“Examination of the diverse views of sustainable development: an approach to monetize the environment, economy, and society”

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Examination of the diverse views of sustainable development: an approach to monetize the environment, economy, and society

Abstract

Monetizing every component of sustainable development is deemed to be important and essential for a complete context of sustainable development dimensions of economy, environment, and society. This study employs the hedonic price approach to monetize the measurement of environmental and of social aspect of the development. These measurements are comparable to the monetary variable of economic development. This study offers an empirical examination for "three-ring circus", "Russian doll", and "night owl" sustainable development concepts. The ideas apply to the newest data of 23 Taiwan's counties/cities in 1994-2003. The results of "three-ring circus model" show that the relationship between the aggregate environmental index and per capita income has a partial U-shape, reaffirming the environmental Kuznets curve. From the perspective of the "Russian doll model", the empirical results clearly indicate that the greater aggregate environmental measurement levels are the lower aggregate social measurement levels are required. The results of the "night owl" model indicate that every 1% increase in social development and income trade for an improvement of only 0.23% in environmental quality. This implies that once the environment has deteriorated, society faces about four times higher costs to rescue this life-support system.

Keywords: sustainable development, hedonic price approach, environmental Kuznets curve, social Kuznets curve.
JEL Classification: Q01, Q51, Q56.

Introduction

Since 1987, when the World Commission on Environment and Development proposed the definition and guidelines of sustainable development, various interpretations and explanations of sustainable development have been suggested (Levett, 1998; Custance, 2001; Mederly et al., 2003). However, the literature shows that definitions and concepts of sustainable development vary according to the different concerns of different professional fields, such as ecologists, sociologists, economists, psychologists, regional planners, political scientists, and many others. As a result, it is difficult to maintain, measure, and compare sustainable development through time or across regions (Kahn, 2001; Welsch, 2002; Stretesky et al., 2003; Graham et al., 2004; Valadbigi and Ghobadi, 2010; Choon et al., 2011).

The central concern of sustainable development focuses on economic development. Not only is this directly related to the subsistence of human beings, but it is also relatively easy to measure. Gross National Product (GNP) and Gross Domestic Product (GDP) are the two most frequently used indicators in this respect. The other two dimensions of sustainable development, society and environment, did not emerge as part of the movement until the 1970s. However, the literatures on sustainable development focus more on debating the ideal concepts and definitions of economy, society, and environment rather than on designing and implementing practical frameworks to link the three.

The first econometric analysis of the relationship between economic development and environmental quality provided the basis for the inverted U-shape environmental Kuznets curve (EKC)[1]. This was performed by Grossman and Krueger (1995) and by Shafik (1994). Since then, an abundance of researches have focused on the existence of the EKC. Most studies use global, cross-country data to verify the relationship between economic development and single environmental quality e.g. carbon dioxide emissions. The environmental quality is perceived to be an overall and aggregate concept (Wu, 1998), however, single environmental quality index can not capture the aggregate view of environment.

Most of the debates and discussions for the substitutable development are focused on the theoretical and conceptual prospects besides the single dimensional examination for the relationship between environmental quality and economic development not to mention comprehensive empirical examinations will be implemented (Ekins, 2003; Hamdouch and Zuindeau, 2010; Tang and Zhou, 2012). Levett (1998), for instance, proposed different conceptual frameworks to capture the relationships between these three dimensions of sustainable development. However, no operational models have been implemented to test whether these frameworks function in practice. Moreover, it remains an open question whether the relationship between economic development and social development can be depicted with an inverse U-shape similar to the EKC. If a complete context of sustainable development in-

[1] A comprehensive review of the research about EKC can be found in the study by Dinda (2004).

cludes the dimensions of economy, environment, and society, then it should be possible to verify a relationship between economic development and social development, and relationship among economy, environment, and society empirically.

This study does not intend to get involved in the theoretical debate about the definition and conceptualization of sustainable development. Instead, the objective of this study is to empirically examine the relationships between the three major dimensions of the doctrine: economy, environment, and society. More specifically, the study examines empirically the "three-ring circus model" and the "Russian doll model" proposed by Levett (1998), as well as the "night owl model" proposed in this study, in order to assess different views of sustainable development.

The evidence comes from the experiences of sustainable development in 23 Taiwanese counties and cities between 1994 and 2003. To carry out this study, it was necessary to develop aggregate measurements reflecting comprehensive idea of the environmental and social aspect of the development. Since monetizing every component of sustainable development is deemed to be important and essential for any perspective of sustainability. As such, this study employs the hedonic price approach to monetize the measurement of environmental and of social aspect of the development. These measurements are comparable to the monetary variable of economic development. The EKC obtained here reaffirms existing researches. The social Kuznets curve (SKC) described here is the first attempt in the literature to capture the connection between the aggregate social aspect development and income level. The integration of both is also the first attempt at a complete investigation and empirical examination of how sustainable development is conceptualized in the literature.

1. The relationships between economy, society, and environment in sustainable development

1.1. Different views of sustainable development. Levett's (1998) proposal presents different relationships between economy, society, and environment that reflect different views of sustainable development. The "three-ring circus model" pictured in Figure 1(A) portrays one type of the interaction between economy, society, and environment. Levett's discussion does not clearly identify cause and effect among these three dimensions, nor does the wider literature on sustainable development shed light on this issue.

Under this model, subsistence measures to satisfy basic needs play major roles in the early stages of development. GNP or GDP per capita are the indicators typically used to measure development. It was not until the 1970s that the scope of sustainable development extended beyond a narrowly defined focus on economic development. Subsequently, the concept of sustainable development expanded to incorporate social and environmental dimensions, such as population growth, education level, and many quality indicators related to environment (Gallaway, 1972; Giri, 2000).

Levett (1998) proposed another model for the interactions between environment, society, and economy called the "Russian doll model", depicted in Figure 1(B). This model regards the environment as the provider of all visible and invisible natural resources. It is also considered to be society's life support system, which should be maintained by the community and the economy. Under such concept, factors affecting social and economic development are constrained by the capacity of the environment, i.e., its ability to tolerate pollution or extraction of natural resources.

