

Evidences of the Environmental Kuznets Curve from CO₂ emissions in six-country analysis

By: Nguyen Anh Tuan

Institut d'Economie et de Politique de l'Energie (IEPE)

BP 47, 38040 Grenoble Cedex 09

FRANCE

Evidences of the Environmental Kuznets Curve from CO₂ emissions in six-country analysis

Abstract: This paper presents firstly a critical review on recent studies of the relationship between environmental quality and income. Then we explore this econometric relationship for a cross-panel sample of six representative countries. We incorporate some dimensions of social changes such as population, economic growth and institutional capacity, into our model to model underlying impacts on the EKC, which can be varied along the development process depending on the income level. A main finding is that the quality of policies and institutions can considerably smooth out the EKC, but the payoff of institutional improvement is not the same for developing and developed countries.

Keywords: EKC model, emissions, income, OECD, developing countries, population, policy.

1 Introduction

This paper is concerned with Environmental Kuznets Curves (EKC) for CO₂ emissions - a U-inverted relationship between income and environment - and impacts of underlying factors on EKC trajectory, one of the issues which have raised many discussions and critics for the last few years.

In particular, we estimate this relationship using a panel of countries, consisting of three Asian countries and three developed countries: Vietnam, Thailand, Korea, France, Japan and United States. These countries represent very different stage of development in terms of energy consumption, population growth, income and institutional capacity¹. It is well known that institutional, demographic and economic constraints at different development stage of a country are different. Vietnam, Thailand and Korea represent very different but consecutive position in

the development path. Korea is at its mature development stage while Thailand is in full take-off process and Vietnam is at the beginning of the take-off. Three others developed countries are in their mature industrialization and post-industrialization process (Nguyen A.T., 1998).

To capture the effects of population pressures, economic growth rate and institutional capacity at different development stage, we include these indicators in the estimation as well. These variables thus may shift the EKC for CO₂ emissions.

In section 2, we summarize and analyze the theoretical and empirical relationships between some environmental indicators and income levels, which have been estimated by different studies on EKC; then in section 3, a detailed analysis of the EKC is presented for the considered countries. We will incorporate some dimensions of the social changes to see their underlying impacts on the EKC: population, economic growth and institutional capacity; we discuss the lessons learned from our modeling and raise some issues concerning these developing countries in final section 4.

2 EKC – theoretical and empirical evidences

2.1 Definition of EKC

The economic literature speaks about Environmental Kuznets Curve (EKC) to indicate a U-inverted relationship between various environmental indicators and income level (GDP/capita). According to that, the environmental degradation increases at the beginning of the economic development to reach a certain level of income and then declines progressively with the growth of the income. The curve is named according to the theory of the distribution of the income developed by Kuznets (1955) who found a U-inverted relation between an indicator of inequality in the income distribution and the income level.

An explanation of these relations between economy and environment is often that the people in poor and rich country have different preferences over the demand for the

environmental quality. One can wait that the inhabitants in a rich country agree to pay more than those in a poor country for a higher environmental quality. Thus, at the beginning of the economic phase of development, the increase in the emissions of pollutants is regarded as an inevitable and acceptable aspect of the economic growth. Nevertheless, starting from a certain level of income, the people pay more attention to the environment, which makes it possible to create new institutions and regulations for the environmental protection, and so on.

The revelation of the relationship between environmental quality and the income in form of U inverted caused alive debates on the implications of the economic growth. The central political question is: does the economic growth continue to be the first priority and the environmental protection a secondary consideration to solve later? Or do the environmental policies to control the environmental degradation at the local, national and global level represent an urgent priority today? (Barbier, 1997). It is thus important to understand what can or cannot be deduced from the EKC based on the experiences of OECD countries, because these economic - environmental relationships have important impacts on the development process of developing country in the future.

Different empirical analyses of the last years mostly concentrate on the two fundamental evidences of the EKC:

- The tests for various environment indicators (emission concentration, emissions per capita, air pollutants, water indicators, deforestation, time series, cross-country, panel estimation, inclusion of other indicators,...) are carried out to see which relation shape they are dependent with the GDP per capita.
- The estimate of EKC turning point. It means to find a level of GDP per capita where the quality of environment reaches its maximum (minimum) and then changes the direction. This turning point is obviously of interest for future global and national emission prospects.

2.2 Econometric relationship

Empirical work uses various curves and equations to estimate the relationship. It can be represented by a synthetic equation:

$$I_{it} = \sum_{n=0}^n \mathbf{a}_n f(Y_{it})^n + \sum_{m=0}^m \mathbf{b}_m f(V_{it})^m + \mathbf{e}_{it}$$

Where I_{it} : environmental indicator for country i at year t ;

\mathbf{a}, \mathbf{b} : the parameters;

\mathbf{e} : the estimation residue;

Y_{it} : income (GDP per capita) in country i at year t ,

V_{it} : other explanatory variables;

$f(.)$: functional forms (logarithmic, linear...).

If $n \& m = 3$, the equation takes a cubic form; if $n \& m = 2$, the equation is quadratic; and if $n \& m = 1$, the equation is linear. The cubic, quadratic or linear form generally depends on the signs and the relative values on α and β . The results of the empirical studies on the relation between environmental quality and income are summarized and presented in the appendix 1 which gives a very mixed impression that the hypothesis of the EKC is found clearly for certain environmental indicators but reveals inaccurate for the others. In the following section we turn to analyze in detail these evidences.

2.3 Critical analysis of the evidences

There are some critical assessments on empirical work of the EKC in the last years. In a remarkable article, Stern, Common and Barbier (1996) made a criticism on the five empirical studies² which have very important impacts on the research of the EKC. From this synthesis, they indicate the existing problems in the estimate of the EKC. At the same time, they try to project future emissions using estimated EKC. Two other studies are of Ekins (1997), who examines recent research as a whole published before 1996, and recently, of Barbier (1997)

who briefly reviews more recent studies on EKC. This paper tries to summarize all the empirical studies which are appeared until now and analyze them in a critical manner the robustness of the evidences and the arguments.

Shape forms: generally, the estimated econometric equations are presented in quadratic or cubic forms (ordinary or logarithm). Other econometric forms of relationship are also tested. Some studies present the relationship in a linear form. The others do not indicate a clear relation or do not find it (Shafik, 1994 for some indicators; Vincent, 1997; Ekins, 1997). Concerning the robustness of empirical relations presented, even the best estimated forms show a relationship with relatively low or insignificant coefficients R^2 .

Pollutants: the local pollutants with direct environmental impact and low cost of reduction have shown better U-inverted relations than the global pollutants with impacts in long term, indirect or with high reduction cost (Arrow et al., 1995; Cole et al., 1997). However, the results do not guarantee an extrapolation for every country (Barbier, 1997). For the water pollutants, although there are evidences of EKC relationship for the BOD, the COD and the nitrates, several studies have difficulty to find out a significant relationship. The same remarks are true for deforestation, a sector where some studies show contradictory results (Panayotou, 1993; Shafik, 1994; Cropper & Griffiths, 1994).

