ASSESSING IMPACT OF ECONOMIC DEVELOPMENT ON WATER POLLUTION IN THAILAND USING DYNAMIC SPATIAL ECONOMETRICS ANALYSIS

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Abstract: Although most developed nations have discovered various solutions to their conventional pollution problems, many developing countries still suffer from environmental degradations. Thailand is a prime example of these countries. Its environmental problems have increased in severity, becoming more complicated to solve despite current global awareness regarding environmental issues. These problems provide the context in which "sustainable development" has been introduced as a key paradigm in creating a balance between economic development and environment. The aim of current paper is to empirically examine the sustainability in Thailand in terms of EKC relationship between economic activities and water pollution, and discuss the implications of our findings on policy implementations. The conventional EKC relationship between water pollution and income is statistically insignificance for the case of Thailand's water pollution data. However, water pollution tends to be inverted-U related with other output level of economic activities such as manufacturing and agricultural products. The study also found that previous investment in education and environment statistically decreases water pollution at the present time.

Keywords: "Dynamic Spatial Econometrics Analysis", "Economic Development", "Environmental Kuznets Hypothesis", "Sustainability", "Water Pollution",

Introduction

There have been several studies of relationship between economic development and environmental degradation for decades. Most of them focused on relationship between income and pollution called environmental Kuznets curve (EKC) hypothesis. EKC hypothesis implies an inverted U-shape relationship between income per capita and pollution concentration. As low income country industrializes, it will increase its production and consumption by using its natural resources and release some pollution. Beyond an income threshold, as income per capita of the country grows higher, it can purchase more environment-friendly technology and change its way of natural-resource use.

Few of empirical studies have shown the conventional inverted U-shape relationship of EKC. In contrast, most of them found that the conventional EKC relationship was not applicable, and there were other economic and social factors affecting the environmental degradation.

Studies on EKC relationship are usually conducted by aggregating cross-sectional or panel data of developed countries. Few of them study on EKC relationship of developing countries due to the lack of data. This has motivated this study to conduct empirical study on EKC hypothesis using data of developing country like Thailand.

Objective

The aim of the current paper is to: 1) empirically examine the sustainability in Thailand in terms of EKC relationship between economic activities and water pollution; 2) clarify the mechanism of how the economic growth of Thailand affect its environment; 3) and finally discuss the implications of our findings on regional policy implementations.

Method

The current study applies dynamic panel generalized method of moment (GMM) technique discussed by Lee et al. (2010) in order to incorporate the irreversible feature of water pollution in Thailand. In addition, since the pollution level of each water source is expected to be spatially related due to the nature of water stream, spatial econometrics technique adopted by Paudel et al. (2005) is also introduced to incorporate such geographical features.

The conventional EKC model of water pollution can be shown by Eq. (1)

$$TCB_{i,t} = \alpha + \beta_1 GPP_{i,t} + \beta_2 GPP_{i,t}^2 + \varepsilon_{i,t} \qquad (1)$$

where TCB is total Coliform bacteria (TCB) concentration in major water sources i, and GPP is total gross provincial product (GPP) aggregated from provinces in each water basin i.

There is an inverted U-shape EKC relationship if the sign of β_1 is positive and β_2 is negative.

Most empirical studies hardly captured the conventional EKC relationship. Hence, other economic and social factors were often included into their econometric models. Table (1) shows some empirical literatures which incorporated social and economic factors into the conventional EKC model.

Table 1: Social and Economic Factors Incorporrated into the Conventional EKC Model

Literature	Variable
Grossman and Krueger (1991)	Institutional Structure, Trade Liberalization Index
Panayotou (1993)	Population Density, Deforestation Rate
Cropper and Griffiths (1994)	Population Density, Lumber Price Index, Country Specific Dummy
Selden and Song (1995)	Population Density, Transportation
Dasgupta, Hamilton, and collegues (2000)	Population, Policy Index,Governance Transparency Rate

Accordingly, in order to examine the effect of economic and social factors on water pollution in Thailand, the current study applies the above studies and incorporates manufacturing product, agricultural product, educational level as well as population into econometric model of Thailand's water pollution. The model is shown by Eq. (2)

$$TCB_{i,t} = \alpha + \beta_1 GDP_{i,t} + \beta_2 GDP_{i,t}^2 + \boldsymbol{\delta}\mathbf{X} + \varepsilon_{i,t} \qquad (2)$$

where $\mathbf{x}$ is a matrix vector of other economic and social factors.

