capita emissions allocation. But developed countries have rejected this principle because per capita emissions allocation will involve a substantial financial resources transfer towards developing countries. With air pollution convergence (divergence) respectively, developed countries will accept (not accept) the principle. The absence of emissions convergence doesn't permit the participation of developing countries to a policy of pollution reduction. Thus the analysis of the convergence of air pollution is important in terms of political policies.

The paper aims to determine the importance of education on air pollution convergence.

On one hand we analyze the convergence in carbon dioxide per capita emissions for 85 countries over the period 1970-2004. It follows the empirical litterature on air pollution convergence illustred by many authors. Strazicich et al.(2003) examine and find beta and stochastic carbon dioxide emissions convergence in 21 industrialiazed countries over the period 1960-1997. They explain results by the fact that these countries are on the downward sloping of environmental kuznet curve and their incomes per capita are lower than incomes per capita at steady state. So the reduction of pollution will be lower at transitional stage than at regular state. Nguyen (2005) examines the convergence in carbon dioxide emissions of 100 countries from 1966 to 1996. They conclude that the environmental convergence hypothesis is half-full or half-empty. The countries with high CO2 per capita emissions relative to sample averages observe a decrease in their relative emissions whereas the relative emissions of low emissions countries remain unchanged during the period of study. Stegman (2005) shows that there is little evidence for convergence in emissions per capita for 97 countries over 1950-1999. She also finds some weak convergence for countries with very high rates of emissions per capita.

Brock and Taylor (2004) examine empirically the existence of convergence in carbon dioxide per capita for 22 OECD countries over the period 1960-1998. They develop the green solow model by introducing a technical progress in a sector activities depolllution in the traditional solow model. This model generate a kuznets curve environmental with balanced growth path of income per capita. They obtain an absence of absolute convergence in emissions per capita for 139 countries and conditional convergence for OECD countries.

On other hand we analyse the role of education on pollution convergence using a augmented green solow model. Contrary to the litterature on growth and economic convergence, the litterature on economy and environment is not very interested in the role of education on air pollution convergence.To analyse the effect of education on environment, we distinguish two approaches that are civic externality and human capital.

Our results suggest that there is divergence in carbon dioxide per capita in world. In developing countries we didn't find a convergence in carbon dioxide per capita and the engine of emissions growth reduction is technical progress. In developed countries education is a factor of emissions convergence if it is associated with good political institutions. Without them, education increases pollution growth.

The remainder of the paper is organized as follows. Section 2 shows how education can influence environment quality. Section 3 derives an estimating equation and shows results and the last is devoted to the conclusion.

2. How does education affect environment quality?

We are using two approaches to analyze the effect of education on environment quality: approch of civic externality and approch of human capital.

The first approach is to take account of the civic externality of education. Nelson & Phelps (1966) consider that education enhances one's ability to receive, decode, and understand information, and that information processing and interpretation is for learning and change behaviours. In recent years, education is considered as a vehicle for sustainable development and thus the fight against pollution. For Robitaille (1998), education is a permanent process of learning contributing to the training of citizens whose goal is the acquisition of knowledge, knowledge-being, know-how and good manners. They can engage in individual and collective actions, based on the principles of interdependence and solidarity. This will promote the harmonization of relations "person-society-environment" and emergence of sustainable societies, socio-political and economically just here and elsewhere, now and in future."

Farzin and Bond (2006) identify three channels for a positive relation between education level and environmental quality improvement.

Firstly, educated people would be more conscious of environmental problems and therefore would have behaviors and lifestyles in favour of environment improvement. The lack of information and knowledge about the consequences of environmental damage may limit the consumers' willingness to pay. So educated people have access to information and change their behaviour. Bimonte (2002) shows that increase in people's education is often accompanied by increases in preferences that favor a higher level of environmental amenities. For a given income, education increases the minimum level of environmental quality at which a country requires.

Secondly, educated people have a better capacity or ability to use existing means and channels in order to express environmental preferences. They can also get organized in pression groups, lobbies to obtain the implementation of environmental public policies. Wheeler et al. (1997) analyse factors encouraging people to complain about environmental damages in China. They show that chinese provinces with relative low education have a lower marginal propensity to complain about environmental damages. Without education, people have little informations about harmful risks, effects of the environmental damages in the long term and are interested only in obvious impact. That could be also explained by fact that less educated people have little confidence in their own capacity to influence authorities. Empirical studies of World Bank (Wheeler & Huq, 1993) show that without effective government policies, communities with high education take favorable actions to control or reduce emissions of pollution.