It is uncertain whether development is an intersection, as the "three-ring circus model," or whether it progresses from an outer limit of environment to an economic core, as in the "Russian doll model." Although the survival of human beings is inseparable from environmental capacity, environment is generally unconsciously ignored or taken for granted by human beings. Mankind usually does not sense his impact on the environment. This study proposes an alternative model focused on the interaction between society and the economy, which together negatively affect the environment. This model is a third categorization of the interaction among environment, economy, and society. It is referred to as the "night owl model,"[1] and is shown in Figure 1(C) in Appendix.

1.2. Examination of environmental quality vs. economic development. The environmental factors embedded in the concept of sustainable development encompass the quality and quantity of all natural resources. The categories of the environmental quality can be classified into three types (Wu, 1998). The first type is directly associated with human subsistence. Access to safe drinking water is one example of this type. Some studies of relationship of income and environmental quality have shown that access to safe drinking water rises with increasing per capita income (Beckerman, 1996).

[1] The name refers to the shape of the picture, with no any connotation associated with night owl.

The second type is one that contributes to better living standards. Factors that reduce the environment's ability to support living conditions include most air pollutants, heavy contamination of water supplies, smoke, nitrous oxides, carbon monoxide, and lead in gasoline belong to this type (Grossman and Krueger, 1995; Beckerman, 1996; Perman and Stern, 2003). Tolerating poor environmental quality of this type is inevitable before pollution control is enforced, and which is normally accompanied by high income.

The third type is one that provides environmental "amenities." This type includes such factors as the per capita productions of solid waste and the emissions of carbon dioxide by households and industries. Individual benefits from controlling this type of pollutants are relatively small compared to the cost. As a result, increases in income or economic development do not guarantee an improvement in this type of environmental quality (Beckerman, 1996; Wu, 1998; Lindmark, 2002; Dijkgraaf and Vollebergh, 2005; Markandya et al., 2006). It can be concluded that the relationship between economic development and environmental quality depends on the types of environmental quality involved (Beckerman, 1996; Wu, 1998).

Investigating the relationship between economic development and any type of environmental quality has been popular since Grossman and Krueger's study appeared in 1995. Some of the first example of analyses involving environmental Kuznet curve can be found in the study by Hole-Eakin and Selden (1995) for instance. However, many of these initial studies of simple or complicated forms of EKC do not use aggregate indicators of environmental quality, in contrast to the comprehensive approach to environment in the modern conceptualization of sustainable development.

1.3. Examination of social development vs. economic development. It is easier to identify environmental variables or indicators in sustainable development than to identify indicators to measure the social development. In fact, any variable that is not economic or environmental can be classified under social development. Theoretically these variables can include politics, culture, education, security, and medical care, and either material or psychosomatic (Giri, 2000; Poston et al., 2003; Gordon et al., 2012).

Researches in this area have sought to improve variables in order to capture better changes in social development. However, no existing studies have investigated the relationship between economic development and social development, nor have they proposed variables to measure social development comprehensively. Therefore, constructions of an aggregate environmental index and of an aggregate social index are required before we can explore the relationships between the economy, environment, and society.

2. Construction of an aggregate environmental index and an aggregate social index for use in sustainable development studies

2.1. Concept of hedonic price approach. Before examining the relationships between environment, society, and economy, we must construct an aggregate environmental index and an aggregated social index. These serve to integrate the broad range of dimensions within sustainable development in relation to environmental quality and social development in order to carry out empirical studies. We use the theoretical framework of the hedonic price approach proposed by Rosen (1974) for this purpose. The underlying assumptions of this approach are extended from Houthakker's (1952) and Lancaster's (1966) concept of utility-bearing characteristics. Characteristics or attributes of goods or services are valued according to their implicit prices, which come from observed prices of differentiated products.

Assume that C is such a differentiated good, containing different quantities of characteristics and attributes Q_m, $m=1,2,...,k$. In this case, good C can be written as function of Q_m, i.e. $C=C(Q_1,Q_2,...Q_k)$. In addition, the price of C is P_c and goods other than C form a composite good S with the price P_s. A consumer with income I who spends all of his or her income on composed good S and differentiated good C gains utility from consuming good S and good C. The optimal consumption of all the attributes is determined from the following maximization problem

$$\begin{aligned} &Max \quad U(S,C) \\ &s.t.: P_S S + P_c C = I \\ &C = C(Q_1,Q_2,...Q_k). \end{aligned} \tag{1}$$

If deviation applies to the choice variable S and C, then the price of differentiated good C can be computed as

$$P_c = \sum_{m=1}^{k} \frac{\partial Q_m}{\partial C} \cdot \left[\frac{\partial U}{\partial Q_m} \bigg/ \frac{\partial U}{\partial I} \right]. \tag{2}$$

Equation (2) can be simplified to

$$P_c = \sum_{m=1}^{k} \frac{\partial Q_m}{\partial C} \cdot \frac{\partial I}{\partial Q_m}. \tag{3}$$

Equation (3) illustrates the fact that the price of differentiated good C is the sum of the implicit prices for all characteristics. If a similar idea is applied to different differentiated good L, the price of good L can be expressed as a function of all its characteristics.

This theory has been used to rank the quality of life among cities and counties. Research by Rosen (1979), Hoehn et al. (1987), and Blomquist et al. (1988) are examples. These studies conclude that different amenities affecting quality of life are best viewed as characteristics of differentiated rents or wages. The implicit price of each amenity is derived from the estimation of the rent or wage function. The quality of life index is constructed by aggregating and multiplying the implicit price of each amenity and its corresponding value. The quality of life among cities can be ranked according to the values of the index in ascending or descending order.

This approach is used here to construct the aggregate environmental index, *EI*. This aggregate index combines the implicit price of the environmental aspect of sustainable development, designated f_i, and its observation value, s_i, i.e.

$$EI = \sum_{i=1}^{n} f_i s_i , \quad (4)$$

where $i = 1, 2, ..., n$ are factors associated with the environmental quality of sustainable development. A similar idea is used to construct the aggregate social index, *SI*. The aggregate index combines the implicit price of the social aspect of sustainable development, designated g_i, and its observation value, e_i, i.e.

$$SI = \sum_{i=n+1}^{k} g_i e_i , \quad (5)$$

where $i = n+1, ..., k$ are the numbers of factors or characteristics that reflect the social dimension of sustainable development.