Data: as all the researchers noted it, the environmental data are irregular, unequal and cover one relatively short period. In particular, the data are rare and inaccurate for the developing countries, the comparison between countries are difficult because of data being affected by a different definition (Shafik, 1994; Stern and al., 1996). Common data in use are taken mostly from the GEMS (Global Environmental Monitoring System on the ambient emission concentration), from FAO (deforestation) and from Penn World Tables (GDP in parity purchasing power). Several researchers also try to use other data bases which can lead to different results (see, for example, Stern et al., 1996). In the recent

studies, the researchers commence to use other environmental indicators like the R&D (Komen et al. 1997), EP (Environmental Performance, a synthetic indicator) (Ekins, 1997), or consumption commodities (Rothman, 1998). The problem of the environmental data is likely to be continued in the future because of the scarce availability of the appropriate environmental data.

Empirical tests: This is the approach of reduced-form equation which has been criticized because it does not allow to analyze political options (HES, 1992), nor to interpret estimated coefficients or to explain why the relation exists (Grossman & Krueger, 1995). However, the advantage of this approach is that it makes possible to test with aggregated data, which is not the case with the structural model which asks for a very detailed data base and poses the problem of the choice of the variables to be included in the structural model (De Bruyn, 1997). The recent tendency is to use decomposition analysis (Ekins, 1997; Panayotou, 1997; De Bruyn, 1997) or the structural model of transition (Moomaw & Unruh, 1997) in order to seek explanations other than the income for the EKC. Another question is the approach of fixed or random effects where the preference is given to the approach of fixed effects. Since Stern et al. (1996) have noted that «in the presence of heteroskedasticity, OLS estimation is inefficient, though unbiased», statistical test methods employed are more and more sophisticated but not necessarily lead to more accurate estimation.

The turning point: the results reported on the turning point are contradictory. In general, they are very high, approximately of 5000 - 9000 US \$85/per., which indicates evidently that the majority of the countries in the world are in the ascending part of the EKC and that the worst environmental situation is to be happening in the future. The very high second turning point (more than 18000 US \$85/habitant) is generally given as an illustrative indication since a few countries reaches this level of income. The highest turning point is

often found for CO₂ emissions, which is considered as a global and long-term-impact pollutant. There are studies which report only a monotonous growth or decrease of the environmental degradation for certain indicators (Shafik, 1994; Carson et al., 1997; Vincent, 1997).

Explanatory variables: they are generally GDP per capita, expressed in US\$ in ppp (parity purchasing power). The recent tendency is to include other explanatory variables in the econometric equation like the time series, the density of population, the price, political indicators, economic growth rate,... but often they are not significant or difficult to be interpreted.

Country representation in the tests: the developing countries are apparently under-represented in the empirical studies on EKC. Except Vincent (1997) who studies the EKC for Malaysia, all other researchers include mainly developed country(ies) in their studies and only few developing countries. This under-representation is explained by difficulty to obtain the data for the developing countries. This under-representation can create bias for the estimated EKC, given the going-on structural changes and specialization in favor of the less polluting activities in industrialized countries (Hettige et al., 1992; Stern et al., 1996). Moreover, strict environmental regulations in the OECD countries encourage the polluting activities to move to developing countries (Ekins et al., 1994). It is thus important to include the developing countries, in particular the Asian developing countries, in the field of study for better understanding of the evolution of the EKC within both developed and developing countries.

The assessment of the studies on the EKC underlines the limits and progress in research on the theory of relation between economic development and the environment, which can have crucial impacts for the rapid development Asian countries (RDAC). It cannot deny the fact that the relation exists. At the same time, theoretical and empirical research opens more questions

than it can answer. Is there a political intervention in this relation? If yes, how does it affect its form? In which proportion do impact the other variables such as the GDP growth rate, the economic scale and its structure? Which are the explicatory capacities of these factors for countries in different development phases? Panayotou (1997) noted that «These are questions that cannot be answered by the simple reduced-form approach to the environmental Kuznets curve... The conventional approach is basically a ‘black box’: it hides more than it reveals since income level is used as a catch-all surrogate variable for all the changes that take place with economic development».

In the following section, we concentrate on an analytical and structural approach developed by Panayotou (1997) through the introduction of the institutional, economic and demographic variables. We take into consideration three RDAC (Vietnam, Thailand and Korea) and the three OECD countries (France, Japan and the United States), who represent, in our opinion, different but consecutive phases in the trajectories of the development (demographic, economic, energy). Our objective is to model the trajectories of the CO₂ emissions and find their turning point, then include others underlying variables in order to understand their impacts on the emission trajectory for the RDAC in a prospective of rapid development.

3 Modeling the EKC

3.1 Hypothesis formulation

Economic, environmental and energy policy can favor an evaluation of individual or collective behaviors in the direction that takes into account the true value of environmental resources. The economic policy can have an impact favorable or unfavorable on the environment as it affects the scale, the composition and the efficiency of the production. The energy policy can increase the energy efficiency, which will often reduce the demand for natural resources. It can influence the substitution between various sources of energy which

emit less emission pollutants. The environmental policy can ensure a greater efficient use of the resources and support the adoption of techniques and methods less prejudicial with the environment.

The impact of the economy on the environment is generally admitted, but with regard to the economic growth rate, it is not sure that at a given level of the income, a higher (or lower) economic growth can lead to a higher (or lower) level of environmental quality, or inversely. However, with a faster economic growth rate, it supposes that the EKC will move higher because the economy produces more pollutants, and that the efforts for their reductions will occur later, as Panayotou (1997) has noted «Shifts in people's preference functions and in social norms are slow adaptive processes that may fall behind a fast rate of environmental degradation than a slow one which allows time for adaptation and adjustment... The faster economic change (and corresponding environmental change) is, the larger is likely to be the gap between the two». In methodology that we present in this section, we will test this hypothesis and we will see in which direction this effect push the EKC.

In our empirical analysis, the political variable is supposed to enter into EKC equations with a positive sign to indicate the positive impact of a better institution on the EKC. Nevertheless, taking into account the difficulty in seizing this impact through a synthetic indicator to represent the quality of the policies and the environmental institutions of a country, we try to build a synthetic indicator for each country from Knack & Keefer (1995).

Another factor that we want to model its impact on the EKC, is the demographic density. The demographic transition in these six countries is evaluated in a different way. A fast growth of the population threatens quality of the natural resources, including the capacity of assimilation of the environment, particularly for the RDAC, when their economies depend excessively on the exploitation of the natural resources. The assumed hypothesis is that the increase in population (through indicators of density of population) cannot be neutral for the

environment and does affect the environmental trajectories in the different way for the OECD and the RDAC.

From our discussions, our tests aim to check the following hypotheses:

1. EKC exist which indicate a relation of the type U-inverted between income and environmental quality.
2. The economic growth rate can have important impact on EKC. A higher rate of economic growth can have a different impact during the economic development.
3. The demographic density is one variable that can have considerable impact on EKC. The higher the demographic density is, the lower the turning point of EKC is, and thus higher environmental quality is.
4. The institutions and policy are important factors in determine the trajectory of EKC. More effective the policy and the institutions are, lower the EKC are, and then more of the environmental improvement with the economic growth.

