Whether Irrigation has started to become a Nuisance Commodity: Relationship between Irrigation and Income Growth using Cross-country Analysis[1]

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Abstract

The relationship between irrigation development and societal income across 65 tropical countries from Asia, Africa and Latin America for the period of 1972 to 1991 is examined. Macro economic policy and structural factors, like technical change in agricultural sector, change in cereals yield, structural change in the economy, agricultural share in GDP, value added in agriculture; and Institutional characteristics (governance) of each country are also hypothesized to affect on irrigation development at any moment. These factors also shape the relationship between irrigation and societal income level. Results show strong evidence of an environmental Kuznets Curve (EKC) relationship between income and irrigation development trends in a global model combining all the tropical countries, and also for a Asia regional model. That means pace of irrigation development is at faster rate at the initial stage of development, however once the economy get transformed to industrial and service sector, there will be less need for expansion of irrigation than at the earlier stage of development. The global and regional (Asia) analyses are separately conducted to isolate some of the country or regional specific factors influencing irrigation decision at any moment. The results suggest that macroeconomic policy and institutional factors are equally important for explaining the irrigation development.

1. Introduction

This paper examines a relationship between irrigation development and societal income level (PPP adjusted per capita GDP) using the framework of Environmental Kuznets Curve (EKC) analysis. Then, the paper tests a hypothesis whether the irrigation is recently becoming a nuisance commodity. The EKC hypothesis assumes that environmental quality will deteriorate during the early stage of economic development, but once the societal income reaches to certain critical level then the rate of destruction of

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environmental quality ceases, rather the trend will reverse and the environmental will start to improve. This sort of inverted-U- shaped functional relationship between environmental quality and income is called Environmental Kuznets Curve hypothesis. This phenomenon has already been observed in some of the other environmental quality indicators, like air pollution (SO2, CO2), deforestation, river water quality, and so on.

It is hypothesized that the irrigation development behaves like a normal good at the initial stage of development, where agrarian sector dominates over others, and irrigation largely contributes for expansion of the crop production and development of the nation (details in figure 1). Once the economy starts to develop, then industrial and service sectors start to play a dominant role in the economy so the public policy formulation process. That means lesser need for irrigation expansion in the society due to shrinking agricultural sector role in national economy. Some of empirical studies conducted so far on topic of income-environment relationship- provide support on such relationship for air quality, water quality, river quality and deforestation. Details of results on EKC for other environmental resources are found in Pinayouto (1997), Grossman and Kruger (1995), Bhattarai and Hammig (2001), and Bhattarai (2000). However, there is no study so far available that analyzes whether there is any possibility on existence of EKC type of relationship for irrigation. Based on the basic concept of EKC hypothesis and the changing structural relationship in an economy, such EKC type of inverted –U- shaped relationship, at least in principle, should also exhibit between societal decision for irrigation development and its income level. As income grows, the societal structure changes and so on the underlying societal value systems for the resources use decisions, and the investment decision in irrigation and agricultural sector in general. Details on such changes in demand for irrigated land is found in Ruttan (1965).

When an economy grows then there is a transformation of economy from agriculture dominant at early stage to industrial based society, and finally to service based society, as illustrated by the real world example of USA, Japan, UK, Germany, etc. Today, more than 40 percent of the annual GDP income of USA is coming from service sector, which was not the case just few decades ago. Such change in the structure of economy has large implications for the societal resources use decision, including irrigation investment.

The major implications from EKC studies for global environmental policy (irrigation or water sector policy) are to identify potential policy programs in developing countries that move the economy to a sustainable path. That is, adopting a development path of the economy with minimum level of the environmental damage by tunneling the economy through the potential EKC path by managing the economy within the ecological threshold limits. Details of this process are explained in figure 1. Hence, the results from this study will directly contribute on the global policy debate like, how much irrigation do we really need? In addition, the study findings here also suggest us policy implications and options for intersectoral allocation of water resources, and when its need will arise in an economy.