2.2. Operational framework to analyze the environmental, social, and economic dimensions of sustainable development. *2.2.1. Operational framework of the "three-ring circus model."* The relationships between *EI*, *SI*, and economic development *I* depend on the theoretical framework used to structure the concept of sustainable development. If the "three-ring circus model" describes sustainable development comprising environmental, social, and economic dimensions, then economic development can be linked with the environmental aspects of sustainable development. As a result, the following three forms of the EKC can be identified:

$$EI_{ht} = \alpha_0 + \alpha_1 (\ln I_{ht}) + \varepsilon_{ht} , \quad (6a)$$

$$EI_{ht} = \alpha'_0 + \alpha'_1 (\ln I_{ht}) + \alpha'_2 (\ln I_{ht})^2 + \varepsilon'_{ht} , \quad (6b)$$

$$EI_{ht} = \alpha''_0 + \alpha''_1 (\ln I_{ht}) + \alpha''_2 (\ln I_{ht})^2 + \alpha''_3 (\ln I_{ht})^3 + \varepsilon''_{ht} , \quad (6c)$$

where $h = 1, 2, ..., H$ and $t = 1, 2, ..., T$ denote cross-sectional observations and time-series observations, respectively, and ε_{ht}, ε'_{ht}, and ε''_{ht} are stochastic terms for each specification.

Following a similar idea, we specify three forms of the SKC:

$$SI_{ht} = \beta_0 + \beta_1 (\ln I_{ht}) + \nu_{ht} , \quad (7a)$$

$$SI_{ht} = \beta'_0 + \beta'_1 (\ln I_{ht}) + \beta'_2 (\ln I_{ht})^2 + \nu'_{ht} , \quad (7b)$$

$$SI_{ht} = \beta''_0 + \beta''_1 (\ln I_{ht}) + \beta''_2 (\ln I_{ht})^2 + \beta''_3 (\ln I_{ht})^3 + \nu''_{ht} . \quad (7c)$$

where ν_{ht}, ν'_{ht}, and ν''_{ht} are stochastic terms for each specified form of SKC. The relationship between aggregate social index *SI* and aggregate environmental index *EI* can be indirectly inferred from the best empirical estimation results found in (6a) to (6b) and in (7a) to (7c). We can also recognize the compatibility and complementarity relationship between the environmental quality and social development of different stage in economic development.

2.2.2. Operational framework of the "Russian doll model." If the environmental, social, and economic dimensions of sustainable development are framed according to the "Russian doll model," then the aggregate environmental index *EI* is a critical element in the determination of the aggregate social index *SI*. Both of these elements determine the economic development index *I*.

This concept can be operationalized using a recursive system. Equations (8a) and (9a) represent a linear, functional recursive system describing the relationship between economic and social development. Similarly, quadratic and cubic recursive systems can be used, as shown respectively in (8b) and (9b) and in (8c) and (9c).

$$SI_{ht} = \lambda_0 + \lambda_1 (\ln EI_{ht}) + \varphi_{ht} , \quad (8a)$$

$$SI_{ht} = \lambda'_0 + \lambda'_1 (\ln EI_{ht}) + \lambda'_2 (\ln EI_{ht})^2 + \varphi'_{ht} , \quad (8b)$$

$$SI_{ht} = \lambda''_0 + \lambda''_1 (\ln EI_{ht}) + \lambda''_2 (\ln EI_{ht})^2 + \lambda''_3 (\ln EI_{ht})^3 + \varphi''_{ht} , \quad (8c)$$

$$I_{ht} = \phi_0 + \phi_1 (\ln SI_{ht}) + \phi_2 (\ln EI_{ht}) + \iota_{ht} , \quad (9a)$$

$$I_{ht} = \phi'_0 + \phi'_1 (\ln SI_{ht}) + \phi'_2 (\ln EI_{ht}) + \phi'_3 (\ln SI_{ht})^2 + \phi'_4 (\ln EI_{ht})^2 + \iota'_{ht} , \quad (9b)$$

$$I_{ht} = \phi_0'' + \phi_1''(\ln SI_{ht}) + \phi_2''(\ln EI_{ht}) + \phi_3''(\ln SI_{ht})^2 + \\ + \phi_4''(\ln EI_{ht})^2 + \phi_5''(\ln SI_{ht})^3 + \phi_6''(\ln EI_{ht})^3 + \iota_{ht}'', \quad (9c)$$

where SI_{ht} is the estimated aggregate social index from each of the previous corresponding estimations in (8a) to (8c). φ_{ht}, φ_{ht}', φ_{ht}'', ι_{ht}, ι_{ht}', and ι_{ht}'' are stochastic terms for the functions specified in (8-1) to (9c), respectively.

2.2.3. Operational framework of the "night owl model." In order for the "night owl model" to accurately capture the relationships between the environmental, social, and economic dimensions of sustainable development, we modify the traditional EKC. In other words, social development and economic development interact to affect the environment. In this perception of sustainable development, two types of functional forms are used to capture the environmental, social, and economic dimensions. The linear and quadratic forms are expressed respectively as follows:

$$EI_{ht} = \gamma_0 + \gamma_1(\ln I_{ht}) + \gamma_2(\ln SI_{ht}) + \\ + \gamma_3(\ln I_{ht})(\ln SI_{ht}) + \tau_{ht}, \quad (10)$$

$$EI_{ht} = \gamma_0' + \gamma_1'(\ln I_{ht}) + \gamma_2'(\ln I_{ht})^2 + \gamma_3'(\ln SI_{ht}) + \\ + \gamma_4'(\ln SI)^2 + \gamma_5'(\ln I_{ht})(\ln SI_{ht}) + \\ + \gamma_6'(\ln I_{ht})^2(\ln SI_{ht})^2 + \tau_{ht}'. \quad (11)$$

Similarly, τ_{ht} and τ_{ht}' are stochastic terms for equations (10) and (11).