3.2 Models

Recently, Panayotou (1997) tried to decompose the economic structural factors affecting the SO₂ emissions, a pollutant often shows a U-inverted relationship with income. Since our interest here is to examine how the institutional policy, the economic and demographic growth rates (the factors affecting the speed to reach a high level of income) have impacts on the EKC in 6 considered countries, we will follow the approach developed by Panayotou to test the EKC for the emission of CO₂. In particular, we will employ a function representing four important hypotheses proposed above, through which the income per capita can affect environmental quality :

$$\begin{aligned}
 I_{it} = & \mathbf{a} + \mathbf{a}_1 Y_{it} + \mathbf{a}_2 Y_{it}^2 + \mathbf{a}_3 Y_{it}^3 \\
 & + \mathbf{a}_4 D_{it} + \mathbf{a}_5 D_{it} Y_{it} \\
 & + \mathbf{a}_6 G_{it} + \mathbf{a}_7 G_{it} Y_{it} + \mathbf{a}_8 P_{it} + \mathbf{a}_9 P_{it} Y_{it} \\
 & + \mathbf{e}_{it}
 \end{aligned}$$

I_{it}	CO ₂ emissions in country i , at year t ;
Y	GDP per capita;
D	Population density;
$G = 100+g$	where g is annual growth rate of GDP/per.;
P	Policy variable (institutional capacity);

By introducing institutional capacity and growth rate like additive and multiplicative variables with the income, we are able to test how they affect the slope of the EKC and/or the interception of the EKC. Based on our hypotheses on the existence of EKC, as in the other studies summarized in the appendix 1, we build a simple model of the economy without interaction with the environment. It means that our model does not take into account the feedback from the environment to the economy or in other words, we suppose that this feedback is insignificant. This is, without a doubt, the limit of this approach because a widely accepted point of view at the present is that the environment is regarded as a factor of the economic production and its degradation can have an impact on the economic growth. However, we suppose that the effect of the environment on the economy, in our case it is CO₂ emission, is negligible with medium term. This hypothesis can lead to biases which constitutes limit of this approach (Stern et al., 1996).

3.3 Data for the models

The principal references on the method of estimation and the emissions factors concerning CO₂ are the subject of the studies of G. Marland & Rotty (1984), of M.J. Grubb (1989). Commercial and traditional energy data to calculate CO₂ emissions in three countries (Korea, Thailand, and Vietnam) result from the statistics of ENERDATA. For the three developed countries, environmental data are obtained from the ‘OCDE environmental compendium, years 1997, 1995 and 1993’.

The GDP is in American dollar, constant 1987 price and obtained from the database of ENERDATA³. For reasons of coherence and compatibility between data, the economic growth rates and the demographic density result also from ENERDATA database.

The political variable is built from the database BERI (Business Environmental Risk Intelligence)⁴. They are four indicators 'Bureaucratic delays', 'Enforceability of contracts', 'Nationalization Risk' and 'Communication and transport infrastructure quality'. These variables are aggregate proxy index of the institutional capacity of the government, evaluated from a series of answers provided by investors on the extent of the administrative formalities to achieve for any transaction, the lawful framework and the measurement of the political pressures. Although these indicators are perhaps biased, they are at the origin of the only international evaluation of the institutional capacity of the countries we have. The four indicators were standardized and related to a common scale: the higher the value of the index is, the more the institutional capacity is effective⁵. Table 1 summarizes the principal statistical characteristics of the variables in our model EKC for our sample.

3.4 Modeling procedure

The problem of multicollinearity was checked by the level of tolerance and through partial coefficients of correlation. Although there is some colinearity between the same variables of different power (for example between income (Y), income square (Y²) and income cubic (Y³)), which is normally supposed with a polynomial regression, we did not find colinearity among our principal explanatory variables (income, economic growth rate, demographic density, policy). The quadratic forms of GDP per capita are also tested but they are less significant, therefore we do not present them thereafter.

Four models were carried out for our sample. Model B includes only the GDP per capita as an explanatory variable to check the hypothesis 1. Furthermore, to understand and interpret the impact of the other factors of hypotheses 2, 3 and 4, we consider 3 other models

which include one of the variables, either demographic density (D), or economic growth rate (G), or institutional capacity (P) as explanatory variable (additive or multiplicative with Y);

3.5 Result analysis

The results of regression by ordinary least squares method (OLS) are presented in table 2. First of all, we test the model B, i.e. the model includes only the income Y as explanatory variable to test the hypothesis of existence of EKC in our regression panel. All the variables have expected signs which indicate the existence of a relation U-inverted of EKC between the CO₂ emissions per capita and the income. The coefficients of determination are not high for the model B (R^2 is 0.395), suggesting that there are may be other important explanatory variables.

For the CO₂ emissions, the EKC reaches the turning point at approximately 18000 \$87/habitant. These results are to a certain extent confirmed with the other studies summarized and presented in appendix 1. The turning point for CO₂, relatively early compared to the other studies, can be explained by our choice of panel of the countries which includes France and Japan – two countries use very early and extensively the nuclear energy without CO₂ emissions.

The result of our modeling with CO₂ implies that the CO₂ emissions follow supposed trajectories of U-inverted. The CO₂ emissions per capita cannot go up indefinitely. At certain levels of income, they begin to decrease, although these turning points vary according to different studies. However, with this basic model B, it is impossible to see the effects of various factors on the EKC.

In three models D, G and P, we introduce three variables to test our hypotheses 2, 3 and 4: the economic growth rate G, the demographic density D and the institutional capacity P. The first observation is that all the variables entered and are statistically significant at 5 percent level. The coefficient of determination increases sharply compared to the basic model B ($R^2 = 0,4\pm 0,93$) which indicates a considerable explanatory capacity of the new variables. It seems that the income level at which the curve reaches turning point is not very sensitive with the

inclusion of the new variables, but rather the vertical intercept of EKC is varied. We will analyze them thereafter.

3.5.1 *Impact of the economic growth: model G*

By the introduction of the economic growth rate of the six countries over the period 1970-1995 into our EKC model, we can see the impact of the variation of the growth rate on the interception and the slope of the EKC. The model G gives the supposed results that the impact of the growth rate is significant but not very important to the EKC, in particular at the low income level. Moreover, the impact of the economic growth on EKC is not the same throughout process of development, as we can see on the variation of the interception and the slope of the EKC in figure 1.

At low income level, the economic growth rate entered with a positive sign (the additive term is more important than multiplicative one) for the CO₂ emissions. This indicates that all things equal, higher economic growth rate means more CO₂ emissions emitted. For example, a percent of increase in the growth rate causes a rise of the CO₂ emission of approximately 94 kg/per. However, *the negative impact* of the growth rate on the EKC is progressively reduced with the increase in income thanks to the interaction with the income (the multiplicative term is more significant than the additive term after a certain level of income), and becomes *positive* after the income level of 6300 \$/per. At high income level, approximately 20000 \$ per capita, an economic growth rate of 8 percent can reduce the CO₂ emission by 10% compared to the growth rate of 2% per annum.

