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Interrelationships among Health, Environment Quality, and Economic Activity

What Consequences for Economic Convergence?

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Abstract

This paper examines the link between health indicators, environmental variables, and economic development, and the consequences of this relationship on economic convergence. In the early stage of economic development, the gain from income growth could be cancelled or mitigated by environmental degradation through health (and other channels), and create a vicious circle in economic activity unlike in developed countries. This in turn could slow down economic convergence. We found through an econometric analysis that environmental degradation affects economic activity negatively and reduces the ability of poor countries to reach developed ones economically.

Keywords: environmental quality, health indicator, income growth, economic convergence, speed of convergence

JEL classification: C33, I18, O11, O40, Q5

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Tables appear at the end of the paper.

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1 Introduction

Environmental protection is an important issue that is gradually becoming more present in the development strategies. It occupies a significant place in the economic policy of many countries and constitutes a major concern for the international community. This concern expressed at international level, is illustrated at many international meetings and conferences: two Nobel Peace prizes were awarded to personalities who raised public awareness on environmental issues—Wangari Maathai in 2004 and Al Gore in 2007—and it is one of the eight Millennium Development Goals (MDG) adopted by the United Nations in 2000. In fact, 192 United Nations member states undertook in 2000 to 'integrate the principles of sustainable development into country policies and programmes, reverse loss of environmental resources, reduce biodiversity loss, and halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation'. This great interest is explained by the fact that environment is intimately connected to a viable ecosystem as explained by the United Nations Secretary General in the United Nations Environmental Programme 2007 Annual Report: 'it keeps the climate stable, clothes our backs, provides the medicines we need, and protects us from radiation from space'.

Although environmental protection is nowadays an important emerging concept, the search for large and sustainable pro-poor economic growth remains a necessity and a priority for all economies. The simultaneous pursuit of these two objectives, that is the wish of all countries, gives rise to at least one question: what is the relationship between economic activity and environmental degradation? During the early decades, many authors tried to give theoretical and empirical responses to this question and the most popular remains the environmental Kuznets curve hypothesis (EKC). The EKC (Grossman 1995; Grossman and Krueger 1995; Torras and Boyce 1998)describes the relationship between declining environmental quality and income as an inverted-U, that is, in the course of economic growth and development, environmental quality initially worsens but ultimately improves with improvements in income level.

The relationship between income and environmental quality should not be limited to the ECK, the environmental degradation in turn can have significant effects on economic activity (Bovenberg and Smulders 1995, 1996; Bruvoll, Glomsrod, and Vennemo 1999). These effects impact growth through many channels, among which health status. Health occupies a dominating role in the economic policy of many developing countries. This importance is illustrated through its weight among the MDGs. Some works estimate the cost of pollution and they show that morbidity and mortality should be considered (Scapecchi 2008).

The aim of this paper is to assess the relationship between health, environment, and economic activity and the consequences of this relationship on economic convergence. In fact, given the EKC hypothesis in the early stages of economic development, the gain from income growth could be cancelled or mitigated by environmental degradation through a populations' health (and other channels) and create a vicious circle in economic activity unlike in developed countries. This in turn could slow down economic convergence.

The interest comes from the fact that very few studies are interested, in a simultaneous way, in these three elements in spite of the importance granted by the international community. The major part of international studies on this relationship, nevertheless, focuses on the EKC hypothesis and those interested in the reverse causality are mainly theoretical works. Moreover, from our knowledge this is the first paper investigating the association between economic convergence and environmental degradation.

Our works show that there is a feedback relationship between economic activity and environmental quality on the one hand and between health and economic activity on the other hand. Health status remains an important channel through which environmental degradation affects economic growth, even if it is not the only one. Environmental degradation affects negatively economic activity and reduces the ability of poor countries to reach developed ones economically.

The rest of this paper is organized in five sections.Section 2 reviews the literature on the relationship between economic activity, health, and environment. Section 3 is devoted to the empirical design—we investigate the association between environmental indicators and economic convergence before examining the relationship between health, environmental degradation, and economic growth through an econometric technique better adapted. Section 4 presents the results and Section 5 concludes.

2 Literature review

In this section, we review the literature on the link between economic outcomes and environment quality. Then, we explain how pollution affects population health.Finally, we examine the association between health and economic performance.

2.1 Economic growth and environment

2.1.1 Growth and economic convergence

Economic convergence—a concept introduced in the economic literature by Solow (1956)—has been tested many times and improved by economists. It was generalized by Barro and Sala-i-Martin (1992), Mankiw, Romer, and Weil (1992), Levine and Renelt (1992) through the conditional convergence notion. Conditional convergence implies that countries would reach their respective steady states. Hence, in looking for convergence in a cross-country study, it is necessary to control for the differences in steady states of different countries. The choice of control variables is very important because the statistical significant level as well as the coefficient amplitude of the variable of interest is sensitive in this choice (Levine and Renelt 1992). In 1992, Mankiw, Romer, and Weil provided an analysis of economic convergence by adding human capital, represented by education level, to the Solow (1956) model and they showed that their results fit better to the predictions of the Solow model. Knowles and Owen (1995) completed this work by adding health as a second human capital.

All these improvements are important but not enough because they do not take into account the role that some omitted variablescould play, in particular the environmental quality which arouses a renewed interest in the last years with the natural resources curse and EKC hypothesis.

2.1.2 Consideration of the environmental aspect

The existence of an intrinsic relation between economic activity and environmental quality remains evident. At the theoretical level several authors tried to give an explanation on the way the environment degradation could impact economic activity (Bovenberg and Smulders 1995, 1996; Bruvoll et al. 1999; Resesodarmo and Thorbecke 1996; Hofkes 1996; Geldrop and Withagen 2000). These theoretical works can be divided into four major categories following Panayotou (2000). Optimal growth models build on a Ramsey (1928) model, as extended by Koopmans (1960) and Cass (1965) constitute the first category (Keeler, Spence, and Garnham 1971; Mäler 1974; Gruver 1976; Brock 1977; Becker 1982; Tahvonen and Kuuluvainen 1994; Selden and Song 1995; Stokey 1998). These are dynamic optimization models, in which the utility-maximization problem of the infinitely lived consumer is solved using the techniques of optimal control theory. Some of these models considered the effects of pollution on the growth path (Keeler, Spence, and Garnham 1971; Gruver 1976; Van der Ploeg and Withagen 1991), whereas others focused on natural resources depletion (Dasgupta and Heal 1974; Solow 1974). In general, models of pollution and optimal growth suggest that some abatement or curtailment of growth will be optimal.

The second category considers not only pollution as an argument of production and utility function, but it also includes environment itself as a factor of production (Lopez 1994; Chichilinsky 1994; Geldrop and Withagen 2000). This measure of environmental quality can be conceptualized as a stock that is damaged by production or pollution. The presence of environmental stock in the production function means that optimal pollution taxes or regulations are not sufficient to achieve the optimal level of environmental quality in the steady state.