3. Analyses of sustainable development experiences in Taiwan

3.1. Data sources and selection of variables. To demonstrate and operationalize different sustainable development views described above, it is necessary to assemble appropriate data. In Taiwan, data for environmental and social dimensions do not exist at the household level. Therefore, we must work with observations at the county and city levels. There is a total of 23 counties and cities on the main island in Taiwan[1], which is an insufficient number of observations for estimating cross-sectional county and city data for certain year. Similarly, there are not enough numbers of yearly time trend data for all the variables intended to be used in the analyses. One way to resolve this problem is to combine time-series and cross-sectional data, i.e. build a set of quasi-panel data. The final dataset was chosen to be the most up-to-date, complete, and consistent; it is a combination of time series between 1994 and 2003 and a cross-section of 23 counties and cities[2]. In total, the sample contains 230 observations. This combination of different types of data necessitated a more sophisticated approach to estimation.

Levett (1998) proposed resonance, scientific validity, measurability, and policy relevance as the criteria for selecting variables to measure sustainable development. Following this idea, environmental variables of suspended particular matter (SPM), population not served by tap water (UNTW), dust-fall (DUST), and amount of disposal solid waste (TR) are the only four variables that passing through all the necessary statistical tests. Additionally, we still select at least one variable from each type of the three classifications of environmental quality mentioned previously, i.e. which associate with human subsistence, contribute to better living standard, provide the environmental amenities, to capture the environmental characteristics described earlier although such limited data available existing for the choice of environmental variables.

Moreover, in light of the expected and consistent impacts of these variables on the income aspect of sustainable development, the magnitude of some of the variables mentioned above must be adjusted according to the original statistics records. One variable that has to be adjusted is population served by tap water, which is changed in the present study to population not served by tap water. As a result, the constructed aggregate environmental index is expected to have a negative impact on economic development.

In line with most researches applying the hedonic price approach to estimate the implicit price of environmental quality, we use annual housing rent (RENT) to capture the environmental and social dimensions of the aggregate index (Hoehn et al., 1987; Wu, 1998; Witte et al., 1979). The indicator of per-capita income is the average current receipts for each county or city. Both housing rent and per-capita current receipts, recorded in current dollars, are deflated by price index (PRICE) using the base year 1994 in order to eliminate price effects.

To capture the social dimension of sustainable development, variables examined education, social security, medical care, transportation, employment, and open space for living. Because the observation unit is the county or city, the living space variables considered the location and surroundings of a house

[1] There are 25 cities and counties in Taiwan totally. Among these, 23 counties and cities are on the main island and the other 2 are out of the main island. Data for these 2 counties are not included in the analyses due to their inconsistency of the data characteristics.

[2] The environmental variables were restructured in 2004. Due to limitations of the data, the latest data year for all variables used in this study is 2003. Combining different structures of the data after 2003 is not recommended by the data-reporting agencies. This means that the results in this study may be biased because of the inclusion of different data structures. This bias may affect the conclusions drawn concerning the experiences of sustainable development in Taiwan. Nevertheless, the conceptual framework and methodology used in the present study remain valuable contributions to the sustainable development literature.

instead of the house *per se*. Again, limitations of the data constrained the choice of these social variables.

Since high school education is prevalent in Taiwan, the percentage of the population older than 15 years old with a college degree is considered to be a better variable for describing the attribute of education among population (EDU) (Chang, 1992). We use the ratio of criminal cases resolved to the number of cases reported in each county or city to represent social security (CRM). The number of doctors and nurses per 10,000 persons is taken to represent the county's or city's level of medical service (MED). In addition, the annual expenditure on medicine and medical services per person is used to denote the overall medical and health care resources allocated to a certain county or city (EDOR). Car ownership per person in each county or city is used to describe an area's transportation and communication facilities (CAR).

Greenland or park acreage per person, percentage of arable land for agricultural production, and percentage of the total acreage of each county or city that is mountainous are the variables used to indicate the open-spaced and natural living environment within counties and cities (PARK, FARM, MT). In order to have the consistently directional impact of the related social dimensional variables on income, the employment rate[1] is used as an overall indication of economic prosperity for each county or city (EM). The variable chosen to indicate absolute change of population is population density[2] (PDMT). The variables described above and their corresponding sources are listed in Table 1.

Table 1. Definitions, mean values, and sources of all variables in the estimation

Definition of variable[a]	Variable name	Mean value	Unit	Data sources
Environmental aspect variables				
Suspended particulate matter	SPM	99.79	Mg/m^3	Environmental Protection Administration, 1995-2004
Dust fall	DUST	6.21	Ton/km^2	Environmental Protection Administration, 1995-2004
Percentage of population not served by tap water	UNTW	13.40	%	Environmental Protection Administration, 1995-2004
Amount of disposal solid waste	TR	1.02	Kg/day/person	Environmental Protection Administration, 1995-2004
Social aspect variables				
Green land or park acreage per person	PARK	7.74	m^2/person	County/City Government Office, 1995-2004
Ratio of criminal cases resolved to the cases reported	CRM	0.69	cases resolved/cases reported	County/City Government Office, 1995-2004
Percentage of college students Above fifteen years old	EDU	4.29	per 10,000 persons	County/City Government Office, 1995-2004
Population density	PDNT	2,119.16	person/km^2	Environmental Protection Administration, 1995-2004
Employment rate	EM	96.81	%	County/City Government Office, 1995-2004
Cars holding per person	CAR	0.83	car/person	County/City Government Office, 1995-2004
Health personnel per 10,000 persons	MED	66.11	health personnel /10,000 persons	Environmental Protection Administration, 1995-2004
Medicine and medical service expenditure per person	EDOR	6.63	100 dollars /person	County/City Government Office, 1995-2004
Percentage of arable land acreage	FARM	26.23	%	Council of Agriculture, 1995-2004
Percentage of mountain acreage	MT	27.42	%	Council of Agriculture, 1995-2004
Economic aspect variables				
Annual disposable income[b]	I	196,781	NT$/year/person	Directorate-General of Budget, Accounting and Statistics, 1995-2004
Rent	RENT	110,353	NT$/year/household	Directorate-General of Budget, Accounting and Statistics, 1995-2004
Price	PRICE	–	%	Directorate-General of Budget, Accounting and Statistics, 1995-2004

Notes: [a] Variables of "population not served by tap water" and "employment rate" have been reversed to the magnitudes from the original statistical data in accordance with the expected and consistent impact on the environmental index and social index described in the text. [b] The annual disposable income per person is computed from the original data as the disposable income per household each year divided by the numbers of household members.