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

Despite the relative consensus on the positive effect of education, other authors believe that education is a factor of pollution. Jorgenson (2003) finds that education has a positive effect on the ecological footprint. Educated people have more income and purchasing power and are encouraged to an overconsumption of material goods. Indeed, they desire to live well by accumulating material goods without caring about the consequences of this happiness and the ideological model of "consume more to be happier’’ (Princen et al. 2002) conveyed by advertising and media lead to great consumption of material goods. Because the overconsumption of good sis a factor of over-exploitation of natural resources, educated people contribute to environmental degradation (pollution of air, soil, and water). These empirical results show a positive and significant effect of enrollment on the ecological footprint per capita.

According to the second approach, the accumulation of education has a positive impact on labor productivity and income (Mankiw, Romer and Weil, 1992). According to the environmental kuznet’s curve, environment quality is reduced initially with the rise of the income and development process. At a given level, income raises can be then associated with an improvement of environment. That is explained by fact that increase of income generates resources necessary for pollution abatement. The effect of education on the environment quality is indirect and depends on income.

Secondly, education facilitates the development and adoption of new technologies more productive in a closed economy (Ann Bartel and Lichtenberg (1987)). According to Welle (1972), educated people adopt innovation sooner than less educated peope. From marketing littérature, he shows that early (consumer) purchasers of new products are more educated. Nelson & Phelps (1966) conclude that “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 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, innovation as a result of these functions of research and dissemination from research centers and institutions and promotes new ideas and knowledge. These institutions can train many engineers and scientists and develop research sector favorable to pollution abatement. Formal R&D spending is concentraded in OECD countries and developing countries spend relatively less on basic science and innovations. So they rely even more on international diffusion of technology.Many recents researchs (Eaton & Kortum 1999; Keller 2001a) concluded that international technology transfers are the major sources of technical progress for both developed and developing countries. Keller (2004) argues that technologoy is more international origin (90 percent or more) that domestic origin. The important question is: does human capital also important for international technology adoption and diffusion? Empirical and theoric papers suggest the affirmative. Eaton & Korton (1996), Caselli & Coleman (2001), Xu (2000) show that inward technology diffusion increases with country’s human capital. Other major determinants of international technology diffusion are Research and Development expenditures, trade through intermediate input imports (Eaton & Kortum (2001, 2002), learning-by-exporting experience (Bernard and Jensen 1999; Clerides, Lach, and Tybout 1998; Mary Hallward-Driemeier, Giuseppe Iarossi, and Kenneth Sokoloff 2002), Foreign direct investment (FDI) and the importance of communication (Keller 2001).

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

3. Empirical analysis

3.1. Econometric specification

The econometric approach of our paper is to analyze the role education on convergence in carbon dioxide per capita emissions. For this purpose, we foolow Brock & Taylor (2004) and estimate the growth of emissions on the level of education and a set of variables of control.

We write the baseline model as follows :

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

with $e_{i,t}$ the average quantity of carbon dioxide (in ton metric) emitted by an individu living in a country i at a year t ; $x_{i,t}$ control variables. This equation will enable us to analyze on the one hand the role of education in pollution growth and on the other hand, to verify if the countries with same economic characteristics and initial conditions have a convergence in pollution emissions per capita. The period is 1970 to 2004 and data are compiled in five-year averages. It’s a sample of 85 countries including 22 developed countries and 63 developing countries.

3.1.1 Determinants of growth rate of of carbon dioxide per capita emissions

A large number of variables have been considered in the literature as possible determinants of dioxide carbone missions. We follow the literature in selecting control variables reflecting the Investment rate, population growth, the openness of the economy, political institutions and technical progress.

Level of carbon dioxide per capita emissions

It's the key variable in the convergence hypothesis. If the estimated coefficient is negative and significative 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 CO_2 emissions have lower emission growth rate than countries with low initial level of per capita CO_2 emissions.