There are several explications for this phenomenon of interaction between economic growth rate and pollutant emissions of CO₂. It may relate with the anti-pollution costs as under the conditions of a rapid growth rate, the environmental impact is too important and it is difficult to control the high anti-pollution cost emissions like CO₂ with a limited resource at the early development stage. Another reason of this complex interaction could be the fact that the

demand for a better environmental quality and regulations are behind, compared to the rapid economic growth at the beginning of the development, but they advance speedily after certain high income level. Also it could be a result of an environmental policy which is less effective under the conditions of a rapid growth at the beginning, but more effective afterwards.

Whatever the explications, the implication of this model is clear : the impact of a fast growth is not the same throughout economic development process, it varies accordingly to the income level. At the early stage of economic development, the impact is considerable in relative but not in absolute term. It is thus more reasonable to direct the efforts on the regulations and the institutional policy than on the constraints of the economic growth, especially for the RDAC at the beginning. On the other hand, the dimension of the economic growth has a significant positive effect on the EKC at the high income levels. After 6000 \$/per., any economic acceleration contributes to a significant reduction of the emissions.

3.5.2 Impact of the population: model D

The results of model D give the expected signs and all the new variables D and DxY are significant to explain the interception and the slope of the EKC, as it was the case with model G. For CO₂ emissions, the change from negative impact to positive on the environmental trajectories is similar. The demographic impact passes from negative to positive with increasing income (figure 2).

At low income level, the environmental impact of a more densely population can be negative, but this negative impact, mainly for the developing countries, will soon disappear. From the income level of 2000 \$/per., a more densely population can lead to a positive environmental impact, i.e. to reduce the emissions. For example, at a income level of 1000 \$ per capita, a demographic density of 250 thousand persons/km² can increase the CO₂ emission 260 kg/per. (that is to say 12%) compared to a demographic density of 150 thousand persons/km². Nevertheless, at income level of 10000 \$/per., the impact of the population

becomes positive and it could reduce CO₂ emissions by 22 percent (from 9.16 tC to 7.08 tC) if the population density increase from 150 thousand person/km² to 250 thousand person/km².

The explanation of demographic impact on the environment may be the same as in the case of model G. Thus, a high demographic density in a country exposes more people to pollution, and can exert more pressures to control the emissions at certain level of high income. Another explanation is that « insofar, as sparsely populated countries are likely to be less concerned about reducing per capita emissions, at every level of income, than more densely populated countries » (Selden & Song, 1993).

Although the initial demographic density has a significant effect on EKC trajectory, particularly for the countries with low income, as we can see it through the additive term in the regression equation, the income level in conjunction with the population density is the determinant factor to take into account to evaluate the effects of population on the trajectory of the emissions. A policy alone on the demographic growth control does not solve the environmental problem. In the combination with a good economic policy, it can have important pressures on the demand for a higher environmental quality.

3.5.3 Impact of the institutional capacity : model P

As it shown in table 2, the political variable P, representing a proxy of institutional capacity, entered the equations of regression with the expected signs. The additive term of the political variable is negative and significant, indicating a strong relationship with the CO₂ emission level. The improvement of institutional capacity by one unit (or 6 percent) can lead to the lowering of the CO₂ emissions by 1,7 tons/per. at the level of income of 1000 \$87/per. At the higher levels of income, the effects of a more effective institutional capacity are even more impressive (see figure 3). The results of our model are confirmed with those models of Panayotou (1997), which noted that «improvement of policy institutions is likely to have much higher payoff at higher rather than lower incomes in making abatement efforts more effective in

controlling..., Furthermore, higher incomes tend to be associated with improved monitoring possibilities and hence accelerate the speed of social adjustments, which in turn lowers the gap between the speed of environmental change and social change».

Figure 3 shows the relation existing between institutional capacity and CO₂ emission level for our sample of six countries. Once the effects of the other variables neutralized, the emission level of a country, having a more effective institutional capacity, is appreciably lower than those of countries with less effective institutional capacity. An effective institutional capacity in a country can make flatter EKC through effects like the introduction of ownership, the faster acceleration of economic growth, the promotion of a sound environmental policies, better information and population mobilization.

The importance of the results from this political model is obvious for the RDAC. Compared to the other options like the demographic or economic policies analyzed before, the political improvement seems to be an impressive and a effective option to decrease the emissions of pollutants, taking into account the low costs of this option compared to the limits on the economic growth or the demographic growth.

4 Conclusion

The pioneer studies on the EKC have found a U-inverted relationship between economic development and environmental quality. At the beginning, the pollution increases because of delays and difficulties in applying new practices, but it decreases with further increase in income. Many factors affect the trajectories of the EKC. This study is concentrated on some of the most important : the population, the economic growth, and the institutional capacity. The most important finding of this modeling of the EKC is that the impacts of the economic growth and the population vary according to the income level. Contrary to the generally perceived ideas, the negative impacts occur at certain level of income only, and then they can become positive thanks to additional resources of an expanding economy or thanks to

more pressures on behalf of large population at high income level. In short, the factors contributing to environmental degradation can vary according to income levels and specific circumstances to each country.

The policies play an essential impact on the EKC trajectories and we could quantitatively include this aspect in our model to evaluate this effect. The institutional capability was always an engine for the growth and the social development, through which it contributes largely to the struggle against environmental degradation, reduces emission abatement costs. The implications of our modeling are that a good institutional capacity in particular, and sound environmental policies in general, can largely contribute to a better environmental quality.

The nature and the scope of the interaction between economic growth and environmental protection are always subject of controversy. The review of the models shows that there is no consensus on this issue. The adequacy and the effectiveness of the economic policies on the environment and vice versa depend on a comprehension of the ecological impacts of pollution. However, the continuous changes of the process of production and the state of the environment make this interaction difficult to be modeled completely. However, our modeling succeeded in showing quantitatively the impacts that intuitively supposed. The degradation of environmental quality is not inevitable. At certain income level, the RDAC can have choices for policy more or less favorable for the environment. The adoption of favorable policies in conjunction with technical progress, as well as a better comprehension of the harmful effects to the environment, could allow a faster economic growth and less detrimental environment for the RDAC, than for the OECD countries in the past.

It was found that the quality of policies and institutions can considerably smooth out the EKC, but the payoff of institutional improvement is not the same for developing and developed countries, at least for the case of CO₂. It is certain that the policies for developing countries

should be different from those in developed countries since they are in different development stages.

As we noticed, the limit of our modeling is that it does not include impact of the environment on the economy. Moreover, our consideration covered only six countries for one relatively short period. A broader model, more representative, including more developing countries, must be built for better understanding the interaction of these complex factors.