[1] The variable "employment rate" is recorded as "unemployment rate" in original statistical data. The same concern is found for the variable "population served by tap water." Thus, the present study computes the employment rate as the difference between the full employment rate and the unemployment rate.
[2] It is generally thought that higher population density implies higher living pressure. However, no good reference can be found that describes the effect of reversing the sign of the variable for population density. We have left this variable as originally recorded.

3.2. Estimation results of the hedonic price function. In total, there are four variables associated with the environmental dimension of sustainable development, and ten variables associated with the social dimension of sustainable development. Those variables measured in monetary terms are deflated by the consumer price index for the year 1994. Estimation of the hedonic price function is the first step in constructing the aggregate environmental index *EI* and the aggregate social index *SI*. The linear functional form most widely used for this purpose is as follows:

$$\begin{aligned} RENT_{ht} &= \delta_0 + \delta_1 SPM_{ht} + \delta_2 DUST_{ht} + \delta_3 UNTW_{ht} + \\ &+ \delta_4 TR_{ht} + \delta_5 PARK_{ht} + \delta_6 CRM_{ht} + \delta_7 EDU + \\ &+ \delta_8 PDNT_{ht} + \delta_9 EM_{ht} + \delta_{10} CAR_{ht} + \delta_{11} MED_{ht} + \\ &+ \delta_{12} EDOR_{ht} + \delta_{13} FARM + \delta_{14} MT + \eta_{ht}. \end{aligned} \quad (12)$$

Due to the set of quasi-panel data, the covariance model (fixed effect model) and error component (random effect model) account for this differentiation. The estimation results are presented in Table 2. The results demonstrate that, in terms of R^2, F, the likelihood multiplier test (LM), the Hausman χ^2, and the t values for all the corresponding estimated coefficients, the fixed effect models outperform the random effect models.

The aggregate environmental index *EI* and the aggregate social index *SI* are computed accordingly. The greater the absolute magnitude of *EI*, the lower the environmental quality is. Conversely, the greater the absolute magnitude of *SI*, the higher social development is.

3.3. The relationships between environment, society, and economy. With the above constructed aggregated environmental index and aggregate social index, their relationship with economic development will then be empirically testified according to different sustainable development conceptual frameworks proposed above. At the county or city level, disposable income per person is used to describe economic development. This measure includes different types of labor income from all sources, interest earnings from all assets and deposits, and government transfer payments. The mean value and source of this variable are listed in Table 1.

Table 2. Results of estimated coefficients for hedonic price function[a]

Variable[b]	Fixed effect model	Random effect model
Constant	1732.7224 (312627.14)	84899.4502 (150163.80)
SPM	-162.0686*** (38.7358)	-157.5559*** (34.9088)
DUST	305.1304 (302.2687)	867.0767*** (278.1045)
UNTW	-155.8421 (109.8111)	-129.7037 (102.8065)
TR	6947.8495 (6792.7431)	7977.8260 (6237.4250)
PARK	448.7694 (343.3349)	-195.2637 (250.8954)
CRM	-19195.9661 (9149.1557)	-16693.7953* 8655.9348)
EDU	-762.7385 (623.1944)	758.1268* (459.1953)
PDNT	-15605.2087*** (8488.4177)	7766.8455*** (2433.0950)
EM	-289.3942 (1858.6089)	230.9832 (1512.9933)
CAR	-92404.2458*** (28564.914)	-45459.2676** (18524.793)
MED	-18.5318 (143.8349)	120.7168 (108.5430)
EDOR	228.6169 (317.2615)	691.4451** (291.6224)
FARM	1851.4039*** (573.4752)	318.5334 (281.6670)
MT	6616.8350 (8503.7639)	130.0007 (253.1181)
R^2	0.9453	0.83
F value	68.80***	-
LM value	-	76.58***
Hausman's χ^2 value	-	86.17***

Notes: [a] The coefficients with one asterisk, two asterisks, and three asterisks indicate that the corresponding variables are significant at 10%, 5%, and 1% level, respectively. [b] The asterisks on the *F*, *LM*, and Hausman's χ^2 have the same explanations as those defined in note *a* above.

3.3.1. The results of the "three-ring circus model." Under the "three-ring circus" model of sustainable development, the relationships between economy, environment, and society are considered by analyzing the interaction between environment and economy and the interaction between society and economy. In this way, the model indirectly infers the relationship between environment and society components. The results for the corresponding specifications (6a) to (6c) and (7a) to (7c) are shown in Table 3.

Table 3. Estimation results of the relationship between aggregate environmental index and income and that between aggregate social index and income under different models[a]

Variables[b]	Aggregate environmental index and income[c]					
	Fixed effect model			Random effect model		
	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic
Constant	-56317.08 (55831.15)	1881791.31 (155238.09)	-141059891.2** (59139372.0)	-70951.99* (37359.21)	1297194.59 (1377871.2)	-11338614.1** (55436324.0)
ln*I*	3859.03 (4585.23)	-315293.58 (255510.12)	3481683.33** (14532548.0)	5060.96* (3067.47)	-220662.09 (226205.97)	27951028.26** (13614906.0)
$(LnI)^2$	-	13136.48 (10515.23)	-2864544.52** (1190230.2)	-	9308.37 (9283.86)	-2297002.3** (1114434.3)
$(LnI)^3$	-	-	78554.77** (32489.59)	-	-	62923.7** (30402.8)
R^2 value	0.56	0.56	0.57	0.01	0.01	0.01
F value	7.44***	7.29***	7.42***	-	-	-
LM value	-	-	-	234.17	233.83***	237.55***
Hausman's χ^2 value	-	-	-	0.12	1.18	2.81