Objectives

The main purpose of this study is to conceptualize the irrigation development process and empirically investigate the relationship between irrigation decision and societal income level, along with the other selected policy implications and macro-economic factors. The specific objectives of this study are: 1). To properly quantify the relationship between irrigation development and per capita GDP level across the tropical countries 2). To conduct an empirical verification of EKC hypothesis, whether there exists an economy wide environmental Kuznets curve sort of relationship for irrigation development. And, 3) to properly model and quantify the impacts of macroeconomic and policy factors on irrigation development.

2. Conceptual framework, Methodology, and Data

In this study, percentage of cropped area irrigated is considered as depended variable, and also the proxy for societal decision for irrigation at any moment. The irrigation income relationship is modeled in EKC hypothesis (details of methodology in Bhattarai and Hammig, 2001), including other selected policy and structural variables, like electricity use, inflation rate, economic growth rate, agricultural share in the economy, rural population factors, and quality of underlying institutional factors (Governance). The basic concept is shown in figure 1. First a basic empirical relationship between irrigation and income level is modeled at global level combining all the 65 tropical countries from all three continents of Asia, Africa and Latin America (Appendix table 1). The basic EKC model consist of income, income squared and time factor as explanatory variables. In the second stage, each of the selected macro economic policy, technical and other structural factors are added in the basic EKC model sequentially. The net impact of each of the policy variables on irrigation development on EKC framework is separately estimated as reported in table 1 and in appendix table 2. The decision for irrigation development over time and the EKC relationship for irrigation at any moment are assumed to be affected by these selected policy variables. Isolating the influence of each of these factors holding influence of income constant will in turn provide better parameter estimates for all variables, including the income effects.

The pace of technology changes in agriculture would pick up when there is certain level of development in agriculture sector, and availability of sufficient rural demand in the economy to absorb the excess capacity of the industries to capture the gain from the scale economy provided by industrial sector. The technological change in the economy will affect the EKC relationship and the societal demand for irrigation at any moment. Once there is sufficient rural capital accumulation and technical changes in the economy, then there may not need to go for the extensification (horizontal expansion on crop production) in agriculture sector. Rather, such structural changes in the economy will demand for the intensification of agriculture, i.e., vertical expansion, and better management of water and land resources and improved management and efficient allocation of other resources in the economy. This process may also be influenced by the changes in employment structure in the economy. In the early stage of economic development, extensification of the agriculture practices dominate the resources use decisions. Once the economy grows to certain critical level then due to increased labor demand from industry sector the intensification of agricultural practices would dominate the resources use decision, as depicted in figure 1.

The relationship between irrigation and income along with other explanatory variables across 65 countries from Asia Africa and Latin America for the period of 1972 to 1991, for which most reliable cross countries macro statistics are available, is modeled following standard panel-data analysis method. More specifically, Fixed- effect weighted Generalized Least Square (GLS) technique with iteration was adopted to model the relationship between income and irrigation, the results from such iteration are in principle equivalent to the results from Maximum likelihood estimation (MLE). A panel regression analysis (time series and cross-countries analysis) is done each for global level-combining three continents, and one model separately for Asia, to better isolate the regional impacts on variation of irrigation at any moment. More than 70 % of the world's irrigated area is in Asia, therefore, the results from the Asia regional model also carry a greater importance in establishing EKC relationship for irrigation. The empirical model of EKC for irrigation is estimated as shown in equation 1 below.

$$\% \text{ C}\textit{roped Irrigated} \text{ Area }_{it} = \alpha_i + \beta_1 Y_{it} + \beta_2 Y^2 + \beta_3 T_{it} + \beta_4 Z_{it} \qquad (1)$$

Where;

i $\Rightarrow$ 1 …. ……n for number of countries in the sample

t $\Rightarrow$ 1………… t for time period, 1 for 1972 and 20 for 1991

% Cropped Irrigated Area $_{it}$ = Percentage of cropped area irrigated of county i^{th} at t^{th} period

T_{it} = Time trend 1 to 20 to capture the any time trend, or the effect of missing exogenous time dependent variables.