The third group is constituted of endogenous growth models that relax the neoclassical specification of the production function assumed in the optimal growth models (Bovenberg and Smulders 1995, 1996; Hofkes 1996; Ligthart and Van der Ploeg 1994; Gradus and Smulders 1993; Stokey 1998). Based on the works of Romer (1986, 1990), these models are characterized by constant or increasing returns to scale to some factors, or a class of factors, because private returns on investment may differ from social returns on investment, often because of externality effects. This category consists of extending this new growth theory to include environment or pollution as a factor of production and environment quality as an argument of the utility function.Bovenberg and Smulders (1995, 1996) modify the Romer (1986) model to include environment as a factor of production. Ligthart and Van der Ploeg (1994), Gradus and Smulders (1993), and Stockey (1998) extend the simple ‘AK’ used by Barro by including environment. Hung, Chang, and Blackburn (1994) use the Romer (1990) work. In general, optimal pollution control requires a lower level of growth than would be achieved in the absence of pollution.

Finally, we have other models that connect environmental degradation and economic growth. This category includes the overlapping generation model based on Diamond (1965), as well asJohn and Pecchenino (1994, 1995). We also have a two country general equilibrium model of growth and environment in presence of trade (Copeland and Taylor 1994). These models reinforce the results of the optimal growth models.

At the empirical level, some economists tried to assess this impact of the environmental degradation on the economic activity. Bruvoll, Glomsrod, and Vennemo (1999) estimated the cost of environmental constraints—called environmental drag—to the Norwegian economy through a dynamic resource environment applied model. Their simulation indicates that the environmental drag reduces the annual economic growth rate by about 0.1 percentage points and annual growth in wealth, including environmental wealth, is reduced by 0.23 percentage points until 2030. Resosudarmo and Thorbecke (1996) show through the social environmental accounting matrix and some simulations, that the improvement of environment quality reduces health problems and therefore stimulates economic growth.

The best way to understand how environmental degradation can affect economic growth is to explain the channels through which this occurs. In the economic literature we can find implicitly or explicitly some of these channels. Most of the channels met in the literature are labour supply and labour productivity.[1] Air pollutions by CO_2, SO_2, NO_x, CO, traffic noise, etc. affect health and leave people unable to work over short or long periods and reduce the productivity of those who work.

The other channels have not been broadly developed in the literature. Among them, we have the deterioration of physical capital (Bruvoll, Glomsrod, and Vennemo 1999; Bovenberg and Smulders 1996). In fact, some pollutants such as SO_2, induce corrosion on capital equipment and increase road depreciation and thus depreciation of public capital. This increases the burden on public expenditures and eventually crowds out private activity (Bruvoll, Glomsrod, and Vennemo 1999). Another channel is welfare degradation. People receive utility from environmental services like recreational values. Some pollutants, such as SO_2 and NO_x, contribute to acidification of lakes and forests and others such as CO and PM_{10}, provoke health-related suffering. This can discourage foreign direct investment and skilled labour. Finally, environmental quality improvement affects saving behaviour, therefore investment (Ricci 2007).

2.1.3 The environmental Kuznets curve hypothesis

It is now clear that environment quality affects economic performance. Economic activity in turn deteriorates environment quality and this in almost all the economic sectors (Shafik 1994, Mansour 2004; Yadav 1997; Repetto and Baliga 1996; Hettige, Mani, and Wheeler 1998). This effect of economic activity on environment quality is complex and depends on some factors, namely preferences, production technology, and the economic structure which are intrinsically linked to the development level. The pollution level depends on the gross domestic product (GDP) composition which itself is linked to the development level (ECK hypothesis).

During the early decades, some authors tried to investigate theoretical and empirical effects of economic development on pollution and the most popular remains the EKC hypothesis. The EKC (Grossman 1995; Grossman and Krueger 1995; Torras and Boyce 1998)describes the relationship between declining environmental quality and income as an inverted-U, that is, in the course of economic growth and development, environmental quality initially worsens, but ultimately improves with improvements in income levels.

The first explanation for the EKC relationship is that the environment can be thought of as a luxury good. In the early stages of economic development a country would be unwilling to exchange consumption for investment in environmental regulation, hence environmental quality declines. When the country reaches the threshold level of income, its citizens start to demand improvement in environmental quality. Another explanation

1 This channel will be the object of particular attention in this paper.

of the EKC hypothesis is that countries pass through technological life cycles, as they move from highly polluting technology (agriculture-based economies) to less polluting technology (service-based systems). In addition to these macroeconomic explanations, the EKC hypothesis is supported by some microeconomic foundations (Andreoni and Levinson 2001).

2.2 Health and environment

A healthy labour force is essential for the development of an economy and requires a healthy environment (clean air, water, recreation, and wilderness). As argued by Pearce and Warford (1993), the immediate and most important consequences of environmental degradation are damage to human health through different forms of diseases. Many authors have assessed how air quality may be associated to population's health. On the one hand, scholars showed that air pollution may increase the mortality rate (Woodruff, Grillo, and Schoendorf 1997; Gangadharan and Valenzuela 2001; Chayand Greenstone 2003; Aunan and Pan2004; Jerrett et al. 2005). Jerrett et al. (2005) investigated whether chronic exposure to particulate air pollution is significantly associated with mortality when the effects of other social, demographic, and lifestyle confounders are taken into account. Their results show substantively large and statistically significant health effects for women and men.

On the other hand, authors assess the link between pollution and particular illnesses, such as cardio-respiratory diseases (Aunan and Pan 2004; Burnett and Krewski 1994; Jerrett et al. 2005), asthma (Nauenberg and Basu 1999),and congenital anomalies (Rankin et al. 2009).

2.3 Health and economic development

The association between income level and population health has been largely studied in the economic literature since many decades. Several channels through which health affects the level of output in a country have been identified. The first is that healthier people are more productive and available as labour. Indeed, they can work harder and longer, and think more clearly. Health may also improve economic outcome through its effect on education. Improvements in health raise the motivation to attend high-level schooling, since the returns to investments in schooling are valuable over a longer working life. Healthier students also have more attendance and higher cognitive functioning, and thus receive a better education for a given level of schooling. Furthermore, lower mortality rate and higher life expectancy encourage saving for retirement, thus raise the levels of investment and capital per worker.

Some scholars assessed empirically how health indicators may influence economic returns in a specific region using individual or household data while others measure the same effect at a more aggregated level, between countries or regions. All these studies could be divided according to the health indicators considered. Indeed, a number of studies utilized health inputs (Weil 2007), whereas others used health outcomes itself. Health inputs, according to Weil (2007), are the physical factors that influence an individual's health and comprise nutrition variables, exposure to pathogens, and the availability of medical care. Health outcomes are characteristics that describe the health status of an individual or a given population. These include health indicators broadly considered such as life expectancy, mortality indicators, the ability to work hard, cognitive functioning, as well as specific illness prevalence such as malaria, AIDS/HIV, Guinea worm, etc.

Using indicators that represent all causes of health outcomes, researchers generally conclude that population health remains an important predictor of economic outcomes (Cuddington andHancock 1994; Barro 1996; Bloom and Malaney 1998; Bloom, Canning, and Malaney 2000; Arora 2001; Bloom, Canning, and Sevilla 2005; Acemoglu and Johnson 2007, 2009; Bloom, Canning, and Fink 2009). Acemoglu and Johnson (2007) give, however, another point of view and present opposing results indicating that increases in life expectancy have no significant effect on economic output per capita. Even though, Bloom, Canning, and Fink (2009) disagree with their results through a comment, they maintained their position in their 2009 paper.

The second branch of the literature assessed the importance of health in economic development by looking at health inputs rather than health outcomes. These studies obviously found a positive effect of health variables on economic growth since rich countries have more health inputs than poor countries. Some of these studies focused on malnutrition and economic productivity. They generally established that calories, anthropometric indicators,and economic output are positively correlated (Alderman and Behrman 2006).