Variables[b]	Aggregate social index and income[d]					
	Fixed effect model			Random effect model		
	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic
Constant	121774.19* (74591.16)	-5197832.12*** (2047234.5)	-277901461.4*** (76703098.0)	237858.6*** (79100.66)	-548233734*** (2045727.6)	-283616826.4*** (76168416.0)
ln*I*	-2089.92 (6125.93)	873901.45*** (336959.28)	67898856.72*** (18848551.0)	-11623.56** (5914.39)	929104.97*** (336640.01)	69285716.6*** (18717564.0)
$(LnI)^2$	-	-36056.23*** (13867.18)	-5526085.73*** (1543715.1)	-	-38670.64*** (13852.7)	-5637193.21*** (1533033.4)
$(LnI)^3$	-	-	149866.51*** (42138.64)	-	-	152802.58*** (41848.5)
R^2 value	0.99	0.99	0.99	0.31	0.35	0.39
F value	10906.08***	10894.76***	11212.55***	-	-	-
LM value	-	-	-	863.11***	890.40***	776.62***
Hausman's χ^2 value	-	-	-	35.68	33.61	56.27

Notes: [a] The coefficients with one asterisk, two asterisks, and three asterisks indicate that the corresponding variables are significant at 10%, 5%, and 1% level, respectively. [b] The asterisks on the *F*, *LM*, and Hausman's χ^2 have the same explanations as those defined in note a above. [c] Linear, quadratic, and cubic are corresponding to the equations specified in (6a), (6b), and (6c). [d] Linear, quadratic, and cubic are corresponding to the equations specified in (7a), (7b), and (7c).

Using methods similar to those used to estimate the hedonic price function, the results shown in Table 3 for (6a)-(6c) and (7a)-(7c) indicate that estimation using fixed effect models with a cubic relationship is better than estimation using random effect models. This means that the relationship between environmental quality and economic development and that between social development and economic development are determined accordingly. A partial U-shaped curve between income and the aggregate environment index *EI* can be calculated from the fixed effect specification of (6c), and it is shown in the third quadrant of Figure 2. The third quadrant in Figure 2 shows that, as environmental quality increases along the vertical axis, the data closely approximate an EKC between income and the aggregate environmental index. The turning point for the simultaneous increase in income and environmental quality is an annual income of NT$ 215,000 (US$ 7,072.36) per person. The exchange rate for the US dollar to New Taiwanese dollar in 1994 is approximately 1:26.5, approximately 1:34.4 in 2003, and an average of 1:30.4 in 1994-2003.

The partial EKC indicates that, at the sample average of annual disposable income equal to NT$196,000 (US$ 6,447.37) per person, Taiwan experiences a decline in the environmental quality with increasing income. At the average income level for the newest data year in the sample – NT$249,000 (US$ 7,238.37) in 2003 – the country experiences an increase in both income and environmental quality.

A similar procedure is used to derive the relationship between income and the aggregate social index *SI* from the fixed effect estimated equation (7c). We find an U-shaped relationship between income and the aggregate social index, shown in the first quadrant in Figure, which we term a "social Kuznets curve." Similar to the results with the EKC, the SKC indicates that Taiwan has seen a decline in social development, despite increasing income during the period of 1994-2003. The turning point for a concurrent increase in aggregate social index and income level is an income of NT$ 275,000 (US$ 9,046.05). This income level is not only far above the past ten years' average for all counties and cities, but it also exceeds the highest income level for the most recent sample year of 2003.

It is optimistic to conclude that high environmental quality or high social development will occur together with high income. In other words, we see an improvement in environmental quality and social development, while simultaneously considering the interaction among environment, society, and economy. The fourth quadrant in Figure 2 (see Appendix) illustrates the indirect relationship between the aggregate environmental index and the aggregate social index in the "three-ring circus" scenario.

We can identify two critical income levels at the nexus of the aggregate social index and the aggregate environmental index: the sample average income level of all counties and cities in 1994-2003 of NT$196,000 (US$ 6,447.37) per person, and the turning-point income level of NT$275,000 (US$ 9,046.05) per person each year for the SKC. We find a trade-off between the aggregate environmental index and the aggregate social index. This implies that at the average income level of NT$249,000 (US$ 7,238.37) in all counties and cities in 2003, gains in environmental quality mean loss of social development, and vice versa. Simultaneous increases in the aggregate environmental index and the aggregate social index do not occur until annual income reaches NT$ 275,000 (US$ 9,046.05) per person.

3.3.2. The results of the "Russian doll model". In the sustainable development view of the "Russian doll model," development is spurred by economic progress, which in turn drives the direction and quality of social development. However, both economic development and social development are limited by environmental quality.

The equations specified in (8a)-(8c) and (9a)-(9c) operationalize these concepts. The first step is to estimate the relationship between aggregate environmental index and aggregate social index. The best results for (8c) are the cubic relationship of a fixed effect model. These results are extended to estimate the relationship between the aggregate social index and the per capita income. Table 4 shows that the cubic form of the fixed effect model in (9c) generates the best estimated results based on statistic test criteria.

The relationship between the aggregate social index and aggregate environmental index can be understood using estimation results of (8c) and (9c), which appears in Figure 3 (see Appendix). In Figure 3, note that the curve EI_c is the lowest environmental quality of the sample, the curve EI_b is the mean environmental quality of the sample, and the curve EI_a is the highest environmental quality in the sample. Upon reaching a certain income level, such as the sample mean value of NT$196,000 (US$ 6,447.37), the support from aggregate social index levels decreases continuously from condition "*c*" to "*b*" through to "*a*" as the aggregate environmental index level increases. In other words, different levels of aggregate environmental index provide different endowment conditions for maintaining certain relation between aggregate social index and per capita income.

More specifically, it is valuable to know what value of aggregate social index is required to support a certain income level under different aggregate environmental index levels. To reach the sample mean income of NT$196,000 (US$ 6,447.37), if the aggregate environmental endowment increases from EI_c to EI_b and further to EI_a the corresponding values of aggregate social index will decrease to NT$250,000 (US$ 8,263.68), to NT$220,000 (US$ 7,236.84), and further to NT$214,000 (US$ 7,039.47), respectively.

3.3.3. The results of the "night owl model". The empirical operation for the "night owl model" of sustainable development is embodied in equations (10) and (11), which describe the relationship between the aggregate environmental index and the interaction of the aggregate social index and per capita income. The estimation results are presented in Table 5. According to the test statistics, the fixed effect models with a quadratic form, i.e. equation (11), perform better than corresponding random effect counterparts. The relationships between environment, society, and economy are illustrated in Figure 4 (see Appendix). This figure shows that, under the income level observed in our dataset, improvement in the aggregate environmental index is insignificant when both income level and the aggregate social index increase simultaneously.

