New Vision on the Relationship between Income and Water Withdrawal in Industry Sector

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ABSTRACT

This paper investigates the relationship between industrial water withdrawal (IWW) and income in selected world countries. The issue is addressed by means of a smooth transition regression (STR) model on cross section data of 132 countries in 2006. The results confirm the nonlinearity of the link between IWW and income. According to the results, the income elasticity of IWW is a bell-shaped curve. Therefore, the policies and management processes in water sector including water allocation between activities and reigns should take into account the development degree and also focus on income level, water scarcity and the economic, social and ecological structure in each country.

Keywords: Water-Income, STR, NRBEKC, Elasticity, Socio-Economic Structure

1. Introduction

Freshwater resources are vital for maintaining human life, health, agricultural production, economic activities as well as critical ecosystem functions. As populations and economies grow, new constraints on freshwater resources are appearing, raising problems for limits of water availability. Accordingly, the analysis of the national water withdrawal intensity measurement becomes an important policy issue. To serve these purposes, some water withdrawal efficiency indicators have been developed and applied to explain differences in performance between countries and international benchmarking [1]. It should be noted that the income elasticity of IWW is one solution used in this paper.

In recent years, the relationship between income elasticity of natural resources use and income has attracted an increasing attention among academic, non-governmental organizations, and the media. A notable empirical finding of the recent environmental economics literature has been the existence of an inverted U-shaped relationship between per capita income and pollution (per capita emissions) of many local air pollutants [2]. Since this relationship bears a resemblance to the Kuznets relationship between income and income inequality, it is known as the Environmental Kuznets Curve (EKC) and has spawned a vast number of papers in recent years. In addition, attempts have been made to estimate EKCs for a wide range of environmental indicators, including energy use, deforestation and municipal waste [3-6,7].

The shape of the EKC, attributed to scale, composition and technique effects (SCTE) as discussed below, would also seem to apply to (income elasticity of) water consumption. The main reason to disregard water use in EKC studies would appear to be a lack of socioeconomic-hydrological data, although some recent investigations and dataset have now resolved somewhat this problem [8-12].

In this paper, we examine the relationship between IWW per capita and GDP per capita using Smooth Transition Regression (STR) model for 132 countries across the world based on cross section data in 2006. The following section will provide a brief review of the related literature. Section 3 introduces the econometric methodology and empirical results, and the final section presents the conclusions of the present study.

The majority of EKC literature examines pollution levels as a function of income. This has led to the criticism that such research ignores the natural resource component of environmental quality [2,13-16]. These studies tend to treat resource use identical to pollution as an indicator of environmental quality pointing to natural resources based on environmental Kuznets curve (NRBEKC). Like pollution, resource use can provide an economic benefit coupled with an undesired environmental impact. Thus,
many of the theoretical explanations for the existence of EKCs for natural resources mirror those for pollution.

The inverted U relationship between income and pollution is typically explained in terms of the interaction of scale, composition and technique effects (SCTEs). The scale effect (SE) implies that as the scale of the economy grows (ceteris paribus), IWW will do so. The composition effect (CE), however, refers to the fact that as economies develop, there is totally a change in emphasis from heavy industry to light manufactures and services sectors, and also from high water intensity to low water intensity in industrial, agriculture and domestic sectors. Since the latter are typically less resource intensive than the former, the composition effect of growth, ceteris paribus, will reduce water use. Finally, there is the technique effect (TE). As incomes rise there is likely to be an increased demand for environmental regulations [5]. The effect of these regulations must be considered to reduce water intensity due to improved techniques of production and consumption.