There is therefore a link between environmental quality, population health, and economic performance. This paper discusses the consequences of this interrelationship on economic convergence. In fact, this interrelationship provokes different consequences depending on the development level if the EKC hypothesis is verified. In countries below EKC income threshold, all attempts to boost economic growth (without abatement) will result in greater environmental degradation. And this will burden economic growth through health and other channels creating a vicious circle. However, when countries above the EKC income threshold try to boost their economic growth, their environment quality will be improved and therefore they will be in a virtuous circle. That will penalize poor countries by slowing down the speed of convergence if they do not take care of environmental concerns.

3 Empirical analysis

3.1 Estimation methodology

This section is devoted to the econometric specifications. The analysis is subdivided into four main steps. First, the effect of environment quality on economic outcomes is assessed through the introduction of pollution indicators in an augmented neoclassical growth model. Then, we evaluate how these variables affect the ability of poor countries to catch up with rich ones by adding to the previous model the interaction term between initial GDP per capita and environmental variable. The third model investigates the role played by health in the impact of environmental variables on economic outcomes. Finally, we develop an explanation to this effect of pollution on convergence by estimating simultaneously a growth equation, a health equation, and an environmental equation, and highlight the interrelationships between these three variables.

3.1.1 Economic growth and environment

Based on the neoclassical augmented growth model, the effect of environment on economic growth could be specified as follows

$$\text{gdpc}_{it} = \alpha_1 \text{g}\, dpc_{it-1} + \alpha_2 envir_{it} + \alpha_k X^{'}_{kit} + \upsilon_{it} \qquad (1)$$

where $gdpc_{it}$ and $envir_{it}$ represent respectively the logarithmic form of GDP per capita and the environment quality of country i in period t. X is the matrix of the control variables introduced in the model which havebeen used frequently in the empirical literature.[2] v_{it} is the error term. The coefficient of the economic catch up variable α_1 is expected to be superior to 0 and inferior to 1 (0<α_1<1) to confirm economic convergence hypothesis. We expect α_2 to be inferior to 0 (α_2<0).

This econometric model could be estimated through panel data with ordinary least squares. But the application of this estimator to our model suffers from three problems. First, it does not take into account country-specific and time-invariant heterogeneity. When we take advantage of the panel structure of the data, and when country-fixedeffects are controlled for, the following model is estimated

$$\text{gdpc}_{it} = \alpha_1 \text{g}\, dpc_{it-1} + \alpha_2 envir_{it} + \alpha_k X^{'}_{kit} + \mu_i + \kappa_t + \upsilon_{it} \qquad (2)$$

The country- and time-fixed effects are represented respectively by μ_i and κ_t.

Even though country-fixedeffects limit the bias induced by time-invariant unobservable variables in the identification of α_2, the second drawback comes from the endogeneity of the environmental variable. This problem arises because of two mains reasons. There is likely a reverse causality in the relationship between environment and economic outcomes. In fact, according to the EKC hypothesis, the development level of a country has significant effects on its level of pollution (Grossman and Krueger 1995). The environmental indicator could also be a proxy of some variables that have significant effect on economic growth, such as the technology use and the structure of the economy. There is a need to solve this by using another approach. The instrumental variable methods and more precisely the two steps least squares (2SLS) estimator seems appropriate. This estimator applied to our model raises the third problem because of its dynamic characteristic. Indeed it leads to a biased estimation of α_1 since $gdpcap_{it-1}$ and v_{it} are correlated. The generalized method of moments (GMM) appliedfor dynamic panel data is suitable to estimate consistently the parameter α_1 and also thecoefficients of predetermined and endogenous variables. We use the system-GMM estimatorwhich combines equation in level and equation in difference and then exploits additionalmoment conditions (Blundell and Bond 1998). Predetermined and endogenous variables areinstrumented by both their lagged values in level and lagged values in difference.[3] Two specification tests check the validity of the instruments. The

2 These variables are listed in the next subsection.

3 The paper uses the two-step system-GMM estimator with the Windmeijer (2005) correction for finite sample bias.

first is the standardSargan-Hansen test of overidentifying restrictions. The second test examines the hypothesisthat there is no secondorder serial correlation in the firstdifference residuals.

3.1.2 Economic convergence and environment

To assess the impact of environment quality on economic convergence, we introduce the interaction term between lag GDP per capita and environment as additional variable into the previous model.

$$\text{gdpc}_{it} = \alpha_1^{'} \text{g}\, dpc_{it-1} + \alpha_2 envir_{it} + \alpha_3 (\text{g}\, dpc_{it-1}) * (envir_{it}) + \alpha_k X_{kit}^{'} + \mu_i + \upsilon_{it} \quad (3)$$

In this model the catch up coefficient is $\frac{\partial(gdpc_t)}{\partial(gdpc_{t-1})} = \alpha_1^{'} + \alpha_3 * envir$ and this is function of environmental quality. $\alpha_1^{'}$ is expected to be 0< $\alpha_1^{'}$ <1, α_2 <0 and α_3 >0.

This model is also estimated with the GMM.

3.1.3 Explanation through the role of health variable

These models allowed us to assess the impact of environment degradation on economic growth and economic convergence when health status is among the control variables. However, this remains insufficient because it does not take into account the interrelation between health, environment, and economic growth. Moreover, it does not permit to assess the impact of environment degradation which affects growth through health. To assess this, we add to previous equations two others: an equation of health and one of environment.

Through these additional equations, we assess the impact of income and environmental degradation on health.Generally, it is assumed that health outcomes of a population improve when the economy grows and these improvements are made easy by the rise in the general standard of living (access to educational opportunities and health services). Health depends also on the quality of physical environment such as the amount of air pollution and the quality of drinking water. At the same time, the quality of a country's physical environment is a result of certain growth factors in the economy (intensive use of land, forest, air, and water pollution).We follow Gangadharan and Valenzuela (2001) by expressing health as a function of income, physical environment quality and other control variables.

$$h_{it} = f(gdpc_{it}, envir_{it}(gdpc_{it}, z_{it}), w_{it}) \quad (4)$$

where h is health indicator, z the non-economic variables that determine environment quality, and w the non-economic variables that determine health status (provision and access to health services, number of physicians, immunization rate, education). The next equation being devoted to environment quality, we ignore its determinants and the health equation can be written as

$$h_{it} = \beta_0 + \beta_1 gdpc + \beta_2 envir_{it} + \beta_3 w_{it} + \rho_{it} \quad (5)$$

Here our purpose is to highlight the relation between economic development and environment quality. Economic growth is generally made at the cost of a deterioration of the quality of the natural environment. But through which analytical relation development levels affect environment? Several studies tried to assess this effect empirically and theoretically (Grossman and Krueger 1995; Torras and Boyce 1998; Andreoni and Levinson 2001). Generally, they found that income is linked to environment quality through an inverted U-relationship. In our model environment quality is explained by income and some social variables.

$$envir_{it} = c + \gamma_1 gdpc_{it} + \gamma_2 gdpc_{it}^2 + \gamma_3 z_{it} + \eta_{it} \qquad (6)$$

where z is the non-economic variables that could affect environment quality such as population density.These two equations are estimated simultaneously with 2SLS methods.

