ENDOGENOUS GROWTH MODELS AND THE ENVIRONMENTAL KUZNETS CURVE: AN ANALYSIS OF GLOBAL ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT

Fertilizer consumption per cubic meter of freshwater is taken as a proxy for global water quality indicator. A global model of environmental quality for 121 countries confirms the Kuznet's hypothesis. Global turning point is reached at nearly five times the average income of all countries. Foreign Direct Investment (FDI) was significant to increase the national income. Increased aid and larger farm size per capita favored higher environmental quality, albeit insignificant. A flow of better technology and possible non-agricultural employment might help improve water quality in developing countries when their net income increases.

BACKGROUND

Economic growth and development often stress the environment as production processes typically bring some environmental externalities in the form of water and air pollution. An environmental Kuznets curve is an inverted U-Shaped relationship between environmental quality and national income, because environmental quality decreases with increased production, but after a point, willingness and ability to pay for a cleaner environment increase with higher national income. Hence, countries with higher per capita national income invest in environmental friendly technologies and use them in the production process, thereby minimizing damages to the environment. However, for developing countries, steady growth over a period of time is more important than environmental quality.

> *"……every nation goes through a dirty phase as it industrializes. As they grow richer, societies clean up their acts. With more wealth, nations can acquire the expensive technology needed to control pollution from vehicles, homes, and factories. As people climb out of poverty environmental damage increases, then falls again as they grow prosperous……"* (Canada & the World Backgrounder, 1998)

The purpose of the paper is to investigate global environmental outcomes from a policy perspective of maintaining current levels of environmental standards on the developed world with an environmental technology transfer to undeveloped countries so that they could reduce emissions.

METHODOLOGY

A two stage augmented environmental model was used in the study. The analytical method remained within the framework of an environmental Kuznets curve. Econometric models were used to relate national income and water quality with the cross-sectional data for 121 countries. Fertilizer consumption in agricultural sector per units of freshwater is chosen as an indicator for water quality, however, differences in soils and climate are not fully incorporated in the model. Excessive use of fertilizers from agricultural activities has a negative impact on soil and water, altering chemistry and levels of nutrients and leading to eutrophication problems (Environmental Sustainability Indicators 2002). Many studies use fertilizer and pesticide use per unit of water to express stress to water in a country (Report of Water Quality in the European Union; Wellbeing

Index). More comprehensive variables such as dissolved oxygen content, suspended solids, electrical conductivity and phosphorus contents are severely limited data in wider country coverage.

Data on production, income and consumption related variables were taken from the WDI 2002 CD-ROM from the Worldbank (www.worldbank.org). Other variables taken from the same source are land area, inputs use, pollutants emissions, population and per capita freshwater availability. Data on energy consumption efficiency was taken from Environmental Sustainability Index report published by Yale Center for Environmental Law and Policy.

Growth Model

Each country's national income is estimated from a production model using capital, labor, and resources as independent variables with given level of technological progress. The proxies for these components are capital formation in current GDP, total labor, and energy consumption per dollar of GDP respectively. A general production function of an individual country in a Cobb-Douglas form can be expressed as

$$Q_i = Ae^{ri}K_i^{a1}L_i^{a2}E_i^{a3}M_i^{a4} \qquad (1)$$

where, K, L, E, and M are capital, labor, energy, and materials input in the production process; A, $a1$, $a2$, $a3$, and $a4$ are constants; r is a constant for technological progress; and i refers to the individual country.

If the sum of the '*a*' exponents is 1, there are constant returns to scale. A double-log econometric model gives the rate of growth with respect to the changes in explanatory variables.

$$lnQ_i = r + a_1 lnK_i + a_2 lnL_i + a_3 lnE_i + a_4 lnM_i + u_i \qquad (2)$$

where all the coefficients are expressed in terms of elasticity. Thus the rate of growth of output is a weighted sum of the individual rates plus r, which is interpreted as the rate of technological progress. As long as r>0, growth can continue, even in the absence of growing inputs.

Environmental model

A linear-in-parameters Kuznets model is:

$$E_i = \beta_0 + \beta_1 Y_i + \beta_2 Y_i^2 + \ldots. + \beta_k Y_i^m + \ldots\ldots + \beta_m X_i + u_i \qquad (3)$$

where E_{it} is an indicator of water quality, Y_{it} is per capita national income of country *i* and X_i are variables that affect water quality other than income.