2. Methodology

2.1. Smooth Transition Regression (STR)

The smooth transition regression (STR) model is a nonlinear regression model that may be viewed as a further development of the switching regression model introduced by [17]. The STR model originated as a generalization of a particular switching regression model in the work of [17]. These authors considered two regression lines and devised a model in which the transition from one line to the other is smooth. The earliest references in the econometrics literature are [18] and [19]. Recent accounts include [20-25]. The standard STR model is defined as follows:

\[ y_t = \phi z_t + \theta z_t G(\gamma, c, s_t) + u_t = (\phi + \theta G(\gamma, c, s_t))z_t + u_t, \]

(1)

where \( z_t = \left(W_t, x_t'\right)' \) is a vector of explanatory variables \( w^t = (1, y_t - 1, \ldots, y_t - p)^t \) and \( x_t' = (x_{t1}, \ldots, x_{tn})' \) are a vector of exogenous variables. Furthermore, \( \phi = (\phi_0, \phi_1, \ldots, \phi_p) \) and \( \theta = (\theta_0, \theta_1, \ldots, \theta_n) \) are \((m+1)\times 1\) parameter vectors and \( u_t \sim \text{iid } (0, \sigma^2) \) are given. Transition function \( G(\gamma, c, s_t) \) is a bounded function of the continuous transition variable \( s_t \), continuous everywhere in the parameter space for any value of \( s_t \). \( \gamma \) is the slope parameter and \( c = (c_1, \ldots, c_K) \) which is a vector of location parameters, \( c_1 \leq c_2 \leq \cdots \leq c_K \). The last expression in equation (1) indicates that the model can be interpreted as a linear model with stochastic time-varying coefficients \( \phi + \theta G(\gamma, c, s_t) \). In this paper it is assumed that the transition function is a general logistic function:

\[ G(\gamma, c, s_t) = \frac{1 + \exp\{-\gamma \sum_{i=1}^{K}(s_t - c_i)\}}{1 + \exp\{-\gamma \sum_{i=1}^{K}(s_t - c_i)\}} \]

(2)

where \( \gamma > 0 \) is an identifying restriction. Equations (1) and (2) jointly define the logistic STR (LSTR) model. The most common choices for \( K \) are \( K = 1 \) and \( K = 2 \).

For \( K = 1 \), the parameters \( \phi + \theta G(\gamma, c, s_t) \) change monotonically as a function of \( s_t \) from \( \phi \) to \( \phi + \theta \). For \( K = 2 \), it change symmetrically around the midpoint \((c_1 + c_2)/2\), where this logistic function attains its minimum value. The minimum lies between zero and 1/2. It reaches zero when \( \gamma \to \infty \) and equals 1/2 when \( c_1 = c_2 \) and \( \gamma < \infty \). Slope parameter \( \gamma \) controls the slope and \( c_1 \) and \( c_2 \) the location of the transition function. Transition function (2) with \( K = 1 \) is also the one that proposed, whereas [18] favored the cumulative distribution function of a normal random variable. In fact, these two functions are close substitutes.

The LSTR model with \( K = 1 \) (LSTR1 model) is capable of characterizing asymmetric behavior. As an example, it is supposed that \( s_t \) measures the phase of the business cycle. Then the LSTR1 model can describe processes whose dynamic properties are different in expansions from what they are in recessions, and the transition from one extreme regime to the other is smooth. On the other hand, the LSTR2 model (\( K = 2 \)) is appropriate in situations in which the local dynamic behavior of the process is similar at both large and small values of \( s_t \) and different in the middle (For further work on parameterizing the transition in the STR framework, see [18]. When \( \gamma = 0 \), the transition function \( G(\gamma, c, s_t) \equiv 1/2 \), and thus the STR model (1) nests the linear model. At the other ends, when \( \gamma \to \infty \), the LSTR1 model approaches the switching regression model with two regimes that have equal variances. When \( \gamma \to \infty \) in the LSTR2 model, the result is another switching regression model with three regimes in which the outer regimes are identical and the mid regime is different from the other two. It is noteworthy that an alternative to the LSTR2 model exists, the so-called exponential STR (ESTR) model. It is Equation (1) with the follow transition function:

\[ G_{\gamma}(\gamma, c, s_t) = 1 - \exp\left\{-\gamma \left(s_t - c_1^*\right)^2\right\} \]

(3)

This function is symmetric around \( s_t = c_1^* \) and has at low and moderate values of slope parameter \( \gamma \), approximately the same shape, albeit a different minimum value (zero), as (2). Because this function contains one parameter less than the LSTR2 model, it can be regarded as a useful alternative to the corresponding logistic transition function. For more discussion [19].