3.1.4 Interrelationships between income, health, and environment

To verify the robustness of our results, we estimate by the three steps least square method (3SLS) equations (2), (5), and (6). In addition to the explanation it brings to our results, the argument that guides this choice, is the ability of this method to take into account the fact that the dependent variable of some equation can be used as an explanatory variable in others. In fact, in our system the variable of economic activity is both used as a dependent and explanatory variable, it is the same for health and environment quality. This simultaneity bias can be corrected for each equation by the 2SLS method and for the system by the 3SLS.

3.2 Variables and data

This study is based on a panel data of 117 developed and developing countries for which data are available from 1971 to 2000 subdivided into five-year periods.[4] The economic outcome is measured by GDP per capita based on purchasing power parity (PPP) in constant 2005 international dollars. This indicator is taken from the World Development Indicatorsof the World Bank (2008). Environment quality is represented by three indicators, carbon dioxide emission in metric tons per capita (CO_2), and sulphur dioxide emission milligrams per GDP (SO_2) for air pollution and biological oxygen demand in milligrams per worker (BOD) for water pollution. BOD is a measure of the oxygen used by micro-organisms to decompose waste. Micro-organisms such as bacteria are responsible for decomposing organic waste. When organic matter such as dead plants, leaves, grass clippings, manure, sewage, or even food waste is present in a water supply, the bacteria will begin the process of breaking down this waste. If there is a large quantity of organic waste in the water supply, there will also be a lot of bacteria working to decompose this waste. In this case, the demand for oxygen will be high (due to all the bacteria) so the BOD level will be high (CIESE)[5]. The BOD and CO_2 are also taken from World Bank (2008)while SO_2emission is from the dataset compiled by

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4 The time periods are1971–5, 1976–80, 1981–5, 1986–90, 1991–5, 1996–2000.

5 According to the Center for Improved Engineering and Science Education (CIESE): http://www.k12science.org/curriculum/waterproj/bod.shtml

David Stern[6] in 2004. As health indicator, we use the logistic form of infant mortality rate. In fact the infant mortality indicator is limited asymptotically, and an increase in this indicator does not represent the same performance when its initial level is weak or high, the best functional form to examine is that where the variable is expressed as a logit, as Grigoriou (2005) underlined.

$$\log it(IMR) = \log(\frac{IMR}{1-IMR})$$

We also use as control variables the gross fixed capital formation as percentage of GDP, annual population growth rate, economic openness (ratio of the sum of import and export to GDP), household final consumption per capita, financial development (money and quasi money as a ratio of GDP), inflation rate, immunization rate against DPT, the number of physicians per 1000 inhabitants and female fertility rate, all taken from World Bank (2008). Income inequality is measured by the Gini coefficient taken from the database created by Galbraith and Kum (2005)and known as the University of Texas inequality project database. Our institutions quality indicator is from polity IV and the variable we use is polity2. Finally, the variable of education quality is from Barro and Lee (2000). The definitions and sources of these variables as well as the list of countries are presented in the Appendix A.

4 Econometric results

We begin by discussing the results from the estimation of the growth model, then we carry out the results of the simultaneous estimation of the health and environmental equations. Finally, we present the results obtained with the simultaneous estimation of the three equations.

4.1 Economic growth and environment

The results obtained from the estimation of equation (2) are presented in the first three columns of Table 1. The dependent variable is GDP per capita and our variable of interest is environment quality, measured by three different indicators (SO2 per GDP, CO_2 per capita and BOD per worker). This equation is estimated with the two-step system-GMM estimator and environmental variables are taken as endogenous and then instrumented by at least theirsecond order lags.[7]

These results suggest that environmental degradations have a negative and statistically significant effect on economic growth whatever the environmental indicator considered. Infant mortality rate also has a negative and significant effect on economic growth. Another interesting result is the coefficient of the catch up variable. Indeed, the coefficient of lagged GDP per capita is around 0.91, this corresponds to a rate of convergence of about 2 per cent per year. That means each year poor countries reduce their gap to their steady state by 2 percent. This convergence rate is close to that found

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[6] We thank David Stern for the provision of data.

[7] To prevent the problem of the proliferation of instruments commonly faced in this methodology, we restrict the maximum number of lags at five, what leads us to a maximum number of instruments equal to 26.

in the literature.All other relevant variables of control present expected signs and are statistically significant at the 10 per cent level, except education level which presents the unexpected sign and inflation rate which presents instable sign.

4.2 Economic convergence and environment quality

As previously argued, environment quality may reduce the ability of poor countries to catch up with developed ones economically. To assess empirically whether pollution affects the speed of convergence, we estimate equation (3) with the two-stepsystem-GMM estimator and environmental variables and the interaction term are taken as endogenous and then instrumented by at least theirsecond order lags. The results obtained are summarized in the last three columns (4, 5, and 6) of Table 1. The coefficients of our variables of interest have the correct signs and are statistically significant. Indeed, the lag of GDP per capita and its interaction term with environmental indicators have positive coefficients, while pollution variables have negative coefficients. This means that the speed of convergence of an economy depends on its pollution level. More precisely, a high level of environmental degradation increases the marginal effect of lag GDP per capita on its current level and therefore reduces the speed of convergence. Environment quality can be viewed as an obstacle for developing countries by reducing their ability to get closer to developed countries economically, given the EKC hypothesis.

Regarding the control variables, only investment, health, institutions quality, and inflation rate appear statistically significant. In fact, investment and institution quality increase economic growth while high mortality and inflation rates reduce it.

The scarcity of education data reduces the number of countries in our sample, since it is not available for many countries. To deal with that, we take again the estimation without education variable. The results are presented in Table 2. The sample size increases from 68 countries to 86 and the results remain unchanged.

4.3 Role of health outcomes

To take the interrelationships between health, environment, and economic growth into account, and to assess the impact of environment degradation which affects growth through health, we estimate simultaneously a health and an environment equation with 2SLS estimator. We perform the Hausman specification test (Hausman 1978) to make our choice between the random and fixed effects models. When the p-value of this test is superior to 10 per cent, the random effects model estimator is better; this is the case of the specification with SO_2 and BOD. Otherwise, we choose the fixed effect estimator. The results obtained through 2SLS are summarized in Table 3.

Columns (1) and (2) of the Table 3 present the results when SO_2per GDP is used as environmental indicator. These results show that lagged income per capita, immunization rate, urbanization, and physicians number are factors that contribute to improve health status. However, environment degradation worsens it. The negative coefficient of environment variable confirms our theoretical argument, namely health is an important channel through which health affects economic growth. The result of the first step regression (environment quality equation in column 2) indicates that the coefficient of lagged income per capita is positive and significant at 1 per cent, showing that economic activity deteriorates environment quality. But the negative and significant coefficient of lagged income square indicates that the negative effect of GDP on environment quality is conditioned to an income threshold above which the effect becomes positive and income improves environment quality confirming the EKC hypothesis. The four last columns of this table present the results when carbon dioxide per GDP (columns 3 and 4) and the biological oxygen demand (columns 5 and 6) are used as environmental variables. All the environmental variables have the correct sign and the EKC hypothesis is verified in each case.

The 2SLS estimations of these two equations allow us to draw some conclusions: there is an inverse causality between economic activity and environmental degradation, and health status is an important channel through which environment degradation affects economic growth even if it is not alone. The effect of economic activity on environment quality is dependent on theincome level. Countries whose income is below the EKC income threshold will be caught in a poverty trap due to environment degradation. However, those whose income is above this threshold will be in a virtuous circle due to the improvement of environment quality. This could reduce the ability of poor countries to catch up with rich ones. Any ambitious economic policy must take into account environmental concerns to avoid its perverse effects.