Table 4. The recursive estimation results of aggregate environmental index, aggregate social index, and income[a]

Variables[b]	Aggregate environmental index and aggregate social index[c]					
	Fixed effect model			Random effect model		
	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic
Constant	252870.06*** (2669.46)	253173.26*** (2758.21)	260663.78*** (4405.04)	252645.13*** (5993.47)	253021.44*** (6095.21)	260503.14*** (6954.15)
Ln*EI*	-98.22 (281.19)	-400.53 (728.85)	9791.69** (4756.41)	-74.18 (282.50)	-439.14 (725.14)	9765.69** (4739.91)
(Ln*EI*)^2	-	28.59 (63.44)	-2454.04** (1146.86)	-	34.39 (63.11)	-2449.78** (1142.35)
(Ln*EI*)^3	-	-	139.32** (64.26)	-	-	139.36** (64.01)
Ln*SI*	-	-	-	-	-	-
(Ln*SI*)^2	-	-	-	-	-	-
(Ln*SI*)^3	-	-	-	-	-	-
R^2 value	0.98	0.98	0.99	0.06	0.18	0.39
F value	5.47***	5.28***	5.23***	-	-	-
LM value	-	-	-	1001.11***	992.14***	962.70***
Hausman's χ^2 value	-	-	-	0.6	1.32	1.36
Variables[b]	Aggregate social index and income[d]					
	Fixed effect model			Random effect model		
	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic
Constant	-44773513.9*** (14268658.02)	-17957913.15** (7185610.4)	1968233252.0*** (62477152.0)	-48842250.7*** (13149820.0)	-20120580.51** (6687308.3)	1899934491.0*** (608287600.0)
Ln*EI*	35963143.47*** (11469395.01)	1048164.46 (1718615.4)	15774228100.01*** (500978130.0)	39249036.62*** (10569487.0)	538610.11 (368726.21)	14751618600.02*** (4877264700.0)
(Ln*EI*)^2	-	1075439.51** (464134.19)	-1960539.21*** (657321.04)	-	1257331.30*** (433688.39)	-395552.98*** (24541.59)
(Ln*EI*)^3	-	-	108347.91*** (35354.03)	-	-	22462.37* (13163.2)
Ln*SI*	98335.01*** (28724.46)	-136978.08* (73062.68)	612331546.8*** (19418716.0)	79208.05*** (26066.60)	-94592.81 (69717.14)	572959502.0*** (18907482.0)
(Ln*SI*)^2	-	21965.21*** (6296.10)	-153479576.08*** (48668799.01)	-	15519.04*** (5732.36)	-143609033.1*** (47387623.0)
(Ln*SI*)^3	-	-	8714998.17*** (2763160.8)	-	-	8154317.01*** (2690427.5)
R^2 value	0.26	0.31	0.44	0.08	0.18	0.23
F value	2.06***	2.39***	2.62***	-	-	-
LM value	-	-	-	4.62***	8.36***	12.73***
Hausman's χ^2 value	-	-	-	3.05	2.32	9.39

Notes [a] The coefficients with one asterisk, two asterisks, and three asterisks indicate that the corresponding variables are significant at 10%, 5%, and 1% level, respectively. [b] The asterisks on the *F*, *LM*, and Hausman's χ^2 have the same explanations as those defined in note *a* above. [c] Linear, quadratic, and cubic are corresponding to the equations specified in (8a), (8b), and (8c). [d] Linear, quadratic, and cubic are corresponding to the equations specified in (9a), (9b), and (9c).

In other words, the income level associated with the aggregate social index which has changed from NT$170,000(US$ 5,592.11) to NT$350,000(US$ 11,513.16), the improvement in aggregate environmental index levels also changes from NT$-10,000 (US$-329.95) to NT$-7,500(US$-246.71) per person each year. This is equivalent to a 106% increase in income and social development with an accompanying return of only 25% in environmental quality.

Conclusions and implications

This study has selected various variables to capture the notions of economy, society, and environment within the concept of sustainable development. It has attempted to reflect the diverse views of sustainable development. We examined three models which describe the relationships between economy, society, and environment: the "three-ring circus model", the "Russian doll model", and the "night owl model."

The results of the "three-ring circus model" show that the relationship between the aggregate environmental index and per capita income has a partial U-shape, reaffirming the EKC. We also see evidence of a SKC relation, i.e., a U-shaped relationship between the aggregate social index and per capita income. At the most recent average income level in the data (2003), Taiwan experienced an increase in both per capita income and the environmental quality, and a decline in the social development.

Table 5. Estimation results of aggregate environmental index, aggregate social index, and income under different model[a]

Variables[b]	Fixed effect model[c]		Random effect model[c]	
	Linear	Quadratic	Linear	Quadratic
Constant	-43507.93 (69735.93)	3215628.75* (1741213.7)	-34544.91 (53904.84)	3026737.91* (1607795.2)
Ln*I*	3082.43 (5726.32)	-530398.51* (284862.15)	2169.15 (4393.76)	-497439.5* (262401.62)
Ln*SI*	-1001.16 (6608.20)	-176485.71*** (68044.51)	-4574.57 (5937.58)	-172861.23*** (57864.59)
ln*SI**ln*I*	-43507.98 (69735.93)	14574.97*** (5602.21)	364.73 (487.82)	14210.57*** (4790.42)
$(\ln I)^2$	-	21812.61* (11655.12)	-	20376.56* (10706.72)
$(\ln SI)^2$	-	7023.56** (2802.05)	-	6779.32*** (2387.36)
$(\ln SI)^2 * (\ln I)^2$	-	-47.99*** (18.86)	-	-45.84*** (16.35)
R^2 value	0.56	0.58	0.04	0.15
F value	7.07***	6.99***	-	-
LM value	-	-	212.88***	148.92***
Hausman's χ^2 value	-	-	2.02	2.85

Notes: [a] The coefficients with one asterisk, two asterisks, and three asterisks indicate that the corresponding variables are significant at 10%, 5%, and 1% level respectively. [b] The asterisks on the *F*, *LM*, and Hausman's χ^2 have the same explanations as those defined in note *a* above. [c] Linear and quadratic refer to the equations specified in (10) and (11).