Investment and population growth rate

According to Brock&Taylor (2004), an investment rate leads to high physical capital stock at regular state and increases carbon dioxide per capita emissions during transitional dynamics. Many authors have analysed the importance of population on environment. According to National Academy of science (NAS, 1992), "The more people there are in the world, the greater is the demand put on resources to provide food, energy, clothing and shelter for them. All these activities necessarily involve emissions of greenhouse gases". Newell & Marcus show there is a ''nearly perfect'' correlation (99,8%) between world population growth and growing concentration of carbon dioxide over the period 1958-1983. Holdren (1991) and Harisson (1994) use mathematical formula to find the contribution of population growth to greenhouse gas emissions. They conclude that population growth is responsable for 40% (36%) of the increase in energy consumption (annual emissions growth) respectively. However Lutz (1993) found that population growth has a small role in industrial carbon dioxide emissions.

Also population growth rate has a positive effect on pollution.

Trade openness

Grossman and Krueger (1995) decompose the effects of trade on environment into scale, technical and composition effects. The scale effect of trade measures the negative environmental consequences of scalar increases in economic activity. And the technical effect is the positive environmental consequences of increases in income that call for cleaner production methods. The composition effect can have a positive or negative impact on the environment because it measures the evolution the economy towards a more or less appropriate productive structure. Thus, Antweiler and Al (2001) conclude that trade reduced emissions of pollution of 43 countries over the period 1971-1996. It is the same for Frankel and Rose (2005) who conclude that trade is favorable to the reduction of pollution. However, other authors such as Managi (2004) conclude that trade has a negative impact on carbon dioxide emissions.

Political institutions

A free political and civil system allows people to easily express their preferences for a better environmental protection. The relation between political freedoms and the environment has been analyzed by many authors. Deacon (1999) and Olson (1993) argue that political freedoms are favorable to environmental protection because non democratic regimes will under produce environment considered as a public good. For them, autocratics are governed by political elites who monopolize and hold a much larger share of national incomes and revenues. The implementation of rigorous environmental policies can lower production, income and consumption, which, in turn impose a higher cost on the elite in an autocracy than on the population whereas the marginal benefit is uniform for both elite and population. Elites in autocracy are therefore relatively less pro-environment than people in democracy. However, Congelton (1992) thinks that political freedoms can have a positive impact on pollution. According to him, democratic governments can be affected by a political myopia contrary to non democratic rulers which lead them to decide on a temporal short horizon.

Technical progress

We define technical progress as all technology and production processes contributing to the reduction even cancellation of environmental damages and/or the use of raw materials, energy and natural resources. We model technical progress from the estimation of economy's carbon dioxide intensity. Indeed, we suppose that the pollution intensity is explained on the one hand by the structure of economy and technical progress to reduce it on the other hand. Structural factors are the level of economy activities (income per capita), openness to international trade and the prices of energy. Our method consists to estimate carbon dioxide intensity on structural factors and the coefficient associated with time trend variable is technical progress. We estimate the equation (10) by OLS for each country i.

$$Log\left(\frac{e_{i,t}}{y_{i,t}}\right) = \gamma_i + \gamma_1 Log(pcpib_{i,t}) + \gamma_2 energ_{i,t} + \gamma_3 ouv_{i,t} + \gamma_3 trend + \omega_{i,t} \quad (2)$$

with $\left(\frac{e_{i,t}}{y_{i,t}}\right)$ carbon dioxide intensity, $pcpib_{i,t}$ income per capita, $energ_{i,t}$ price of oil and $ouv_{i,t}$ openness to trade and $trend$ is time specific dummies.

3.2. Estimation method

To estomate this model we should use adequate econometric techniques. The panel data takes into account of transversal and temporal dimensions and also the unobserved heterogeneity (for example influence of economic specificities and environmental policies, etc).

We can run estimations using OLS. But OLS estimator is weak and biaised because our model is a dynamic panel and dependent variable is lagged and endogenous. We then take country and time -specific effects into account and use 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 timevarying 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) have evidence from 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, neither test of the statistics allows us to reject the validity of the lagged variables as instruments and the lack of second order autocorrelation.

3.3. Descriptive analysis of data

The data of carbon dioxide per capita emissions, investment rate, the trade openness and population growth rate are from World Development Indicators (World Bank, 2005). The data of education and political institutions come respectively from Barrolee (2000) and Polity IV (2002).

The carbon dioxide per capita emissions are measured in metric ton per capita come from the combustion of fossil energies and cement industries in the liquid, solid or gas form. The trade openness and investment rate correspond respectively to the share of the sum of exports and imports and investments in gross domestic product (GDP). As political institutions, we chose the index of polity(2) that is a score obtained by the difference of the index of democracy and 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 choose political elites. The autocracy is characterized by the absence or the restriction of political competition, economic planning and control. The exercise of the power is slightly constrained by institutions and the leaders are only selected within a “political elite”. The data of education resulting from Barro&Lee (2000) correspond to the average schooling years in the total population.