4.4 Interrelationships between income, health, and environment

In order to confirm the results already analysed, we estimate simultaneously all the three equations (growth, health, and environment equations) with the 3SLS estimator.[8] The results obtained are presented in Table 4.

These results are similar to those obtained previously in Tables 1, 2, and 3. The first three columns present the results whenSO_2per GDP is used as an environmental indicator. This environmental indicator affects negatively and significantly economic activity as presented in column 1 and degrades health status (column 2). And the EKC hypothesis is confirmed in column 3.

The six other columns of this table present the results when carbon dioxide per GDP (columns 4, 5, and 6) and the biological oxygen demand (columns 7, 8, and 9) are used as environmental variables. All the environmental variables have the correct sign and the EKC hypothesis is verified in each case.

5 Concluding remarks

The main goal of this paper is the analysis of the interrelationships between health, income, and environment quality and its consequences on the economic convergence process. We introduce an environment variable in a growth model and we observe itseffect on economic growth. Our results show that environmental degradation negatively affects economic activity and reduces the ability of poor countries to reach developed ones economically. This reinforces our theoretical argument according to which environment quality improvement plays a considerable role in the economic convergence process. Two-step GMM and least square estimations of health and

[8] Here the environmental indicators are expressed in natural logarithmic form to be interpreted as elasticity.

environment equations allow us to confirm the inverse causality between environment quality and economic growth and between economic growth and health. Health status remains an important channel through which environment degradation affects economic growth even if it is not alone. Poor countries which have chosen rapid economic growth at the price of environment quality will penalize themselves and have little chance to reach their goal. Such policy can reduce growth through health and other channels.

Poor countries cannot postpone attending environmental concerns in the hope that the environment will improve with increased incomes and avoid poverty traps due to environment degradation. Policy makers in these countries should, on the contrary, take into account environmental concerns as promoted by the international community through the MDGs.

This paper can also be placed into the debate about development aid effectiveness. In fact, development assistance based on less polluting production technology will help poor countries to avoid the vicious circles shown in this paper.

One way this research can be extended is to use other health and environment indicators and compare the results for each indicator. Another way to extend this paper is the use of other technical approaches in order to confirm our idea.

Appendix

Table A1: Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
GDP per capita	259	11212.43	10918.89	355.8692	55491.52
Inf. mort. rate	259	36.90442	33.55625	3.48	138.656
SO_2 per GDP	253	0.0069203	0.017175	0.0000922	0.1760821
CO_2 per capita	259	5.060414	5.543132	0.0319344	35.87007
BOD per worker	256	0.1950967	0.0519381	0.0694487	0.4478187
Pop. growth	259	1.337404	3.075527	-44.40836	5.603235
School	211	23.11564	22.01362	0	84.1
Investment	258	20.90701	5.34708	9.488747	40.29905
Openness	256	68.85741	39.29941	2.003065	238.6728
Consumption	219	4469.355	5270.451	87.23995	22281.84
Financial dev.	221	44.7538	32.07666	9.198633	227.4642
Polity2	226	3.879646	6.691901	-10	10
Inflation rate	254	38.59134	190.1751	-1.659683	2342.221
Immunization	259	81.51004	16.49692	24	99
Physician	259	1.445306	1.155825	.0198895	4.173381
Fertility rate	259	3.132003	1.578447	1.152	7.845
Inequality	259	42.36337	6.444149	26.135	64.2473

Table A2: Variables definitions and sources

Variables	Characteristics	Sources
GDP per capita	Gross domestic product per capita	World Bank (2008)
Inf. mort. rate	Infant mortality rate	UNICEF
SO_2 per GDP	Sulphur dioxide emission per GDP	David Stern
CO_2 per capita	Carbon dioxide emission per capita	World Bank (2008)
BOD per worker	Biological Oxygen Demand per worker	World Bank (2008)
Pop. growth	Population growth rate	World Bank (2008)
School	Percentage of ‘no schooling’ in the total	Barro and Lee 2000
Investment	Gross fixed capital formation	World Bank (2008)
Openness	Ratio of the sum of export and import to	World Bank (2008)
Consumption	Household final consumption rate per capita	World Bank (2008)
Financial dev.	Money and quasi money as a ratio of GDP	World Bank (2008)
Polity2	Institution quality	Polity IV
Inflation rate	Consumption index price	World Bank (2008)
Immunization	Immunization rate against DPT	World Bank (2008)
Physician	Number of physicians per 1000 inhabitants	World Bank (2008)
Fertility rate	Women fertility rate	World Bank (2008)
Inequality	Gini coefficient of income	University of Texas

Table A3: List of countries in the sample

Albania,Algeria, Argentina, Armenia, Australia, Austria, Azerbaijan, Belgium, Bangladesh, Bulgaria, Bahrain, Belize, Bolivia, Brazil, Bhutan, Botswana, Central African Republic, Canada, Chile, China, Côte d'Ivoire, Cameroon, Congo, Rep., Colombia, Cape Verde, Costa Rica, Croatia, Cyprus, Denmark, Ecuador, Egypt, Arab Rep., Ethiopia, Finland, Fiji, France, Gabon, Germany, Ghana, Greece, Guatemala, Honduras, Haiti, Hungary, Indonesia, India, Ireland, Iran, Islamic Rep., Iceland, Israel, Italy, Jamaica, Jordan, Japan, Kenya, Kyrgyz Republic, Korea, Rep., Kuwait, Sri Lanka, Lithuania, Luxembourg, Latvia, Morocco, Moldova, Madagascar, Mexico, Macedonia, FYR, Malta, Myanmar, Mongolia, Mozambique, Mauritius, Malawi, Malaysia, Namibia, Nigeria, Netherlands, Norway, Nepal, New Zealand, Oman, Pakistan, Panama, Peru, Philippines, Papua New Guinea, Poland, Portugal, Paraguay, Romania, Russian Federation, Rwanda, Saudi Arabia, Senegal, Singapore, El Salvador, Spain, Suriname, Slovak Republic, Slovenia, Sweden, Swaziland, Syrian Arab Republic, Thailand, Tonga, Trinidad and Tobago, Tunisia, Turkey, United Kingdom, Uganda, Ukraine, Uruguay, United States, St. Vincent and the Grenadines, Venezuela, South Africa, Zambia,

References

Acemoglu, D., andJ. Johnson (2007). 'Disease and Development: The Effect of Life Expectancy on Economic Growth'. *Journal of Political Economy*, 115(6): 925–85.

—— (2009).'Disease and Development: The Effect of Life Expectancy on Economic Growth'.In M. Spence and M. Lewis (eds), *Health and Growth*. Washington, DC:World Bank, Commission on Growth and Development.

Alderman, H., and J. R. Behrman (2006), 'Reducing the Incidence of Low Birth Weight in Low-Income Countries Has Substantial Economic Benefits'. *World Bank Research Observer*,21 (1): 25–48.

Andreoni, J., and A. Levinson(1998).'The Simple Analysis of the Environmental Kuznets Curve'. Working Paper 6739. Cambridge, MA: NBER.

Arora, S.(2001).'Health, Human Productivity, and Long-Term Economic Growth'.*The Journal of Economic History*, 61: 699–749.