2.2. The Modeling Cycle

In this section we consider modeling nonlinear relationships using STR model (1) with transition function (2). We present a modeling cycle consisting of three stages: specification, estimation, and evaluation. The specification stage entails two phases. First, the linear model forming
the starting point is subjected to linearity tests, and then the type of STR model (LSTR1 or LSTR2) is selected. Economic theory may give an idea of which variables should be included in the linear model but may not be particularly helpful in specifying the dynamic structure of the model. Linearity is tested against an STR model with a predetermined transition variable. If economic theory is not explicit about this variable, the test is repeated for each variable in the predetermined set of potential transition variables, which is usually a subset of the elements in \( z_t \).

Testing linearity against STAR or STR has been discussed, for example, in [20,21].

\[ y_t = \beta_{yx} + \sum_{j=1}^{3} \beta_j x_{jt} + u_{yt}, t = 1 \ldots T \quad (4) \]

where \( u_{yt} = u_t + R(\gamma, c, s_t) \theta z_t \) with the remainder \( R3(\gamma, c, s_t) \). The null hypothesis is \( H_0: \beta_1 = \beta_2 = \beta_3 = 0 \) because each \( \beta_j, j = 1, 2, 3 \), is of the form \( \gamma \beta \neq 0 \) is a function of \( \theta \) and \( c \). This is a linear hypothesis in a linear (in parameters) model. Because \( u_{yt} = u_t \) under the null hypothesis, the asymptotic distribution theory is not affected if an LM-type test is used.

3. Empirical Results

The basis of our empirical approach is exactly the same as that used by many authors in literature. The observations in this modeling experiment come from AQUASTAT FAO and WDI database of the [22]. The purpose of the study is to investigate the effect of GDP per capita on the annual water withdrawal (IWW). The IWW is assumed to be a nonlinear function of the GDP per capita. Figure 1 demonstrates a clearly nonlinear relationship between the logarithmic values of GDP per capita (x-axis) and the IWW (y-axis) as long as kernel fitting curve. The results of the linearity tests appearing in Table 1 p-values are remarkably small. Hypothesis \( H_0 \) is the general null hypothesis based on the third-order Taylor expansion of the transition function. Hypotheses \( H_{04} \), \( H_{03} \), and \( H_{02} \) are the ones discussed in the Section of methodology. Because the p-value of the test of \( H_{03} \) is much larger than the ones corresponding to testing \( H_{04} \) and \( H_{02} \), the choice of \( K = 1 \) in Equation (6) (the LSTR1 model) is quite clear. This is also obvious from Figure 1, for there appears to be a single transition from one regression line to the other. The next step is to estimate the LSTR1 model, which yields:

\[ L_y = -7.427 + 1.260LX - (58.49007 - 5.64000LX) \left[ \left( 1 + \exp \left( -2036.0894 / \sigma x \right) \right) \left( Lx - 9.7948 \right) \right]^{-1} \]

\[ \begin{align*}
  \sigma_y & = 1.946, n = 132, R^2 = 0.4055, p_{\text{RESET}}(1,129) = 0.1808 \\
  LY & = -5.990 + 1.070LX \\
  \text{(9.418)} & \quad (21.946, 132, 0.4055, (1,129) 0.1808) \\
\end{align*} \quad (5) \]

An STR model is fitted to the logarithmic data. The transition function is defined as a logistic function. Where \( \delta \) equals the residual standard deviation and \( p_{\text{RESET}} \) is the p-value of the RESET test. The test does indicate serious misspecification of (5). On the other hand, the residuals arranged according to \( Lx \) in ascending order and graphed in Figure 2 show that the linear model is not adequate. It can be seen in \( p_{\text{RESET}} \) large value in Equation (5).