Because of endogeneity, the predicted value of national income was used as an instrumental variable in the model to facilitate the simulation and comparison. We assume that higher order coefficients are insignificant, gives a quadratic equation that exhibits an inverted U-shape with respect to income.

$$E_i = \beta_0 + \beta_1 Y_i + \beta_2 Y_i^2 + \sum \beta_k Xi + u_i \qquad (4)$$

The steepness of the curve indicates level of environmental quality degradation with increased income. A turning point is derived from the first order condition as:

$$\partial E_i/\partial Y = \partial E(\beta_0 + \beta_1 Y_i + \beta_2 Y_i^2 + \sum \beta_k Xi) = 0 \qquad (5)$$

$$\text{or} \qquad Y^* = -\frac{\beta_1}{2\beta_2} \qquad (6)$$

This turning point shows the level of national income of a country at which the environmental quality degradation is at its maximum. Further increase in national income will make the citizens willing and able to pay for a cleaner environment and the environment quality improves from this level.

Simulation

Transfer of technology through grants and direct investments from developed to developing countries are augmented in the models to see the effects of foreign direct investment or grants from developed to developing countries. A recursive use of results from growth model into the environmental model gave the net changes in the water quality as represented by the fertilizer use per unit volume of freshwater.

RESULTS AND DISCUSSION

The growth model shows a high R^2 but suffers from heteroskedasticity problem (white $X^2=104.1$, $p<0.0001$). The estimators were divided by the consistent covariance standard errors to derive the adjusted t-ratios. The results are given in table 1.

The results in table 1 indicate that capital is significantly increasing the national income per capita where as labor has negative effect. Aid is negative and significant at slightly higher level. Aid is targeted to help increase the income in poor country, and the fact that it is always attracted to low income countries, it has negative but insignificant sign. Income level significantly increased with higher foreign direct investment. A favorable condition in emerging countries might attract more foreign investment and thereby further increase their income. Energy inefficiency, agricultural productivity and land use intensity have signs as expected but insignificant.

Table 1 Results of first stage growth model

Variables	Coefficients
Intercept	-4791.15
	(2938.229)
Capital (log)	1131.701**
	(147.786)
Labor (log)	-1158.78**
	(241.843)
Energy efficiency (BTU per dollar)	-17.1261
	(15.982)
Aid (per capita)	-7.821*
	(4.330)
Foreign Direct Investment (per capita)	3.2753**
	(1.632)
Agricultural productivity (dollar per acre)	18.367
	(15.887)
Land use intensity (Arable land per capita)	-1.866
	(5.535)
Donor dummy (1=Net donor, 0=Otherwise)	15717.52**
	(2165.378)
$R2 = 0.918$	
N = 123	

** significant at 10% level*

*** significant at 5% level*

The following results are obtained for homoskedastic environmental quality model by using the predicted values of national income per capita from the first stage model as independent variables. Aid, foreign direct investment and per capita crop land have been augmented in the model. Significant coefficients with expected signs of GDP (+ve) and its square term (-ve) suggested Kuznets phenomenon of income-environment quality relationship.

Table 2 Results of second stage environmental quality model

Variable	Coefficient
Intercept	3.213367 (3.084)
Aid (per capita)	-0.02959 (0.0475)
Foreign Direct Investment (per capita)	0.000503 (0.00631)
GDP (per capita)	0.001929 (0.000833)**
GDP^2 (per capita)	-6.21E-8* (3.545E-8)
Crop land (per capita)	-2.33316 (10.5446)
R2 = 0.08 N = 121	

* *significant at 10% level*

** *significant at 5% level*

First order condition for the environment quality model gives the optimum value for environment quality reversal at 15,531 (current US$). This value is nearly five times higher than the average income of the countries.

An average of 1.34% growth might exhaust all the environmental quality if we wait for the income level to reach the turning point before we start cleaning the environment in the low income countries. A simulation is done to see if any transfer of technology from high income countries to low income countries can improve the environmental quality and reduce the pick of the curve. Changes in policy and technological progress in pollution abatement possibly reduce pollution raising incomes (Anderson and Cavendish). Simulation with different levels of aid and direct investment as well as growth without foreign intervention show different interesting results. In the absence of any other multiplier effects and no technology transfer associated with investment, a 21 dollars (10%) increase in foreign direct investment in next 10 years increases the national income per capita by equal amount. In the same time, it will further decrease the environment quality by 0.7% of current level. A similar investment with energy efficient technology has different scenario. A 20% (42 dollars) increase in foreign direct investment coupled with 20% gain in energy efficiency (decrease 2BTU per dollar from 9.1BTU) increases the income per capita by 76 dollars and decreases the environmental bad by 2.8% of current level. A best possible scenario of results from such intervention is given in figure 1.

CONCLUSION

Low income countries can clean their environment while increasing their income if they are provided with the efficient technology. An early policy intervention in developing countries might prevent further deterioration of the environment. The model suggests an increase in environmental bad with increasing income until the point, however, with quick technology transfer the goal can be achieved earlier and thus saving the environment.

Need is felt for using more direct measure of water quality indicators as they become available. Further analysis using different slopes and intercept for different income groups is planned. Incorporating level of current environmental sustainability efforts by countries is planned for further analysis.

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Figure 1 An example of effects of early technology transfer to low income country