Table (1) presents descriptive statistics of education, carbon dioxide emissions level and growth rate. It shows a high growth rate of carbon dioxide per capita emissions in world (8.23%). This can be explained by 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.

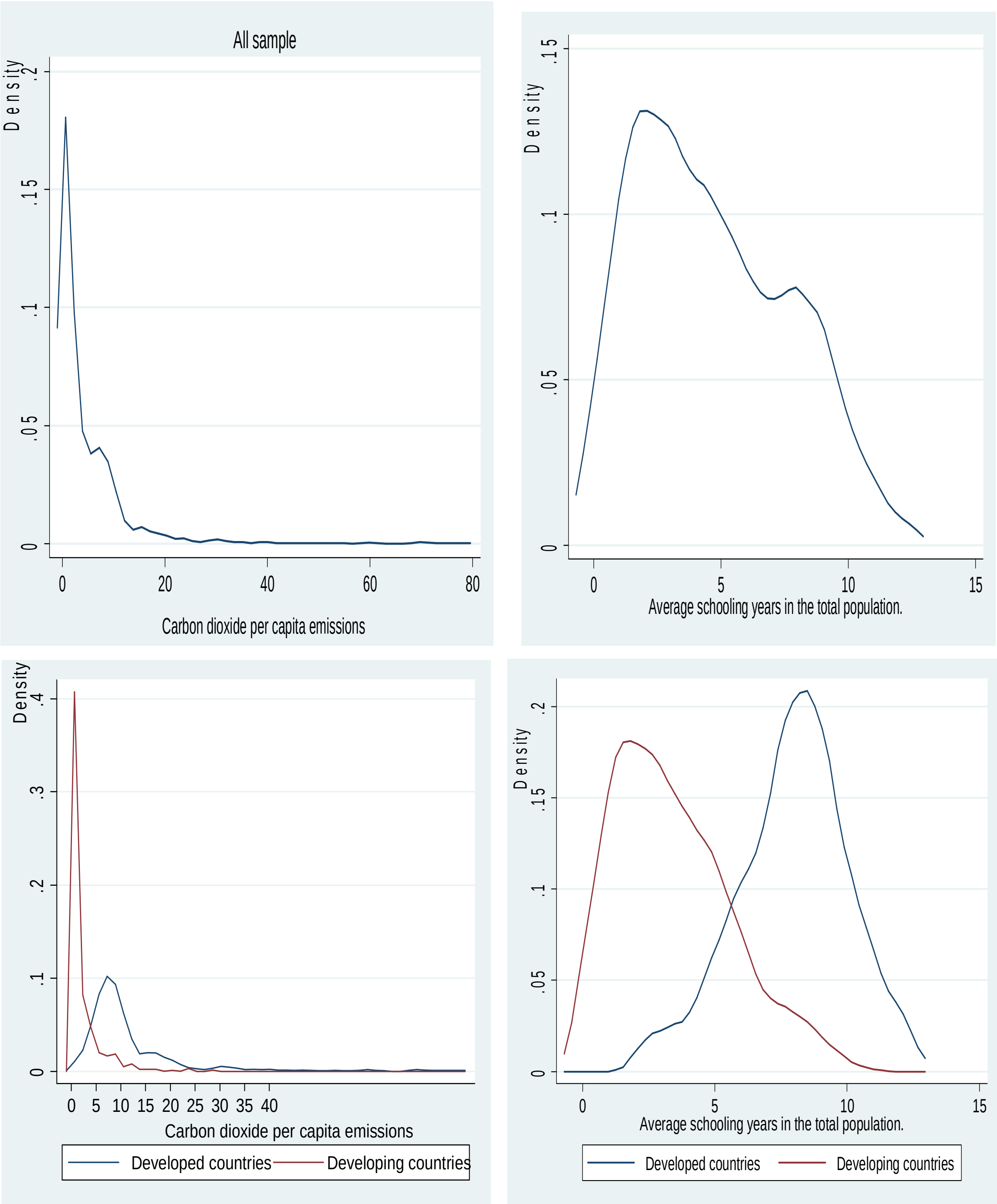
Table1: Descriptive statistics of emissions of dioxide carbon and education

	Average	Standard deviation	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 -2003
Source: Author

In addition, a deepen analysis of carbon dioxides and education levels allows to note that their distribution (figure1) differs according to economic development. The distribution graphs of emissions and education of developed countries are more on the right side than these of developing countries. This implies not only a more polluting economic structure in developed countries contrary to developing countries but also a positive correlation between education and carbon dioxide per capita emissions.