α_i = intercept vary across the countries to capture the fixed effect and country specific historical institutions and structural factor.

β_i = are the coefficients to be estimated from the panel regression model

Y_{it} = GDP per capita (PPP adjusted constant dollars value)

Z_{it} = Other macro policy and institutional variables having impact on irrigation. One policy variable (z_i) was added at a time in the equation above.

The data sets of irrigation development (percentage of cropped area) across the countries and other macro policy related variables, like, per capita GDP (PPP adjusted income), income growth are taken from the publications of The World Bank's World Development Indicator (2001). Cereal yield variable is taken from FAO statistics.

3. Results

This study is the first attempt for testing the Kuznetian type of relationship (EKC relationship) for irrigation development. Declining irrigated area in the Western Europe and in North American countries, and similar trend recently seen in the developed Asian economy like, Japan, Korea, Taiwan and China, strongly suggest for possibility of existence of such inverted-U-shaped relation between irrigation and societal income level. The recent trend of changes in cereals yield in India and China clearly shows this sort of reverse in trend of irrigated area and resources use decision in agriculture (FAO statistics). Despite reduction on the total irrigated land, the agriculture productivity in China has dramatically increased in the recent past mainly due to change in other sectors of the economy, and the timely changes on institutional and policy factors. Whereas, in spite of massive level of expansion of irrigation in India over the last few decades, there is a much less improvement on the aggregate agricultural productivity (cereal yield) in India over the same period (FAO data source).

The summary of results from estimation of EKC model for irrigation is illustrated in table 1. First for the basic EKC model, and coefficient of each variables reported afterward. The positive GDP per capita (GDP per capita in PPP adjusted constant US dollars) and the negative of its squared term in all regression equations strongly suggest for presence of EKC type of relationship for basic model, as well as each of the EKC extension model with policy variables. The time trend is positive in all cases, that means the percentage of cropped irrigated area is in increasing trend both in global model and in Asia model. This is consistent with the fact that all the countries selected are from the tropical region.

The GDP growth rate is negative in global model, which conceptually supports the EKC hypothesis that higher the economic growth less require on expansion of irrigated cropped area, however, this relationship is not so straightforward in Asia. The electricity per capita is positive both in global as well as well in Asia model, which indicates that access to electricity positively contributes for expansion of irrigated-cropped area. This is plausible considering the increasing importance of Groundwater irrigation in the recent past and energy cost component of Ground water irrigation. The sign of inflation variable in global model is negative which means irrigation investment is higher at lower inflationary society. This is logical considering the long gestation period required for realizing the benefits of irrigation investment. However, this is not significant at 10 % level n Asia, may be due to lower level of inflation pressure in Asia in the recent past compared to other countries, particularly Latin American countries.

The cereal yield -proxy for the technological change- is positive in global model, this suggests that the rate of growth of percentage of cropped area and improvement in cereal yield go hand in hand in the earlier stage of the development (irrigation development). This is plausible, since countries from all the three continents in a global model, irrigation development is mostly at rising trend. Whereas, the variable sign is negative in Asia model, which may be due to already a larger scale irrigation development occurred in Asia, and rate of expansion of irrigated land is at decreasing trend in Asia. This explanation is further supported when the variable "Ag. Value Added %" (in % of total GDP) is included in the model, its sign is also reveres in Asia from the global model.

The sign of manufacturing value added growth rate is negative in global model, which further provides an evidence for the EKC hypothesis in irrigation, societal decision for irrigation is influenced by structural changes in an economy. However, the result is not significant, at acceptable limit, in Asia. Rural population density is negative in global combined model, which says that rural population factor is not the pulling factor for irrigation development globally. But, its sign is opposite in that means the demands for cropped land increases in Asia is influenced by the rural population pressure, so the need for irrigation needs and intensification of agriculture. The rural population pressures is much high in Asia than in Africa and Latin America, so this is a plausible results.