Since this study expects that water pollution tends to be auto-correlated over time due to the irreversibility feature of water pollution, dynamic GMM model is applied as shown by Eq. (3)

$$TCB_{i,t} = \alpha TCB_{i,t-1} + \beta_1 GDP_{i,t} + \beta_2 GDP_{i,t}^2 + \boldsymbol{\delta}\mathbf{X} + \eta_i + \phi_t + \varepsilon_{i,t} \qquad (3)$$

where η_i is region-specific error, and ϕ_t is time-specific error

Since TCB concentration of each water basin is expected to be spatially related due to the nature of water stream, the study applies spatial econometrics analysis to incorporate such geographical features. In general, the effects of adjacent parishes or "spillover effects" are estimated by multiplying an explanatory variable of neighborhood areas with a spatial weight. Spatial weight refers to a weight value indicating dependency between two areas. The concept is that nearer areas affect a particular area more than farther areas. There are three approaches to measure spatial weight: nearest neighbor, maximum distance, and inverse distance approaches. The current study uses the technique discussed by Dubin (1998) to tests validity of each spatial weight scheme, and finds that inverse distance approach is most applicable for the current model. Inverse distance weight w_{ij} between parish i and parish j is calculated by the inverse of distance d_{ij} between the two parishes shown by Eq. (4)

$$w_{ij} = \frac{1}{d_{ij}^{p}} \tag{4}$$

where p is a constant term indicating the degree of influential effect. Larger p means smaller influence. Most empirical studies generally set p value equal to 2. For panel data analysis, we can write a matrix of inverse distance weight matrix as $\mathbf{W}$.

There are various kinds of spatial econometric techniques. This study adopts spatial autoregressive model (SA) discussed by Maddison (2004). The model can be written as Eq. (5)

$$TCB_{i,t} = \alpha TCB_{i,t-1} + \beta_1 GDP_{i,t} + \beta_2 GDP_{i,t}^2 + \boldsymbol{\delta}\mathbf{X} + \varepsilon_{it} \tag{5}$$

$$\varepsilon_{it} = \lambda W_{it} + \mu_{it}$$

This study applies spatial autoregressive model shown in equation (5) to test the EKC hypothesis.

Data

The panel dataset used in this study spans from the period 1991 to 2008. The data accounts for 7 major rivers running through the northern part of Thailand: Ping, Wang, Yom, Nan, Sagraegrung, Pasak, and Chao Phraya rivers. The study divided the data into 6 major water basins according to geographical features. Figure 1 shows the map of objective river basins: Northern water basin, Sagraegrung basin, Pasak basin, Upper Chao Phraya basin, Central Chao Phraya basin, and Lower Chao Phraya basin. TCB data are provided by Thailand's Pollution Control Department while economic and social data are derived from National Economic and Social Development Board of Thailand. For distance data, a distance between water basin i and j is estimated by the distance from the central point of water basin i to the central point of j. The central point of each basin is calculated by the average length of the rivers in the basin.