Figure1: Kernel density of carbon dioxide per capita emissions and education



3.4. Results

Table (2) shows our estimate results obtained by Generlized Method of Moments-system (GMM-system). Column (1) shows the absence of conditional convergence in carbon dioxide per capita emissions in world because the coefficient is insignificant and equal to (- 0.003). This result is in conformity with the preceding studies (Stegman (2005), Aldy (2006), Nguyen (2006)) that conclude with an absence of convergence in air pollution at international level. The investment, engine of economic growth and economic development, contributes enormously to pollution growth. Technical progress has a negative and significant effect on pollution growth whereas education and political institutions have no impact on it.

As countries have pollution behaviour according to economic development, we separate developing countries from developed countries in estimations. Indeed, we could suppose that Botswana and Luxembourg could have different pollution behaviors.

Columns 2 and 3 of the table (3) show that basic results change when the sample is restricted to developing countries or developed countries. We find a conditional convergence in carbon dioxide per capita emissions for developed countries and a divergence for developing countries. We also see that the effects of education and political institutions on pollution growth are significantly different according to the level of development (developing or developed countries). Indeed contrary to developing countries where it doensn't influence, education favours pollution growth in developed countries. It is same for institutions which contribute to pollution (depollution) in the developed countries respectively.

The role of institutions and human capital as fundamental sources of difference in economic development, highlighted by economic literature, questions us on the possibility that the effect of education on the environment can differ according to the quality of institutions in a given country. Political institutions have a positive impact (negative) on pollution growth in developing countries (developed countries).

3.4.1. The nonlinear effect of education: Interaction between education and institutions

Regarded as a public good, environment quality improvement could not be directly determined by the preference of people but rather by their reflection through political institutions. In other words, education and institutions interaction could affect environment protection. Mahon (2006) considers that the effect of education on environment quality could be more effective in the presence of stable political institutions regarded as a channel of expression of people. To include an interactive variable between education and institutions to our equation suggests that effect of education on pollution growth would be conditional with political institutions.

Columns (4) and (5) confirm that growth rate of carbon dioxide per capita depends positively and significantly on investment rate. It is important determinant of air pollution in developing countries. In these countries, people are not very concerned by environment problems. They are worried by many developments problems (low and unstable growth, unemployement) These investments can also reduce poverty because they are motor of economic growth. Foreign and domestic investments allow countries to access international markets, trade, new technologies and competences. However these opportunities differ with countries and development countries.

In some countries, investments are directed towards sectors of construction, services and manufactures. In other countries, they are directed towards natural resource sectors in particular, oil firms, wood companies, big consumers of energy and thus pollutants. For example in Africa, 65% of direct foreign investments are in natural resources sectors. The expected effects are employment, a rise of taxes, revenues for the states and the reduction of poverty. These countries can also be less sensitive to environmental problems. In the same way, the weakness of infrastructures, particularly roads strongly increases the use of energy and consumption of polluting resources.

Tableau2: Estimation of growth of carbon dioxide per capita (GMM-System)

	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)
Technical progress	-0.209 (1.88)*	-0.209 (1.90)*	0.045 (1.75)*	-0.178 (2.16)**	0.026 (1.03)
Political 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* Political 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
Nombre de pays	85	63	22	63	22

Note: * significant at 10%; ** at 5%; *** at 1%. The period is 1970-2003. Temporal dummy variables were taken into account in the model

Political institutions have a significant and contrary effect according to the level of development. In developing countries, the positive effect can be explained by ‘‘free rider behavior’’ (Carlsson and Al 2003). People, companies and political leaders consider pollution as a public good and are not very inclined to fight it. In developed countries, political institutions reduce carbon dioxide per capita growth. This effect is more important and significant with people education. Columns (3) and (5) show that the effect of institutions on pollution growth is conditional on the level of education.