Table 1 : Summary of the data statistics

Variables		Observations	Mean	Standard deviation	Minimum	Maximum
CO ₂ (ton/per.)	I	80	8,42	6,15	0,60	20,20
Income (1000\$87 GDP/per.)	Y	80	12,75	7,79	0,42	24,11
Population density (1000 per. /km ²)	D	80	194,19	148,61	21,40	454,30
Economic growth rate (100*GDP _t /GDP _{t-1})	G	80	104,14	3,62	97,44	117,24
Institutional capacity	P	52	10,32	2,04	7,27	13,60

Table 2 : results of regression for CO₂

model	B	D	G	P
Constant (α)	1,397 (0,809)	-1,010 (-0,703)	-8,600 (-0,305)	15,356 (3,918)
Y	0,671 (0,794)	2,769 (4,139)	2,263 (0,788)	1,102 (5,206)
Y ²	0,021 (0,263)	-0,200 (-2,952)	0,023 (0,284)	-0,134 (-13,001)
Y ³	-0,0015 (-0,725)	0,0056 (3,153)	-0,0016 (-0,741)	0,003 (9,782)
D		0,0052 (0,893)		
D x Y		-0,0026 (-6,685)		
G			0,094 (0,358)	
G x Y			-0,015 (-0,580)	
P				-1,793 (-3,830)
P x Y				0,095 (3,424)

R ²	0,395	0,752	0,398	0,935
F-value	16,525	44,996	9,765	133,067

Note : t-statistics in parentheses (); Significant at the 5 percent level.

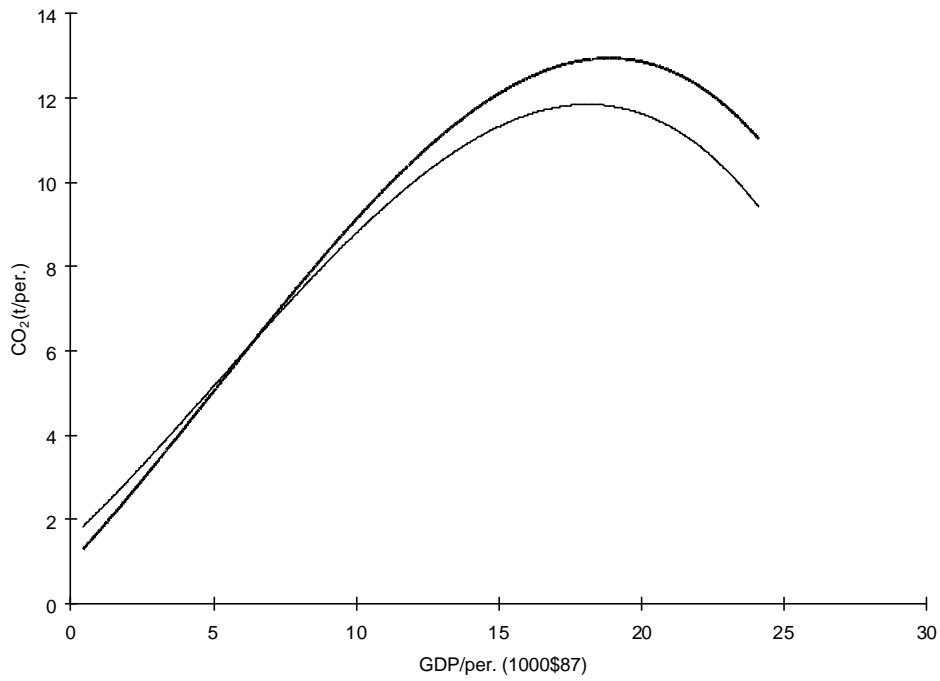


Figure 1 : Impact of economic growth on EKC

(Higher growth rate can lead to a higher EKC at the beginning, but lower after a certain income level ; ---- : Growth rate at 8%/year ; $\frac{3}{4}$ $\frac{3}{4}$: growth rate at 2%/year).

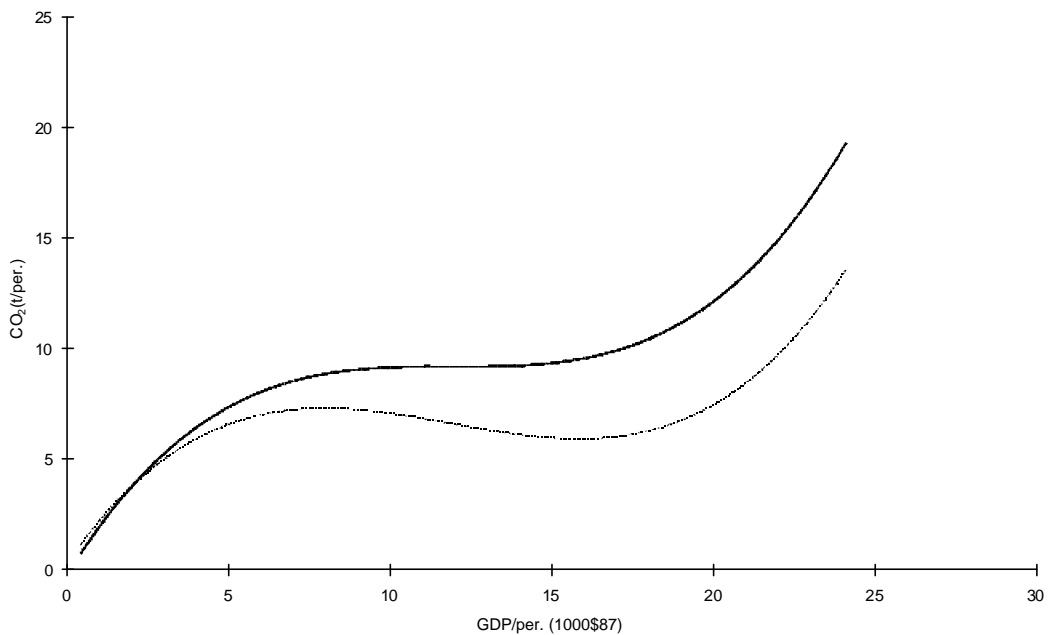


Figure 2 : Impact of population density on EKC

(Higher population density can exert more pressure on emission control which results in EKC lower; -----: 250 thousand per./km²; $\frac{3}{4}$ $\frac{3}{4}$: 150 thousand per./km²)