We have also included Governance factor (sum of political freedom and civil liberties) in the model, and it’s positive and statistically highly in both models. That means the irrigation development is positively supported by the improvement in the underlying governing institutions. To further isolate the income and institutions impact on irrigation, a separate interaction term of income and institutions (Governance * GDP PC) is also included in the EKC model, which is positive and significant in both models. That means the income effects on irrigation in fact also depends upon the local institutional development process. In other word, higher the income level, the greater the impacts of institutions on irrigation development.

4 Conclusion

This study is first attempt on empirically testing the “Environmental Kuznets Curve” hypothesis for irrigation issue. From global and regional level analyses, this study illustrates how societal decision for irrigation development at any moment is influenced by the changing societal income and value system over the use of resources, and other structural changes in the economy. Very scanty literature so far available that analyze factors explaining the societal irrigation decision at any moment, except few country level case studies, which largely depends upon the country level specific factors. We cannot generalize a broad level concept and global policy implication from such one or two country level case studies or at the irrigation system level studies, usually seen in the irrigation literature. For which, the cross-country analysis with pulling large sets of diverse countries is the preferred answer, and the recent data compilation by the World bank and FAO on cross-country setting facilitate for such comprehensive study as proposed in this study.

The results described in the earlier section clearly demonstrate the presence of EKC type of relation in irrigation sector, as observed for other environmental resources in the recent past. That means, there is a greater need for irrigation development at the initial development of an economy, however its intensity for the irrigation development will decline as societal income reaches certain critical level. Different macroeconomic policy, economic structure, technological development, and underlying institutions (Governance), as illustrated in the paper, affect the relationship between irrigation and income. The findings of this study contribute for improved understanding on global modeling on irrigation requirement, with economic and policy variables and other structural factors. The issues discussed here are also equally useful on some of the recent global debates on irrigation and water policy (how much irrigation we need), and on the role of the irrigated agriculture to the societal development process.

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Table 1. Kuznets relationship for the changes in percentage of irrigated cropped area, combined tropical countries (model 1) and in Asia (model 2), 1971-91.

Independent Variable	All countries (Model 1)	Asia (Model 2)
GDP PC	Positive (***)	Positive (***)
GDP PC Squared	Negative (***)	Negative (***)
Time Trend	Positive (***)	Positive (***)
----------------------One variable is added at one time to the above basic EKC model-------------		
GDP Growth Rate	Negative (**)	Positive (N S.)
Electricity (-1)	Positive (***)	Positive (***)
Inflation rate %	Negative (**)	Negative (N.S.)
Cereal Yield (Kg/ha)	Positive (***)	Negative (***)
Ag. Value Added %	Positive (***)	Negative (***)
Manuf. Value added Gw. Rate	Negative (*)	Positive (N.S.)
Rural Pop. Density	Negative (***)	Positive (***)
Governance	Positive (**)	Positive (***)
Governance*GDP PC	Positive (**)	Positive (***)