Education seems to be a factor of environmental pollution in developed countries although its effect is slightly mitigated in presence of freedom policies. In developing countries, education and its interactive variable have no effect on the growth of carbon dioxide per capita emissions. The absence of effect of education in developing countries could be explained by low education level and relative weakness of political institutions. The combination of these factors strongly reduces the capability of people to express their preferences for a better environment. So the average effect of education on emissions growth is negligible.

Furthermore, less educated people (relatively to those of developed countries) are also poorer and consume least materiels goods factor of environmental degradation.

Technical progress has no impact on pollution growth in developed countries whereas it is the key motor of depollution in developing countries. These results are not surprising. In developed countries, high levels of education are also factors of knowledge creation and technical progress. We can then think that developing countries have few technical progress and they could be technology transfers. As technical progress level is relatively low and that their technology needs are so enormous, an increase of technical progress (new technology trransfers) has a high marginal effect on pollution growth. In other words technical progress is more effective in countries which do not have it or very little.

3.4.2. Results robustness

Although GMM-system estimator is used by many economists in recent years, critics appear. Sevestre (2002) shows that GMM system estimator is biaised when the used instruments are weak. It's possible to get results that respect the conditions of Sargan with possible weak correlation between endegenous variables and instruments. Indeed, there could be weaked instruments (lagged variables) that increase the p-value associated with the test of Hansen/Sargan. We showed that results meets the conditions of validity of the instruments and absence of autocorrelation of the errors of second order with surplus respectively of 82% and 21%.

To check the validity of results, we regress each endogenous variable (technical progress and trade) on their instruments and control variables in order to check the significance of associated coefficients. Indeed, we suspect some of our explanatory variables like technical progress and trade not to be exogenic. Although ideal model considers technical progress in the sector of depollution as exogenic, we can doubt it. We think that increase in pollution in an economy can stimulate authorities to encourage efforts of research and development (R & D). We can moderate this assertion in the case of developing countries where technical progress is technology transfers from developed countries. In the same way, we can wonder whether pollution affects trade. Countries with high pollution can be countries where environmental regulation is not very constraining. According to Copeland and Taylor (1994), these countries can have a comparative advantage and specialize in polluting industries and thus become pollution haven. Table (3) shows that lagged variables explain endogenous variables and we conclude that instruments are valid.

Table3: Instrumentation of technical progress and trade openess

	Rate of technical progress (1)	Log of trade opening(2)
Technical progress (t-1)	0.826	
	(9.91)***	
Technical progress (t-2)	-0.075	
	(1.25)	
Log of trade opening (t-1)		1.011
		17.07)***
Log of trade opening (t-2)		-0.092
		(1.72)*
Constant	-0.365	0.386
	(4.73)***	(6.80)***
Observations	253	253
R2	0,44	0,20
	85	85
Number of countries		

Note: * significant at 10%; ** at 5%; *** at 1%. The period is 1970-2003. Temporal dummy variables were taken into account in the model. Addition of the other exogenous variables does not modify the results.

Another analysis of the strength of our results would be to consider other education measures. As tables (4a and 4b) suggest it, our results remain stable in spite of use of seven alternative variables. Thus, the average secondary and high schooling years in the population. have similar effects on growth of carbon dioxide per capita emissions and these effects are differentiated according to the level of development.

Finally, we verify if the effect of education on emissions per capita would be simply due to the omission of the income variable (GDP per capita). On the basis that education contributes to a rise of income and economic growth, education increases use of environmental resources. It is thus a source of pollution via income per capita. May our results obtained could be simply explained omission of GDP/capita. That leads us to control the strength of our results by including income per capita. Table (5) shows that income per capita does not have a significant effect on growth of emissions per capita and results are stable, coherent and valid.

Tableau4a : Estimation of growth of carbon dioxide per capita (GMM-System with alternative human capital for 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%, ** significant at 5%, *** significant at 1%. period is 1970-2003. Other variables of controls and temporal dummies are taken into account in estimations. Variables Educ1,… Educ8 correspond respectively to the logarithm of mean of years of education: in general for individuals being +15 years old, - at higher level,- at higher level for individuals being +15 years old, - at secondary level for individuals, - at the secondary level for individuals having more than 15 years, - with percentage of population having completed higher education, - with percentage of population having completed secondary school.