Aunan, K.,and X.C.Pan(2004).'Exposure-Response Functions for Health Effects of Ambient Air Pollution Applicable for China – AMeta-Analysis'.*Science of the Total Environment*, 329: 3–16.

Bloom, D., and P. N. Malaney (1998).'Macroeconomic Consequences of the Russian Mortality Crisis'.*World Development*, 26: 2073–85.

Bloom, D. E., D. Canning, and G. Fink. (2009). 'Disease and Development Revisited'. Working Paper 15137. Cambridge, MA: Harvard School of Public Health.

Bloom, D. E., D. Canning, and P. N. Malaney (2000). 'Demographic Change and Economic Growth in Asia'.*Population and Development Review*, 26(supp.): 257–90.

Bloom, D.E., D. Canning, and J. Sevilla (2005).'The Effect of Health on Economic Growth: A Production Function Approach'.*World Development*, 32(1) 1–13.

Barro, R. (1996). *Health and Economic Growth*. Cambridge, MA: Harvard University.

Barro, J.R., and X.Sala-i-Martin (1992).‘Convergence’.*Journal of Political Economy*’, C: 223–51.

Barro, R. J., and J.-W. Lee (2000). ‘International Data on Educational Attainment: Updates and Implications’. Working Paper 42. Cambridge, MA: Harvard University, CID.

Becker, R. A.(1982).‘Intergenerational Equity: The Capital-Environment Trade-Off’.*Journal of Environmental Economics and Management*, 9: 165–85.

Blundell R., and S. Bond (1998).‘Initial Conditions and Moment Restrictions in Dynamic Panel Data Models’.*Journal of Econometrics*, 87: 115–43.

Bovenberg, A. L., and S. Smulders (1995).‘Environmental Quality Pollution-Augmenting Technological Change in a Two Sector Endogenous Growth Model’. *Journal of Public Economics*, 1: 369–91.

—— (1996).‘Transitional Impacts of Environmental Policy in an Endogenous Growth Model’.*International Economic Review*, 37: 861–93.

Brock, W. A.(1977).‘A Polluted Golden Age’.In V. Smith (ed.), *Economics of Natural Environmental Resources*. New York: Gordon and Breach.

Bruvol, A., S. Glomsrod, and H.Vennemo(1999).‘EnvironmentalDrag: Evidence from Norway’.*Ecological Economics*, 30: 235–49.

Burnett, R., and D. Krewski(1994).‘Air Pollution Effects on Hospital Admission Rates: A Random Effects Modeling Approach’, *The Canadian Journal of Statistics*, 22 (4): 441–58.

Cass, D.(1965)‘Optimal Growth in an Aggregate Model of Capital Accumulation’.*Review of Economic Studies*, 32: 233–40.

Chay, K. Y.,and M. Greenstone(2003).‘The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by a Recession’.*The Quarterly Journal of Economics*, 118 (3): 1121–67.

Chichilinsky, G.(1994).‘North-South Trade and the Global Environment’.*The American Economic Review*,84 (4): 851–74.

Copeland, B.R., and M.S.Taylor(1994).‘North-South Trade and the Environment’.*Quarterly Journal of Economics*, 109 (3): 755–85.

Cuddington, J.T, and J. D. Hancock (1994). ‘Assessing the Impact of AIDS on the Growth of the Malawian Economy’.*Journal of Development Economics*, 43: 363–8.

Dasgupta, P., and G. Heal (1974).‘The Optimal Depletion of Exhaustible Resources’.*Review of Economic Studies*, 3–28.

Diamond, P.(1965).‘National Debt in a Neoclassical Growth Model’.*American Economic Review*, 55: 1126–50.

Galbraith, J. K., and H. Kum (2005).‘Estimating the Inequality of Household Incomes: A Statistical Approach to the Creation of a Dense and Consistent Global Data Set’. *Review of Income and Wealth*, 51 (1): 115–43.

Gangadharan, L., and M. R.Valenzuela(2001).‘Interrelationships between Income, Health and the Environment: Extending the Environmental Kuznets Curve Hypothesis’. *Ecological Economics*, 36: 513–31.

Geldrop, V., and C.Withagen(2000).‘Natural Capital and Sustainability’.*Ecological Economics*, 32 (3): 445–55.

Gradus, R., and S.Smulders(1993).‘The Trade off between Environment Care and Long-Term Growth – Pollution in the Three Prototype Growth Models’.*Journal of Economic*, 58 (1): 25–51.

Grigoriou, C. (2005).‘Essais sur la Vulnérabilité des Enfants dans les Pays en Développement: L’Impact de la Politique Économique’.PhD Thesis.Auvergne: Université d’Auvergne, Centre d’Etudes and de Recherches sur le Développement International.

Grossman, G., and A.B.Krueger(1995).‘Pollution Growth and the Environment’. *Quarterly Journal of Economics*, 110: 353–77.

Grossman, M.(1972).‘On the Concept of Health Capital and the Demand for Health’.*Journal of Political Economy*, 80: S74–S103.

Gruver, J. W.(1976).‘Optimal Investment in Pollution Control Capital in a Neoclassical Context’.*Journal of Environmental Economics and Management*, 3: 165–77.

Hausman, J. (1978).‘Specification Test in Econometrics’. *Econometrica*, 46: 1251–71.

Hettige, H., M. Mani, and D. Wheeler(1998).‘Industrial Pollution and Economic Development’, Policy Research Working Paper 1876. Washington, DC: World Bank.

Hofkes, M. W. (1996). ‘Modelling Sustainable Development: An Economy-Ecology Integrated Model’.*Economic Modelling*, 13: 333–53.

Hung, V.T.Y., P. Chang, and K.Blackburn(1993).‘Endogenous Growth, Environment and R&D’.Nota di Lavoro 23.93. Milan: Fondazione ENI Enrico Mattei.

Jerrett, M., M. Buzzelli, R.T.Burnett, and P.F.DeLuca(2005).‘Particulate Air Pollution, Social Confounders, and Mortality in Small Areas of an Industrial City’. *Social Science & Medicine*, 60: 2845–63.

John, A., and R.Pecchenino(1994).‘An Overlapping Generation Model of Growth and the Environment’.*The Economic Journal*, 104: 1393–1410.

Keeler, E., M. Spence, and D.Garnham (1971).‘The Optimal Control of Pollution’. *Journal of Economic Theory*, 4: 19–34.

Knowles, S., and P.D.Owen(1994).‘Health Capital and Cross-Country Variation in Income Per Capita in the Mankiw-Romer-Weil Model’.*Economics Letter*, 48(1): 99–106.

Koopmans, T.C.(1965).‘On the Concept of Optimal Economic Growth’.In *The Econometric Approach to Development Planning*. North-Holland Publ. Co. and Rand McNally. A Reissue of Pontificiae Academiae Scientiarum Scripta Varia, 28 (1965): 225–300.

Levine R., and D.Renelt(1992).‘A Sensitivity Analysis of Cross Country Growth Regressions’.*American Economic Review*, 82: 942–63.

Ligthart, J.E., and F.Van Der Ploeg(1994).‘Pollution, the Cost of Public Funds and Endogenous Growth’.*Economics Letters*,46 (4): 339–49.

Lopez, R.(1994).‘The Environment as a Factor of Production: the Effect ofEconomic Growth and Trade Liberalization’.*Journal of Environmental Economics and Management*, 27: 163–84.