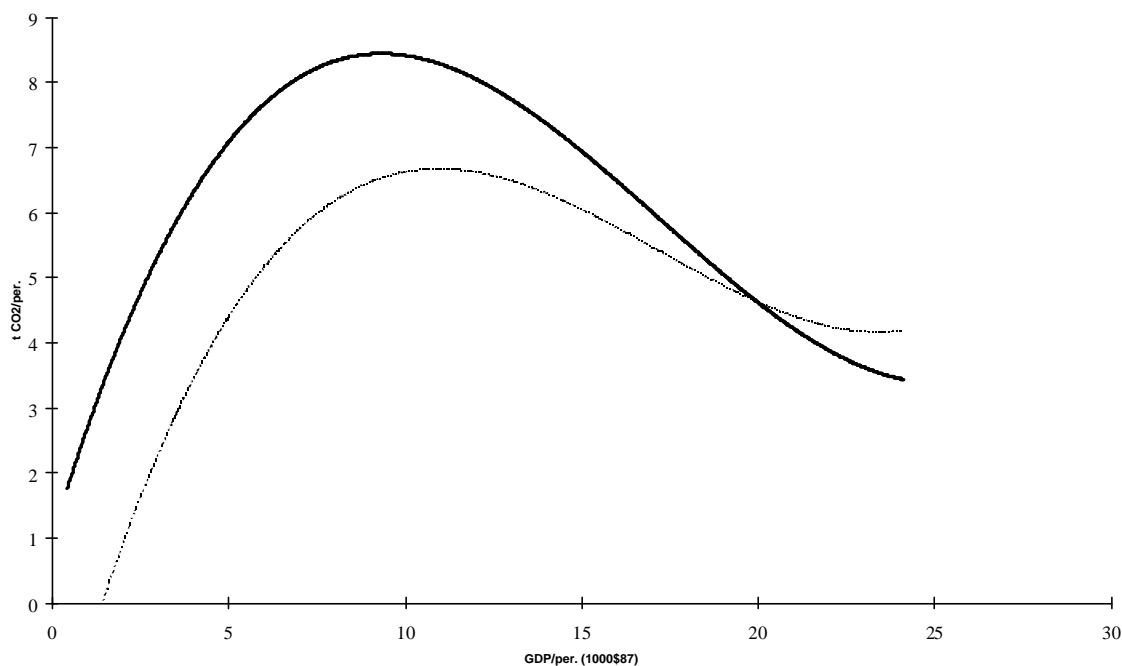


Figure 3 : Impact of institutional capacity on EKC

More effective and sound institutional capacity can results to an EKC lower that means less CO₂ emissions ; ---- : policy =10; — : policy = 8.

References

- Arrow K. et al., 1995, 'Economic growth, carrying capacity and the environment', *Science* 268, pp. 520-521.
- Barbier E.B., 1997, 'Introduction to the environmental Kuznets curve special issue', *Environment and development economics* 2, pp. 369-381
- Berkeman W., 1995, '*Growth, the environment and the distribution of incomes : Essays by a Sceptical Optimist*', Economists of the Twentieth Century Series, Edward Elgas, England.
- Berkeman W., 1992, 'Economic growth and the environment: Whose growth? Whose environment?', *World Development*, 20 (4), pp. 481-496.
- Boulding Kenneth, 1966, 'The Economics of the Coming Spaceship Earth', dans H.E. Jarrett, ed., '*Environmental quality in a Growing Economy*', Johns Hopkins Press, Baltimore.
- Carson R., Jeon Y., McCubbin D., 1997, 'The relationship between air pollution emissions and income: USA data', *Environment and Development Economics* 2, pp. 433-450.
- Chesnais J.C., 1986, '*La transition démographique – Etapes, formes, implications économiques*', Presse Universitaire de France.
- Cole M.A., Rayner A.J., Bates J.M., 1997, 'The environmental Kuznets Curve: an empirical analysis', *Environment and Development Economics* 2, pp. 401-416. Cropper M.L.,

- Griffiths C., 1994, 'The interaction of population growth and environmental quality', *American Economic Review papers and proceedings* 84, pp. 250-254.
- De Bruyn S., 1997, 'Explaining the environmental Kuznets curve : structural change and international agreements in reducing sulphur emissions', *Environment and Development Economics* 2, pp. 485-504.
- De Bruyn S.M., Bergh J.C. van den & Opschoor, 1998, 'Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves', *Ecological Economics* 25, pp. 161-177.
- Ekins P., 1997, 'The Kuznets curve for the environment and economic growth: examining the evidence', *Environment and Planning A*, 29, pp.805-830.
- Ekins P., Folke C. et Costanza R., 1994, 'Trade, environment and development: the issues in perspective', *Ecological Economics* Vol. 9, pp.1-12.
- ENERDATA s.a., Base de données
- Fisher A.C., 1994, '*Environment and resource economics – selected essays of Anthony C. Fisher*', Edward Elgar.
- Grosseman G.M., 1993, 'Pollution and Growth : What do we know', Conférence du centre de développement de l'OCDE sur « Sustainable Economic Development : Domestic and International Policy », Paris 24-25 mai 1993.
- Grosseman G.M., Krueger A.B., 1993, 'Environmental impacts of a North American Free Trade Agreement', dans Garber P. ed. 'The US-Mexico free trade agreement', MIT Press Cambridge, MA.
- Grosseman G.M., Krueger A.B., 1995, 'Economic growth and the Environment', *Quarterly Journal of Economics*, May.
- Grubb M., 1989, '*On coefficients for determining greenhouse gas emission from fossil fuel*', IEA/OECD Seminar, Paris 12-14 April.
- Hettige H., Lucas R., Wheeler D., 'The toxic intensity of industrial production: global patterns, trends and trade policy', *American Economic Review Paper and Proceedings* 82, pp. 478-481.
- Hettige M. et al., 1996, Determinants of pollution abatement in developing countries : evidence from South and South-east Asia', *World development*.
- Kaufmann R.K et al., 1998, 'The determinants of atmospheric SO₂ concentrations ; reconsidering the environmental Kuznets curve', *Ecological economics* 25, pp. 209-220.
- Kazushi U., 1995, 'The environmental Kuznets curve and Japan', Proceedings of 18th IAEE conference Washington D.C., Jullet 5-8.
- Komen M., Gerking S., Folmer H., 1997, 'Income and environmental R&D : empirical evidence from OECD countries', *Environment and Development Economics* 2, pp. 505-515.
- Kuznets S., 1955, 'Economic growth and income inequality', *American Economic Review*, 49, pp. 1-28.
- Marland G., Rotty R.M., 1984, 'Carbon dioxide emissions from fossil fuel: a procedure for estimation and results for 1950-1982', *Tellus* (36B), pp. 232-261.
- Moomaw W.R., Unruh G.C., 1997, 'Are environmental Kuznets curves misleading us ? The case of CO₂ emissions', *Environment and development economics* 2, pp. 451-464.