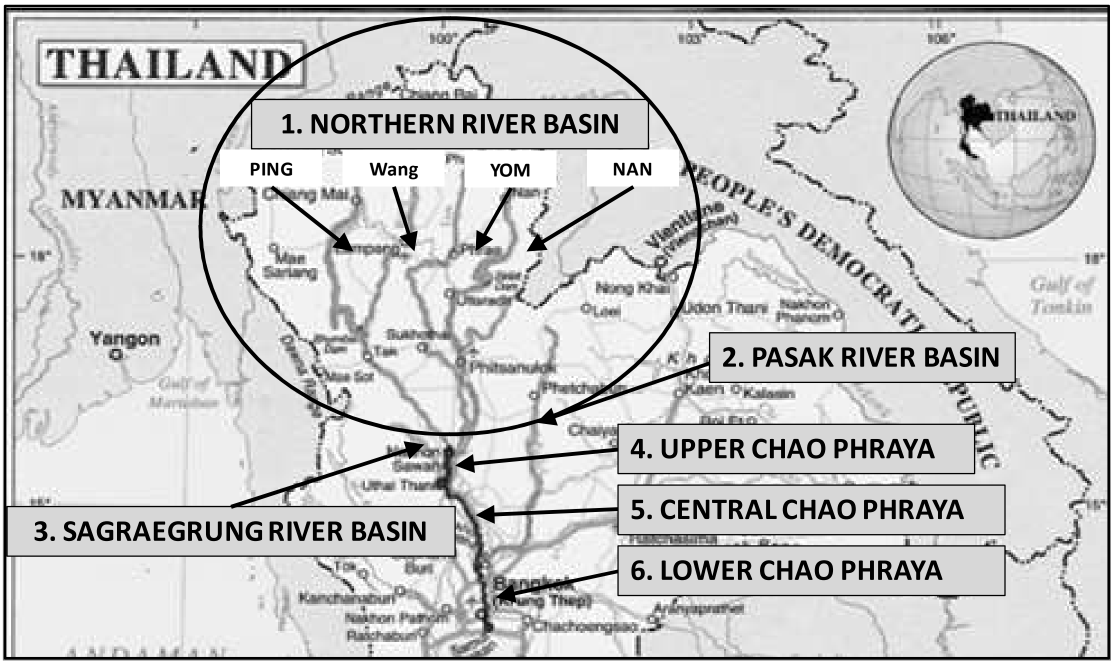

Figure 1: The Map of Objective River Basins

Map Source: United Nations World Map

Table 2: Descriptive Statistics for 1991 to 2008 of 6 river basins

	TCB (MPN/100 ml)	GPP (million Baht)	POPULATION (thousand persons)	MANUFACTURING PRODUCT (thousand Baht)	AGRICULTURAL PRODUCT (thousand Baht)	EDUCATIONAL BUDGET PER STUDENT (baht per person)
Mean	56863.26	324738.8	4167.212	121911.1	14762.43	15413
Maximum	827366.7	1516065	9185.14	514701.7	40871.8	44327
Minimum	1266.667	16387.1	679	1334.7	3654.8	7876
Std. Dev.	125145.4	437080.5	3334.917	152541.2	11734.13	8269
Skewness	4.253889	1.721856	0.522306	1.262932	1.085879	1.939648
Kurtosis	24.18717	4.346512	1.441255	3.189199	2.857068	5.701235
Jarque-Bera	1433.515	37.59869	9.682478	17.64341	13.02666	61.45043
Probability	0	0	0.007897	0.000147	0.001484	0

* , **, *** represent the significant level at 10%, 5% and 1% respectively

Table 3: Estimation Result of Total Coliform Bacteria

Method: One-step Arellano-Bond Dynamic Panel-data Estimation

Regressor	Coefficient	Prob.
$\log(TCB)_{t-1}$	-0.011413	0.933
$\log(Envibudget)_{t-2}$	-1.075724	0.000
$\log(Edubudget)_{t-3}$	-7.892025	0.000
$Spatial\ Weight$	0.3620758	0.000
$\log(GPPcap)_{t-1}$	168.0451	0.146
$\log(GPPcap)_{t-1}^2$	-9.526542	0.288
$\log(MANU)_{t-1}$	265.2986	0.000
$\log(MANU)_{t-1}^2$	-34.41997	0.000
$\log(AGRI)_{t-1}$	277.7527	0.000
$\log(AGRI)_{t-1}^2$	-35.87488	0.000

Number of instruments	12
Wald chi2(4)	869.82
Prob > chi2	0.0000

* , **, *** represent the significant level at 10%, 5% and 1% respectively

Empirical Result

The study utilizes GMM techniques to estimate Eq. (5) for EKC relationship between TCB concentration and GPP of 6 major river basins in Thailand. The study also applies instrumental variables by using lagged value of dependent and independent variables suggested by Arrelano and Bond (1991) and Lee et al. (2010).