Tableau 4b : Estimation of growth of carbon dioxide per capita (GMM-System with alternative human capital for developing countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log of initial carbon dioxide	-0.11	0.05	-0,16	-0,47	-1,15	-0,03	0,42	-0,41
per capita	(-0,28)	(-0,10)	(-0,42)	(0.69)	(-0.67)	(-0.08)	(0.52)	(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%. period is 1970-2003. Other variables of controls and temporal dummies are taken into account in estimations. Variables Educ1,… Educ8 correspond respectively to the logarithm of mean of years of education: in general for individuals being +15 years old, - at higher level,- at higher level for individuals being +15 years old, - at secondary level for individuals, - at the secondary level for individuals having more than 15 years, - with percentage of population having completed higher education, - with percentage of population having completed secondary school.

Table5: Estimate of growth of carbon dioxide per capita including GDP/capita

	Developed countries	Developing countries
Log of initial carbon dioxide per	-0,19	-0,084
capita	(-2,14)**	(-0,61)
Log of investment	0.340	0.402
	(2,80)**	(3.30)***
Log of trade openness	0.026	0.147
	(0.51)	(1.30)
Technical progress	0.031	-0.178
	(1.04)	(2.16)**
Political institutions	0.035	0.034
	(1.45)	(1.76)*
Growth of population	-0.029	-0.140
	(1.69)	(1.27)
Log of GDP per capita	0.006	0.004
	(0.42)	(0.33)
Education	0.542	0.005
	(12.63)***	(0.02)
Education* Political Institutions	-0.036	-0.009
Constant	(3.14)***	(0.95)
	-1.407	-1.61
	(2.55)**	(2.46)**
Number of countries	22	63

4. Conclusion

The study of carbon dioxide per capita emissions convergence brings in light a divergence of this one at global level during the period of 1970-2004. For developing countries, there is a divergence in carbon dioxide per capita diverge and education does not have any significant effect on pollution growth. Technical progress contributes to pollution growth reduction. Investment, engine of economic growth, is an important source of pollution in both developing countries and developed countries. For the latter, pollution per capita converge and education is a factor of pollution. However, it contributes to environment quality only when it interacts with political institutions. The carbon dioxide emissions convergence in developed countries and divergence in developing countries highlight interests and difficulties of multilateral negotiations on climate warming.

The article also highlights the importance of other factors such as technical progress, political institutions and investments in pollution growth.

Our results are important in terms of economic policies. Initially, they highlight the importance of education in environmental protection. The current accumulation of knowledge is certainly a factor of economic growth but also of growth of pollution. We are not recommending to question education policies whose intrinsic values are obvious. On the contrary, there is a need for introducing a change of perception and role of education in favor of environment. That should be very urgent in developing countries because the realization of the Millennium Development Goals (MDG) regarding education will be followed by environmental pollution. Then, there is a phenomenon of free rider of some countries in fight against climate warming. In addition, investments being a key factor of economic growth and determinant of pollution, reduction of these effects will be necessarily followed by the setting up of ecologically appropriate investments. Finally, divergence of pollution at an international and developing countries levels requires the transformation of protocol of Kyoto which should include agreements of technology transfers and promote of ecological development.

This paper opens ways for future research. Indeed, it highlights a differentiated impact on environment of political institutions in developed and developing countries. It will be then interesting to analyze the deep determinants of this behaviour of free riders of developing countries.

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Appendices

Table6: Definition and source of variables

Variables	Definitions	Data Source
Emissions of carbon dioxide per capita	Carbon dioxide per capita (metric ton per capita)	World Development Indicators (2006)
Emissions per capita initial	Carbon dioxide per capita at the beginning of each period	
Investment rate	Investment/PIB	
Trade openess rate	(Exportations+Importations) / Gross Domestic Product	
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	Number of average years of instruction of population	Barrolee 2000
Technical progress	Rate of technical progress. It is coefficient of trend (t) in a regression in panel where explained variable is the intensity of economy in carbon dioxide and explanatory variables are GDP per capita, trade and price of energy	Author

List of countries included in the sample

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

Table7: Descriptive statistics

	Average	**Standard deviation**	**Minimum**	**Maximum**
Log of initial per capita dioxide carbon emissions	4,56	0,35	0,0015	78,61
Growth rate of per capita dioxide carbon emissions	0,08	7,91	-4,44	2,76
Investment rate	21,42	7,39	2,53	86,79
Trade opening rate	71,14	41,51	5,71	297,33
Technological progress rate	-1,46	1,22	-7,28	0,64
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 (2006), Polity IV, Barrolee 2000 and computed by autor