- Nguyen A.T., 1998, 'Energy-Environmental policies in Asian developing country: why should they be different', Paper presented at 21st international conference of IAEE, may, Québec, Canada.
- OECD, different issues, 'OECD environmental compendium', OECD, Paris.
- Panayotou T., 1993, '*Empirical Tests and policy analysis of environmental degradation at different stages of economic development*', Working paper WP238, Technology and Employment programme, Geneva: International Labor Office.
- Panayotou T., 1997, 'Demystifying the environmental Kuznets curve : turning a black box into a policy tool', *Environment and development economics* 2, pp. 465-484.
- Pearson P.J.G, 1994, 'Energy, Externalities and Environmental quality : will development cure the ills it creates', *Energy studies review*, Vol. 6, No 3.
- Rock M., 1996, 'Pollution intensity of GDP and trade policy: can the World Bank be wrong?', *World development* 24, pp.471-479.
- Rothman D.S., 1998, 'Environmental Kuznets curves- real progress or passing the buck ? : A case for consumption-based approaches', *Ecological economics* 25, pp. 177-194.
- Selden T.M., Song D., 1994, 'Environmental quality and development: is there a Kuznets curve for air pollution emissions?', *Journal of environmental economics and management* N°27, p. 147-162.
- Shafik N., 1994, 'Economic Development and Environmental Quality - An Econometric Analysis', *Oxford Economic Papers* 46.
- Shafik N., Bandyopadhyay S., 1992, 'Economic growth and environmental quality: time series and cross-countries evidence', Background paper for the World development report 1992, The World Bank.
- Stern D., Common M. S., Barbier E.B., 1996, 'Economic growth and environmental degradation : the environmental Kuznets curve and sustainable development', *World development* 24(7) pp. 1151-1160.
- Summers R., Heston A., 1991, 'The Penn World Table (Mark 5) : an expanded set of international comparisons, 1950-1988', *The Quarterly Journal of Economics* 106, pp. 327-368.
- Suri V., Chapman D., 1998, 'Economic growth, trade and energy : implications for the environmental Kuznets curve', *Ecological economics* 25, pp. 195-208.
- Torras M., Boyce J.K., 1998, 'Income, inequality and pollution : a reassessment of the environmental Kuznets curve', *Ecological economics* 25, pp. 147-160.
- Vincent J.R., 1997, 'Testing for environmental Kuznets curves within a developing country', *Environment and development economics* 2, pp. 417-431.
- World Bank, 1992, 'World development report 1992', Oxford University Press.

Appendix 1 : Résumé of studies on EKC relationship between economy and environment

<i>Study and explanatory indicator</i>	<i>Environmental Indicator</i>	<i>Relation shape</i>	<i>Turning point (GDP/per.)</i>	<i>Remarks</i>
I	II	III	IV	V
HLW (1992) GDP US\$85 ;	Toxic intensity by GDP Toxic intensity by par industrial output	Quadratic, 3 Quadratic, 2	12790 na	Global ; Toxic intensity of 80 countries; Logarithm ;
HES (1992) GDP/per. US\$85	CO ₂	Quadratic, 3 Cubic, 5	35400 28010	Global ; Emissions per capita
PAN (1993) GDP/per. US\$85	SO ₂ NO _x PES Deforestation rate	Quadratic, 3 Quadratic, 3 Quadratic, 3 Quadratic, 3	3000 5500 4500 1200	Global ; Emissions per capita ; Deforestation ;
GK (1993) ; GDP/per. US\$85	SO ₂ SPM Smoke	Cubic, 5 Cubic, 1 Cubic, 5	a) 4107 b) 14000 Decreasing a) 5000 b) 10000	Global; Data of GEMS; Urban concentration of pollutants;
SHA (1994) GDP/per. US\$85; Time series	Lack of safe water Lack of urban sanitation Annual deforestation Total deforestation Dissolved oxygen in rivers Fecal coliform in rivers Ambient SPM Ambient SO ₂ Municipal waste per capita CO ₂ /per.	Linear, 1 Linear, 1 Quadratic, 3 Quadratic, 3 Linear, 1 Cubic, 5 Quadratic, 3 Quadratic, 3 Linear, 2 Linear, 2	na na na a) 1375 b) 11500 3280 3670 na na	Global; Data of the World Bank (WDR 1992, environmental data appendix); Linear, quadratic et cubic logarithm are tested;
SS (1994) GDP/per. US\$85; Population density	<u>Estimation by random effect</u> SO ₂ SPM NO _x CO <u>Estimation by fixed effect</u> SO ₂	Cubic, 3 Cubic, 3 Cubic, 3 Cubic, 3 Cubic, 3	10700 9600 21800 19100 8900	Global (30 pays); Emissions per capita; Period 73-84; Data of WRI

	SPM NO _x CO	Cubic, 3 Cubic, 3 Cubic, 3	9800 12000 6200	
CG (1994) GDP/per. US\$85; Wood price; Density of rural population.	Deforestation rate	Quadratic : Africa, 3 L. America, 3 Asia, na.	4760 5420 na.	Regional ; Data of deforestation from FAO
KAZ (1995) GDP/per. Yen70	Deforestation SO ₂ NO _x	Quadratic, 3 Quadratic, 3 Quadratic, 3	446 \$70 1295\$70 1587\$70	Japan ; Annual concentration in ppm; Yen is converted to Dollar by this study.
GK (1995) ; GDP/per. US\$85 et Mean GDP/per. During last 3 years.	SO ₂ Smoke Heavy particles Dissolved oxygen BOD COD Nitrates Fecal coliform Total coliform Lead Cadmium Arsenic Mercury Nickel	Cubic, 5 Cubic, 3 Cubic, 1 Cubic, 4 Cubic, 3 Cubic, 3 Cubic, 3 Cubic, 3 Cubic, 5 Cubic, 5 Cubic, 3 Cubic, 5 Cubic, 5 Cubic, 5	a) 4053 b) 14000 6151 Decreasing 2703(*) 7623 7853 10524 7955 3043 1887 11632 4900 5047 4113	Global ; GEMS data; Pollutant concentration in cities and rivers;
R (1996) GDP US\$85	Heavy metals	Quadratic, 3	10800	Emissions of heavy metals
PAN (1997) GDP/per. US\$85 ; Population density; Industry share; GDP growth; Policy	SO ₂	Cubic, 5	a) 5000 b) 15000	panel and cross-country (30 obser.); Median of annual concentration µg/m ³ (GEMS)
CRB (1997) GDP/per. US\$85 ; Intensity of commerce ; Time series;	NO _x SO ₂ SPM CO NO _x of transport sector SO ₂ of transport sector	Quadratic, 3 Quadratic, 3 Quadratic, 3 Quadratic, 3 Quadratic, 3 Quadratic, 3	15100 (14700)** 5700 (6900) 8100 (7300) 10100 (9900) 15100 (17600) 9400 (9800)	Principally for OEDC;