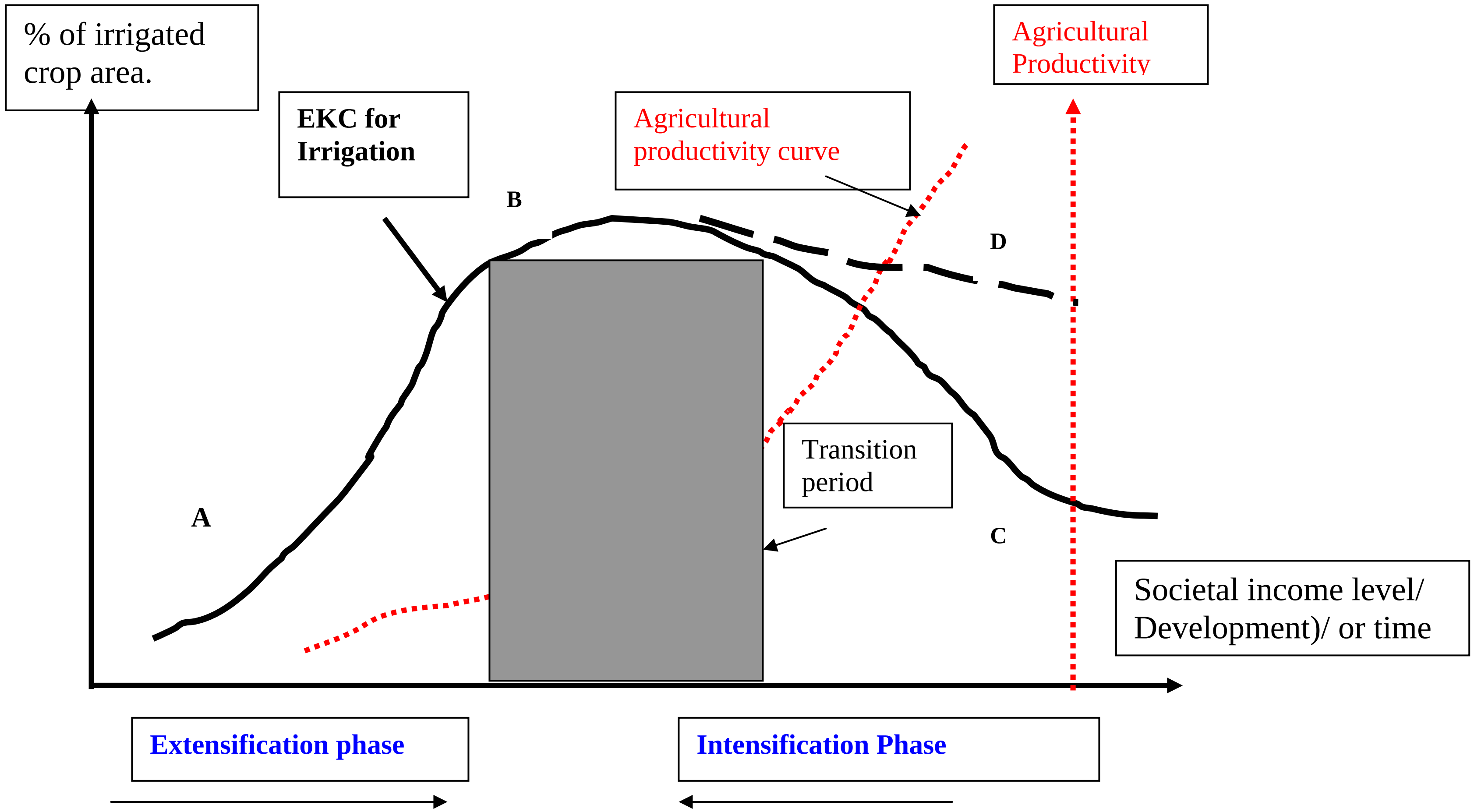
Note: 1). Values in parentheses are absolute t-statistics; * = significant at 10%, ** = significant at 5%, *** = significant at 1%. N.S. Not significant at 10%. F statistics of above all the models are significant at 1%, 2). All models were estimated as fixed effects panel regressions using GLS, with lag one year for all explanatory variables.
3). The basic EKC model is significant in all cases, so only significance of other variables is reported here. To avoid multicoliearity, one variable is added sequentially in the basic EKC model as shown in ap. table 1.
4). Variables Definition: i) GDP PC= GDP per capita in PPP adjusted constant US $ value ii). Governance is sum of political liberty and Civil liberty variables in that year, adapted from Gastil Index (1998). iii). Governance*GDP PC measures the effects of interaction between GDP and governing institutions on irrigation development. iv). Manuf. Value added Gw. Rate= Manufacturing Value added Growth Rate in %. v). Ag. Value Added % = Agricultural Value added % of GDP. Other variables are self-explanatory.

Appendix Table 1. Countries Selected for the Regression Analysis and their Real income in 1990 (GDP per capita with adjusted from PPP income).