Table (2) shows descriptive statistics of dependent and independent variables implying that the data are normally distributed during the period.

The result of dynamic panel analysis is shown in Table (3). The dependent variable is log value of TCB concentration $\log(TCB)_t$. Explanatory variables are log lagged value of TCB contration $\log(TCB)_{t-1}$, log lagged value of governmental budget on environmental reservation $\log(Envibudget)_{t-3}$, log lagged value of governmental budget on elementary-level education $\log(Edubudget)_{t-3}$, inverse distance spatial weight, log lagged value of gross regional product at first and second order $\log(GPP)_{t-1}$, log lagged value of gross manufacturing product at first and second order $\log(MANU)_{t-1}$, and log lagged value of gross agricultural product at first and second order $\log(AGRI)_{t-1}$ respectively. Coefficients are shown in the second column while p-values are shown in parentheses of the third column. Instrumental variables are 12 lagged values of dependent and explanatory variables. The chi-square distribution indicates that null hypothesis of over identifying restrictions can be rejected and instrumental variables are valid.

It can be seen from the result that growth rate of gross regional product (GPP) does not statistically determine TCB concentration of the northern river basins of Thailand. However, growth in manufacturing product and agricultural product in previous year statistically affect the level of TCB concentration. One percent increase in manufacturing product and agricultural product results in 3.85 percent and 3.81 percent decrease in water concentration respectively. The turning points of manufacturing and agricultural product are 7.14 and 7.32 million Baht per region per year respectively. These low values of turning point implies that Thailand has not reached the real level of EKC turning point yet. Additionally, while one percent increase in environmental budget in previous two period reduces the concentration of water pollution by only one percent, one percent increase in educational budget in previous three period decreases water pollution concentration as much as seven percent. The statistical result also proves that water pollution of the upstream is slightly correlated with water pollution of the downstream.

Policy Implications

The study result indicates that the economic growth does not directly affect water pollution of the country, implying that economic growth policy can be promoted without affecting water pollution over time. However, a strong caution should be made in stimulating growth of the nation. Since manufacturing and agricultural activities tend to affect water pollution over time, it is urged that Thai government focus on imposing stricter regulations on manufacturing sector and agricultural sector especially on the upstream of the river basins in order to prevent water degradation. Additionally, since the result shows that educational policy plays a crucial role in improvement of water quality, Thailand should also focus on promoting education to raise social consciousness on environmental reservation in the long term. It also can be seen that governmental budget on environmental reservation also improves water pollution concentration. Therefore, it is urged that Thai government continually invest in environmental projects. The proposed policies might prevent environmental degradation as Thailand's economy continues to develop, and create sustainable development in the long term.

Conclusion

The contributions of the current paper can be divided into three points. First, since there are few studies on EKC hypothesis for samples of developing countries, the current study examines the EKC relationship of Thailand in order to make a progress on EKC hypothesis for data of developing countries. Second, the study utilizes dynamic GMM technique to verify the EKC hypothesis for data of water pollution in Thailand. The technique would capture time-correlated feature of water pollution and eliminate unobserved cross-sectional effect occurred in the normal panel analysis. Third, spatial econometric technique is also utilized in this paper to incorporate the effect of river upstream on downstream.

The paper indicates that the inverted-U shape relationship between TCB concentration and GPP is not statistically discernible for the case of Thailand's water pollution. In contrast, the water quality is directly correlated with manufacturing and agricultural activities especially in the upper stream. Most importantly, educational promotion and environmental reservation play an important role in water quality improvement. Therefore, it is urged that Thai government impose regulations on manufacturing and agricultural sectors, and promote higher education as well as environmental reservation in the long term.

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