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\[ \begin{align*}
  \hat{L}_y & = -5.928 + 1.260LX - (58.49007 - 5.64000LX) \left[ \left( 1 + \exp \left( -2036.0894 / \sigma x \right) \right) \left( Lx - 9.7948 \right) \right]^{-1} \\
  \text{(–5.928) (8.215) (–4.548) (4.464) (0.0002) (0.8008)} \\
  T & = 132, R^2 = 0.512, \sigma = 1.3916, \sigma x = 1.1582, \sigma / \sigma_L = 1.2015 \\
\end{align*} \quad (6) \]
where, $\sigma_{lx}$ is the sample standard deviation of $Lx$, $\sigma$ is the residual standard deviation of linear model and $\sigma_l$ is that of non-linear one. It should be noted that there are two large standard deviations, which suggests that the full model may be somewhat over parameterized. This is often the case when the STR model is based on the linear model without any restrictions. Model (6) is an example of such a situation. It may appear strange that the need to reduce the size of the model is obvious in this model already because it only has a single explanatory variable.

The first reaction of the model would perhaps be to tighten the specification by removing the nonlinear intercept, Restriction $\varphi = 0$ or $G(Lx, \gamma, c) = 0$. Another possibility would be to restrict the intercepts by imposing the exclusion restriction $\varphi_0 = \theta_0$. In fact, the first alternative yields a model with a slightly better fit than the latter one. The model estimated with this restriction is, see Equation (7):

\[
E_i = \frac{\partial Lx}{\partial Lx} = \alpha + \beta_0 Lx + \beta_1 Lx \gamma + \beta_2 Lx c + \beta_3 Lx \gamma c + \beta_4 Lx c^2 + \epsilon_i
\]

(10)

In this specification, a negative value of $\beta_1$ may also lead to the increase of elasticity. The estimated parameters in this part could not be interpreted as elasticity. In Equation (11), the income elasticity of IWW per capita $E_i$ for country $i$ is:

\[
E_i = \frac{\partial Lx}{\partial Lx} = \alpha + \beta_0 Lx + \beta_1 Lx \gamma + \beta_2 Lx c + \beta_3 Lx \gamma c + \beta_4 Lx c^2 + \epsilon_i
\]

(11)

4. Analysis

According on empirical result the relationship between industrial water use and income is nonlinear model so we can calculate the elasticity of water use. In STR model, income elasticity of IWW per capita $(E_i)$ depends on (log GDP per pita) level $(Lx_i)$. So it allows the parameters to change smoothly as a function of the threshold or transition variable. Indeed, the elasticity of income is explained by the weighted average of parameters including $\beta_0$ and $\beta_1$. The income elasticity $(E_i)$ for country $i$ is:

\[
E_i = \frac{\partial Lx}{\partial Lx} = \alpha + \beta_0 Lx + \beta_1 Lx \gamma + \beta_2 Lx c + \beta_3 Lx \gamma c + \beta_4 Lx c^2 + \epsilon_i
\]

(10)

In this specification, a negative value of $\beta_1$ may also lead to the increase of elasticity. The estimated parameters in this part could not be interpreted as elasticity. In Equation (11), the income elasticity of IWW $(E_i)$ has been presented. All calculations are computed with Matlab and JMULTI software’s. The equation used to calculate elasticity is given as the following:

\[
E_i = \frac{\partial Lx}{\partial Lx} = \alpha + \beta_0 Lx + \beta_1 Lx \gamma + \beta_2 Lx c + \beta_3 Lx \gamma c + \beta_4 Lx c^2 + \epsilon_i
\]

(11)
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5. Conclusions

In this paper, STR model based on cross section data was used to estimate the relationship between IWW and income for 132 countries throughout the world. It does seem that it is an inverse U-shaped curve for world countries. The results suggest an importance to search for alternative ways of water use to reduce the demand for additional water in the process of industrialization. According to the results, the income elasticity of IWW in selected countries is bell-shaped curve. These results justify ideas of (NRBEKC), (STCE) and (OVW) concepts that are combining ecological and social benefit as a whole. The findings suggest that income and socio-economic criteria along with water scarcity can have an effect on industrial water withdrawal in water-scarce countries and water intensity of use.

This line of thinking also has important implications for the models of water use and economic growth developed by [33], and the other issues of water-income relationship by [1,5,8,35,11]. One way to accomplish this is by estimating the water savings attributable to the structural transformation of an economy.

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