Latin AMERICA	1990 Income	**AFRICA**	1990 Income	**ASIA**	1990 Income
Argentina	4,706	Angola	678	Bangladesh	1,390
Bolivia	1,658	Benin	920	Bhutan	882
Brazil	4,042	Botswana	2,285	China	1,324
Chile	4,338	Burkina Faso	511	India	1,264
Colombia	3,300	Cameron	1,226	Indonesia	1,974
Costa Rica	3,599	Central Af. Rep.	579	Korea, Rep.	6,673
Dominican Rep	2,166	Chad	399	Malaysia	5,124
Ecuador	2,755	Congo, Dem. R.	384	Myanmar	611
El Salvador	1,824	Congo, Rep.	2,211	Nepal	1,036
Guatemala	2,127	C"te d'Ivoire	1,213	Pakistan	1,394
Honduras	1,377	Ethiopia	324	Philippines	1,763
Jamaica	2,545	Gabon	3,958	Sri Lanka	2,096
Mexico	5,827	Gambia	790	Thailand	3,580
Nicaragua	1,294	The Ghana	902		
Panama	2,888	Guinea	767		
Paraguay	2,128	Kenya	911		
Peru	2,188	Liberia	853		
Tranidad & Tob.	7,764	Madagascar	675		
Uruguay	4,602	Malawi	519		
Venezuela	6,055	Mali	531		
		Mauritania	791		
		Mozambique	760		
		Niger	484		
		Nigeria	995		
		Rwanda	7,56		
		Sierra Leone	901		
		Somalia	775		
		Sudan	757		
		Tanzania	550		
		Togo	641		
		Uganda	554		
		Zambia	689		
		Zimbabwe	1,182		
Avg. income	**3,360**		**925**		**2,240**

Note. 1990 income is real GDP per capita (PPP adjusted 1985 constant US $).
Source. Summers and Heston. 1991, and updated by World Bank Growth Researchers Team available at their web sites http://www.worldbank.org/research/growth/index.htm

Figure 1. Policy Implications from Environmental Kuznets Curve (EKC) for Irrigation and Agriculture Development Process.



APPENDIX TABLE 1. FACTORS AFFECTING ANNUAL AVERAGE PERCENT OF THE IRRIGATED CROPPED AREA IN ALL TROPICAL COUNTRIES, ASIA AFRICA AND LATIN AMERICA COMBINED MODEL, 1972-91.

Independent Variables/ Equation Number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GDP	0.05	0.04	0.09	0.075	0.06	0.033	0.06	0.09
	(3.45)**	(1.9)*	(5.4)***	(4.6)**	(3.03)***	(2.3)***	(4.4)***	(4.77)***
GDP Squared	-0.009	-0.003	-0.012	-0.01	-0.0086	-0.008	-0.02	-0.007
	(-2.44)**	(1.01)	(3.33)***	(2.6)***	(2.31)**	(2.2)***	(1.7)*	(1.65)*
Time	0.004	0.008	0.009	0.01	0.007	0.002	0.009	0.008
	(13.22)**	(20.3)***	(24.0)***	(26.4)***	(18.3)***	(7.7)***	(25.9)***	(18.9)***
Electricity (-1)		0.0004						
		(7.5)***						
Inflation rate (-1)			-0.00005					
			(2.3)**					
GDP growth rate (-1)				-0.0006				
				(2.09)**				
Ag Value Added (-1)					0.0008			
					(2.17)**			
Cereal Yield (-1)						0.00005		
						(4.8)***		
Ag. Value added Gw (-1)							-0.0002	
							(0.8)	
Manuf. Value add Gw (-1)								-0.0003
								(1.65)
Adjusted R^2 (unweighted)	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Number of observations	1210	892	1123	1130	1128	1210	1079	969
Number of countries	64	47	63	63	64	64	62	59

F statistics are significant at 1% level for all regression models. Values in parentheses are absolute t- statistics, * = significant at 10%, ** = significant at 5%, *** = significant at 1%.