Mäler, K. G.(1974).*Environmental Economics: A Theoretical Inquiry*.Baltimore, MA: The JohnsHopkins University Press.

Mankiw,N., G. Romer, and D.N.Weil(1992).‘A Contribution to the Empirics of Economic Growth’.*The Quarterly Journal of Economics*, 107: 407–37.

Mansour S. A.(2004).‘Pesticide Exposure – Egyptian Scene’. Toxicology, 198: 91–115.

Panayotou, T.(2000).‘Economic Growth and the Environment’. Working Paper 56.Cambridge, MA: Harvard University, CID.

Nauenberg, E., and K. Basu (1999).‘Effect of Insurance Coverage on the Relationship between Asthma Hospitalizations and Exposure to Air Pollution’.*Public Health Reports*, 114 (2): 135–48.

Pearce, D. W., and J. J. Warford (1993).*World without End: Economics, Environment and Sustainable Development*. Oxford: Oxford University Press.

Ramsey, F. P.(1928).‘A Mathematical Theory of Saving’.*Economic Journal*, 38: 543–59.

Rankin, J., T. Chadwick, M. Natarajan, D.Howel, P.Pearce, and T. Pless-Mulloli(2009).‘Maternal Exposure to Ambient Air Pollutants and Risk of Congenital Anomalies’.*Environmental Research*, 109: 181–7.

Resosudarmo, B.P., and E. Thorbecke (1996).‘The Impact of Environment Policies on Household Income for Different Socio-Economic Classes: The Case of Air Pollutants in Indonesia’.*Ecological Economics*, 17 (2): 83–94.

Ricci, F.(2007).‘Channels of Transmission of Environmental Policy to Economic Growth: A Survey of the Theory’.*Ecological Economics*, 60 (4): 688–99.

Romer, P. M.(1986).‘Increasing Returns and Long Run Growth’.*Journal of Political Economy*, 94: 1002–37.

—— (1990).‘Endogenous Technological Change’, *Journal of Political Economy* 71–101.

Scapecchi, P.(2008).‘The Health Costs of Inaction with Respect to Air Pollution’.Environment WorkingPapers 2. Paris: OECD.

Selden, T.M., and D. Song(1995).‘Neoclassical Growth, the J Curve for Abatement, and the Inverted U Curve for Pollution’.*Journal of Environmental Economics and Management*, 29: 162–8.

Shafik, N.(1994).‘Economic Development and Environment Quality: An Econometric Analysis’.*Oxford Economic Paper*, 46: 757–73.

Solow, R.M.(1956).‘A Contribution to the Theory of Economic Growth’.*Quarterly Journal of Economics*, LXX: 65–94.

—— (1974).‘Intergenerational Equity and Exhaustible Resources’.*TheReviewof Economic Studies* (Symposium Issue): 29–46.

Stern, D.(2005).‘Reversal in the Trend of Global Anthrogenic Sulfur Emissions’. Working Papers in Economics 0504. Troy, NY: Rensselaer.

Stokey, N. L.(1998).‘Are There Limits to Growth?’.*International Economic Review*, 39:1–31.

Tahvonen, O., and J.Kuuluvainen(1993).‘Economic Growth, Pollution and Renewable Resources’.*Journal of Environmental Economics and Management*, 24: 101–18.

Torras, M., and J.K. Boyce(1998).‘Income, Inequality and Pollution: A Reassessment of the Environment Kuznets Curve’.*Ecological Economics*, 25: 147–60.

United Nations Environment Programme (UNEP) (2007). ‘Annual Report’. Nairobi: UNEP.

Van der Ploeg, F., and C. Withagen (1991).‘Pollution Control and the Ramsey Problem’. *Environmental and Resource Economics*, 1: 215–36.

Weil, D. (2007).‘Accounting for the Effect of Health on Economic Growth’. *The Quarterly Journal of Economics*, 122 (3): 1265–306.

Windmeijer, F. (2005).‘A Finite Sample Correction for the Variance of Linear Efficient Two-Step GMM Estimators’.*Journal of Econometrics* 126: 25–51.

Woodruff, T. J., J. Grillo, and K.C. Schoendorf (1997).‘The Relationship between Selected Causes of Postneonatal Infant Mortality and Particulate Air Pollution in the United States’.*Environmental Health Perspectives*, 105(6): 608–12.

World Bank (2008). *World Development Indicators Online*. Washington, DC: World Bank.

Repetto, R., and S. S. Baliga (1996).*Pesticide and Immune System: The Public Health Risk*. Washington, DC: World Resources Institute.

Yadav, S. N.(1997).‘Dynamic Optimization of Nitrogen Use When Groundwater Contamination is Interlised at the Standard in the Long Run’, *American Journal of Agricultural Economics*, 79 (1997): 931–45.

Table 1: Two-step system-GMM results of the economic convergence effect of environmental variables

	Dependent variables: GDP per capita PPP in constant value 2005					
	SO_2 per GDP	CO_2 per capita	BOD per worker	SO_2 per GDP	CO_2 per capita	BOD per worker
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Log initial GDP per capita	0.913***	0.917***	0.907***	0.903***	0.936***	0.675***
	(14.73)	(8.73)	(42.12)	(13.40)	(5.19)	(6.74)
(Environment)x(initial GDP)				2.313**	0.013***	0.910**
				(2.36)	(2.98)	(2.40)
Environmental variables	-0.622**	-0.007*	-0.666*	-16.547**	-0.128***	-7.692**
	(2.00)	(1.93)	(1.66)	(2.36)	(2.94)	(2.42)
Population growth	-0.000	0.003	-0.008	0.001	-0.002	0.006
	(0.06)	(0.53)	(0.99)	(0.33)	(0.26)	(0.53)
Log schooling	0.013*	0.005	0.011	0.005	0.002	0.014
	(1.94)	(0.45)	(1.16)	(0.75)	(0.19)	(1.07)
Log investment	-0.015	0.091***	0.051	0.090***	0.134***	0.064*
	(0.44)	(3.68)	(1.64)	(3.26)	(3.36)	(1.85)
Logit health	-0.048***	-0.044***	-0.028*	-0.040***	-0.035***	-0.080***
	(4.03)	(4.15)	(1.77)	(3.26)	(2.66)	(2.63)
Openness	0.056**	0.018	0.037	0.023	0.018	-0.036
	(2.32)	(0.75)	(1.53)	(1.46)	(0.72)	(0.95)
Log consumption	0.049	0.050	0.043**	0.041	0.018	0.078
	(0.88)	(0.59)	(2.36)	(0.76)	(0.13)	(1.15)
Financial development	-94.851	-66.054	-132.090***	-83.703	-102.375	151.914
	(1.25)	(1.41)	(2.95)	(1.19)	(1.60)	(1.37)
Polity2	0.001	0.002**	0.002**	0.003***	0.002**	0.002*

	(1.31)	(2.21)	(1.98)	(2.76)	(2.17)	(1.72)
Inflation	0.005*	-0.003***	-0.003***	-0.002***	-0.003***	-0.002***
	(1.72)	(5.44)	(5.91)	(5.18)	(3.70)	(2.60)
Constant	0.228	-0.066	0.357*	0.106	-0.067	1.732***
	(1.31)	(0.30)	(1.93)	(0.69)	(0.17)	(2.85)
Observations	235	239	203	235	239	203
Countries	68	69	63	68	69	63
AR1	0.019	0.009	0.014	0.004	0.010	0.010
AR2	0.127	0.094	0.117	0.128	0.115	0.151
Hansen p-value	0.388	0.156	0.259	0.389	0.285	0.139
Number of instruments	26	17	15	17	17	19

Note: Robust t-statistics in parentheses. Standard errors are corrected by the Windmeijer (2005) method designed for finite sample bias in a two-step system-GMM estimator. *p< 0.10, **p< 0.05, ***p< 0.01.