	SPM of transport sector Nitrates CO ₂ Energy consumption CFCs et halons NH ₄ (methane) Municipal waste Transport energy use Traffic volume	Quadratic, 3 Quadratic, 3 Quadratic, 3 Quadratic, 3 Quadratic, 3 Quadratic, 1 Quadratic, 1 Quadratic, 3 Quadratic, 3	15000 (18000) 15600 (25000) 25100 (62700) 22500 (34700) 15400 (12600) na na 400000 (4 mill.) 108200 (65300)	
VIN (1997) GDP/per. RM78; Population density	SPM BOD COD Ammoniac nitrogen pH Solid particles in rivers	Cubic, 6 Cubic, 6 Cubic, 6 Cubic, na Cubic, na Cubic, na	na (increasing) na (decreasing) na (increasing) na (no form) na (no form) na (no form)	Malaysia; Ambient concentration; Period 70-90
CJM (1997) GDP/per. US\$82 ; (Population density and urbanization are tested but not significant)	Greenhouse gas, 1985 Atmospheric toxic, 90 CO, 1990 NO _x , 1990 SO ₂ , 1990 VOC, 1990 PM ₁₀ , 1990 Atmospheric toxic, 88-94	Linear, 1 Linear, 1 Linear, 1 Linear, 1 Linear, 1 Linear, 1 Linear, 1	Decreasing Decreasing Decreasing Decreasing Decreasing Decreasing Decreasing	Data only for USA (50 States), 88-94 ; Cross-section ; Emissions ;
MU (1997) GDP/per. US\$85	CO ₂ (panel) CO ₂ (for each country)	Cubic, 5 Linear, 1 & 2	12813 18333 na	Test for 16 countries of OECD; 2 regime tests
KGF (1997) GDP/per. US\$91	PRD	Linear, 2	na	19 countries of OCDE ;
EK (1997) GDP/per. US\$91	EP	na	na (No clear relation)	22 pays OCDE ; Synthetic indicator;
TB (1998) GDP/per. US\$85 ppp; Gini coefficient of inequality ; Degree of alphabetization ; Urbanization ; Politic rights and liberty;	SO ₂ Smoke Heavy particles Dissolved oxygen Fecal coliform Access to safe water	Cubic, 5 Cubic, 5 Cubic, 5 Cubic, 5 Cubic, 5 Cubic, 5	3890 (3360) 4350 (na) Decreasing (na) Increasing (19865) Increasing (na) 11255 (6900)	Global estimation with GEMS data. Two tests are carried out : with & without Gini coefficient of inequality. In parentheses are the estimations with Gini coefficient.

	Access to sanitary system	Cubic, 5	10957 (increasing)	
BBO (1998) Economic growth rate; Energy price; Income per capita	CO ₂ NO _x SO ₂	Linear logarithm Linear logarithm Linear logarithm	na na na	Tests are carried out for each country separately : Netherlands, UK, USA and Germany.
ROT (1998) GDP/per. US\$85 ppp	Food, beverages and tobacco Garment and footwear Gross rent, fuel and power Medical care and services other commodities	Quadratic, 3 Quadratic, 3 Quadratic, 3 Quadratic, 3 Quadratic, 3 or 4	12889 35263 23278 47171 ...	Data from United Nation International Comparison Programme.
SUC (1998) GDP/per. ; Import-manufacturing ratio; Export-manufact. ratio; Industry share;	Energy per capita consumption	Quadratic, 3	55535 (model 1) 143806 (model 2)	33 countries
KDGP (1998) GDP/per. ; Economic scale (GDP/km ²) ; Steel export	SO ₂ (Cross-section) SO ₂ (Fixed effects) SO ₂ (Random effects)	Quadratic, 3 Quadratic, 3 Quadratic, 3	11577 12500 12175	23 countries between 1974-1989

Note (by column N°) :

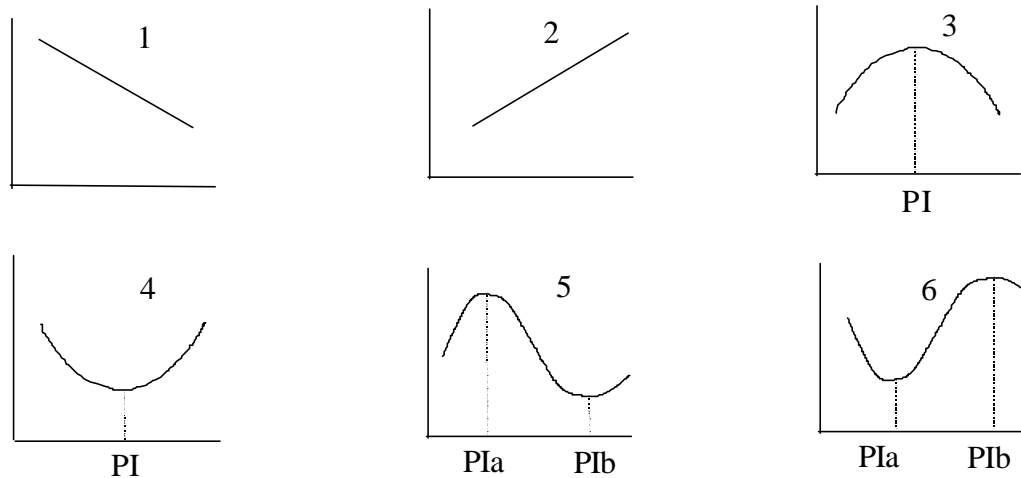
I – Cited study and explanatory indicators :

BBO : Bruyn, Bergh et Opschoor; CG :Cropper & Griffiths; CJM: Carson, Jeon & McCubbin; CRB : Cole, Rayner & Bates; EK : Ekins; GK : Grossman & Krueger; HLW : Hettige et al.; HES : Holtz-Eakin & Selden; KAZ : Kazushi Uemura; KDGP : Kaufmann, Davidsdottir, Garnham & Pauly; KGF : Komen, Gerking & Folmer; MU : Moomaw & Unruh; PAN : Panayotou; R : Rock; ROT : Rothman; SHA : Shafik; SS : Selden & Song; SUC : Suri et Chapman; TB : Torras & Boyce; VIN : Vincent.

II – Pollutant Indicators

SPM Suspended Particulate Matter
BOD Biological Oxygen Demand in Rivers
COD Chemical Oxygen Demand in Rivers
VOC Volatile Organic Carbon
PM₁₀ Particulate matter less than ten microns in diameter
PRD Per capita public Research and Development budget appropriations, aimed at protecting the environment from degradation
EP Environmental Performance, which included 12 indicators for 22 OECD countries (CO₂, NO_x, SO₂, municipal wastes...).

III - Relation shape : generally, the studies tested several forms that it can be presented in six forms :



1 : Linear downward sloping; 2 : Linear upward sloping ; 3 : Quadratic U-inverted; 4 : Quadratic U-normal; 5 : Cubic N-normal with PIa the first turning point and PIb the second turning point ; 6 : Cubic N-inverted with PIa and PIb ; na : not applicable;

IV - Turning point : the level of GDP/per. where the tested pollutant indicators change the upward or downward tendency. (a) is first turning point, (b) is second. Often the second turning point is given as indicative because few data reached this high income level, therefore the estimation is not certain; na : not applicable.

(*) This is minimum, not maximum, because high values are desirable in this case;

(**) In parentheses for quadratic logarithm

Sources : Elaborate from cited studies.

¹ See, for example, Nguyen A.T. (1998) who presents in detail energy, demographic and economic phases of these countries.

² These studies are : Grossman & Krueger (1994) ; Shafik & Bandyopadhyay (1992) ; Selden and Song (1994) ; Panayotou (1993) ; Cropper and Griffiths (1994).

³ The reason for the use of GDP at constant price, not in ppp is that we do not dispose these data for Vietnam, a country which just starts to adopt such economic indicator as GDP.

⁴ These data were provided from 'Center for Institutional Reform and the Informal Sector (IRIS), University of Maryland, with the permission from Ted Haner, the President of BERI.

⁵ See Knack & Keefer (1995) for more information on these indicators.