Table 2: Two-step system-GMM results of the economic convergence effect of environmental variables without education.

Dependent variables:	GDP per capita PPP in constant value 2005		
	SO_2 per GDP	CO_2 per capita	BOD per worker
Variables	(1)	(2)	(3)
Log Initial GDP per capita	0.891***	0.870***	0.797***
	(10.59)	(5.83)	(12.29)
(Environment)x(initial GDP)	1.520*	0.010*	0.690*
	(1.66)	(1.94)	(1.94)
Environmental variables	-11.060*	-0.105*	-5.832*
	(1.69)	(1.94)	(1.96)
Population growth	-0.000	-0.003	-0.001
	(0.07)	(0.38)	(0.11)
Log Investment	0.068**	0.124***	0.056*
	(2.28)	(2.81)	(1.92)
Logit health	-0.031***	-0.014	-0.050**
	(2.71)	(0.84)	(2.47)
Openness	0.031	0.067*	-0.013
	(1.27)	(1.79)	(0.40)
Log consumption	0.055	0.078	0.015
	(0.78)	(0.67)	(0.54)
Financial development	-45.268	-131.795*	103.831
	(0.76)	(1.72)	(1.10)
Polity2	0.002**	0.002	0.002*
	(1.99)	(1.63)	(1.74)
Inflation	-0.003***	-0.002***	-0.003***
	(5.88)	(3.73)	(7.03)
Constant	0.214	0.131	1.315**
	(1.19)	(0.35)	(2.18)
Observations	287	292	233
Countries	84	86	73
AR1	0.006	0.017	0.003
AR2	0.129	0.150	0.106
Hansen p-value	0.191	0.210	0.545
Number of instruments	13	18	14

Note: Robust t-statistics in parentheses. Standard errors are corrected by the Windmeijer (2005) method designed for finite sample bias in a two-step system-GMM estimator. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Table 3: 2SLS estimation of the health effect of environmental degradation and environmental Kuznets Curve hypothesis

	Random effects		Fixed effects		Random effects	
	Inf. mort. rate	SO_2 per GDP	Inf. mort. rate	CO_2 per capita	Inf. mort. rate	BOD per worker
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Immunization	-0.837***	0.0013	-0.670***	0.090	-1.000***	0.011
	(4.22)	(0.45)	(3.82)	(0.06)	(3.39)	(0.57)
Physician	-0.539***	0.002***	-0.570***	2.265***	-0.052	0.0036
	(6.67)	(2.59)	(7.02)	(3.77)	(0.76)	(0.77)
Urban population	-1.135*	0.008	-1.372**	5.296	0.173	-0.039
	(1.70)	(0.90)	(2.06)	(0.89)	(0.44)	(-1.49)
Log fertility rate	-0.282	0.009***	0.152	-1.072	0.312	0.0371***
	(1.16)	(3.88)	(1.05)	(-0.70)	(1.51)	(3.41)
Log GDP per	-0.124		-0.221		-0.445***	
capita lag		0.0414***		26.05***		0.111***
	(0.82)	(2.78)	(1.57)	(2.75)	(5.33)	(2.65)
Environment	52.782**		0.055**		11.746***	
	(2.53)		(2.17)		(3.38)	
Log GDP per capita square lag		-0.0026***		-1.583***		-0.0063**
		(-3.08)		(-2.99)		(-2.55)
Income inequality		-.00005		-0.111***		0.0013***
		(-0.79)		(-2.83)		(3.05)
Constant	-0.607	-0.1703**	-0.101	-100.2**	-1.701**	-0.369**
	(0.53)	(-2.55)	(0.08)	(-2.32)	(1.98)	(-2.10)
Observations	253	253	259	259	257	257
Countries	113	113	117	117	117	117
Hausman test (p-value)	0.99		0.00		0.29	

Note: Robust t-statistics in parentheses. *p< 0.10, **p< 0.05, ***p< 0.01.

Table 4: 3SLS estimation of the interrelationships between health, environment and economic activity

	3SLS estimation of the relationships between health, environment and economic activity								
	GDP per capita	Inf. mort. Rate	SO_2 per GDP	GDP per capita	Inf. mort. Rate	CO_2 per capita	GDP per capita	Inf. mort. Rate	BOD per worker
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Pop. growth	-0.00696			0.00187			-0.00570		
	(-1.197)			(0.408)			(-1.008)		
Initial GDP	0.920***			0.979***			0.905***		
	(54.32)			(29.17)			(67.29)		
Schooling	0.0245***			0.0244***			0.0244**		
	(2.900)			(3.214)			(2.545)		
Investment	0.0884***			0.113***			0.0454**		
	(5.016)			(4.898)			(2.007)		
Inf. mort	-0.0910***			-0.154***			-0.0897***		
	(-4.594)			(-7.337)			(-3.033)		
Log cons.	-0.00927			-0.00996			0.0269*		
	(-0.393)			(-0.593)			(1.869)		
Financial dev.	-129.5			-17.75			-28.18		
	(-1.473)			(-0.473)			(-0.584)		
Polity2	0.00119			0.000830			0.00203***		
	(1.322)			(1.143)			(2.826)		
Inflation	-0.000972			-0.00229			-0.00214		
	(-0.630)			(-1.418)			(-1.383)		
Immunization		-0.850***			-0.331***			-0.493***	
		(-5.272)			(-2.729)			(-3.417)	
Physician		-0.0789*			-0.0596			-0.136***	
		(-1.951)			(-1.577)			(-3.014)	
Fertility rate		0.645***			0.925***			0.602***	
		(6.697)			(8.245)			(5.263)	
Environment	-0.0692***	0.465***		-0.0550**	0.458***		-0.0992	0.845***	
	(-3.180)	(6.216)		(-2.568)	(5.114)		(-1.281)	(3.298)	
Log GDP per capita		-0.197***	4.045***		-0.948***	4.455***		-0.359***	0.308
		(-3.520)	(5.464)		(-9.285)	(7.825)		(-7.731)	(1.615)

Log GDP per square capita			-0.268***			-0.185***			-0.0213*
			(-6.089)			(-5.588)			(-1.875)
Inequality			-0.00165			-0.005			0.0125***
			(-0.169)			(0.60)			(4.511)
Constant	-0.252**	0.887*	-20.36***	-0.615**	3.655***	-23.34***	-0.0273	0.832	-3.202***
	(-2.518)	(1.755)	(-6.573)	(-2.291)	(4.684)	(-9.858)	(-0.353)	(1.371)	(-4.087)
Observations	179	179	179	216	216	216	180	180	180
R-squared	0.993	0.724	0.197	0.994	0.798	0.817	0.997	0.840	0.262

Note : Robust t-statistics in parentheses. $^{*}p< 0.10$, $^{**}p< 0.05$, $^{***}p< 0.01$. All the independent variables are in natural logarithmic form, except health variable, population growth, polity2 and inflation rate.