From the perspective of the "Russian doll model", the development of income is concurrently influenced by environmental quality and social development. The empirical results of this model clearly indicate that greater aggregate environmental index levels means that lower aggregate social index levels are required in order to reach certain income level. This may be indirect evidence of a substitution relationship between the support from environmental quality and social development.

Finally, the results demonstrate that, in the "night owl model," given the observable income level, 1% increases in both social development and income implies an improvement of only 0.23% in environmental quality. This implies that society will have to pay an almost four times higher cost to rescue its environmental life-support system once it has been damaged.

The operational models proposed in this study are the first attempt in the literature to empirically testify various conceptual frameworks of sustainable development. In extending the ideas inspired from this study and the empirical results within Taiwan and to other countries, further research should seek to improve the selection of comprehensive variables and use other data sources to develop a complete conceptualization of the economy, environment, and society within the framework of sustainable development.

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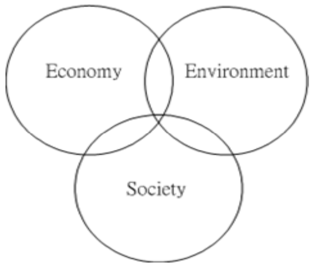
References

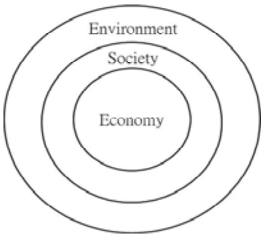
1. Beckerman, W. (1996). *Through Green-colored Classes: Environmentalism Reconsidered*, Washington, DC: Cato Institute.
2. Blomquist, G.C., Berger, M.C., and Hoehn, J.P. (1988). New Estimates of Quality of Life in Urban Areas, *American Economic Review*, Vol. 78, No. 1, pp. 89-107.
3. Chang, C.H. (1992). Historical Trends in the Equality of Educational Opportunity in Taiwan, *Taiwan Economic Review*, Vol. 20, No.1, pp. 23-50.
4. Choon, S.W., Siwar, C., Pereira, J.J., Jemain, A.A., Hashim, H.S., and Hadi, A.S. (2011). A Sustainable City Index for Malaysia, *International Journal of Sustainable Development* World, Vol. 18, No. 1, pp. 28-35.
5. Council of Agriculture. (1995-2004). The Report on 1995-2004 Agricultural, Forestry, Fishery and Husbandry Census, Council of Agriculture, Executive Yuan, Taipei: Taiwan-Fukien District, the Republic of China.
6. County/City Government Office. (1995-2004). Statistics Abstract of Various Counties/Cities, Taiwan: County/City Government Office.
7. Custance, J. (2001). The Development of National, Regional and Local Indicators of Sustainable Development in the United Kingdom. Paper Presented in the Conference of European Statisticians, Ottawa, Canada, October 1-4.

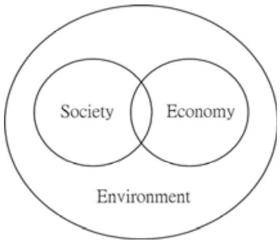
8. Dinda, S. (2004). Environmental Kuznets Curve Hypothesis: A Survey, *Ecological Economics*, Vol. 49, No. 4, pp. 431-455.
9. Dijkgraaf, E. and Vollebergh, H.R.J. (2005). A Test for Parameter Homogeneity in CO_2 Panel EKC Estimations, *Environmental and Resource Economics*, Vol. 32, No. 2, pp. 229-239.
10. Directorate-General of Budget, Accounting and Statistics (1995-2004). Report on the Survey of Family Income and Expenditure. Executive Yuan, Taipei: Directorate-General of Budget, Accounting and Statistics.
11. Ekins, P. (2003). Identifying Critical Natural Capital: Conclusions about Critical Natural Capital, *Ecological Economics*, Vol. 44, No. 2-3, pp. 277-292.
12. Environmental Protection Administration (1995-2004). Environmental Statistic Yearbook, Taiwan, the Republic of China, Executive Yuan, Taipei: Environmental Protection Administration.
13. Gallaway, L.E. (1972). The Quality of Life, Population, and Environment: The Importance of Historical Perspective, *Review of Social Economy*, Vol. 30, No. 1, pp. 37-45.
14. Giri, A.K. (2000). Rethinking Human Well-being: A Dialogue with Amartya Sen, *Journal of International Development*, Vol. 12, No. 7, pp. 1003-1018.
15. Gordon, M., Lockwook, M., Vanclay, F., Hanson, D., and Schirmer, J. (2012). Divergent Stakeholder Views of Corporate Social Responsibility in the Australian Forest Plantation Section, *Journal of Environmental Management*, Vol. 113, pp. 390-398.
16. Graham, C., Eggers, A., and Sukhtankar, S. (2004). Does Happiness Pay? An Exploration Based on Panel Data from Russia, *Journal of Economic Behavior & Organization*, Vol. 55, No. 3, pp. 319-342.
17. Grossman, G.M. and Krueger, A.B. (1995). Economic Growth and the Environment, *Quarterly Journal of Economics*, Vol. 110, No. 2, pp. 353-377.
18. Hamdouch, A. and Zuindeau, B. (2010). Sustainable Development, 20 Years on: Methodological Innovations, Practices and Open Issues, *Journal of Environmental Planning and Management*, Vol. 53, No. 4, pp. 427-438.
19. Hoehn, J.P., Berger, M.C., and Blomquist, G.C. (1987). A Hedonic Model of Interregional Wages, Rents and Amenity Values, *Journal of Regional Science*, Vol. 27, No. 4, pp. 605-620.
20. Holtz-Eakin, D. and Selden, T.M. (1995). Stoking the Fires? CO_2 Emissions and Economic Growth, *Journal of Public Economics*, Vol. 57, No. 1, pp. 85-101.
21. Houthakker, H.S. (1952). Compensated Changes in Quantities and Qualities Consumed, *Review of Economic Studies*, Vol. 19, No.3, pp. 155-164.
22. Kahn, M.E. (2001). City Quality-of-life Dynamics: Measuring the Costs of Growth, *Journal of Real Estate Finance and Economics*, Vol. 22, No. 2-3, pp. 339-352.
23. Lancaster, K. (1966). A New Approach to Consumer Theory, *Journal of Political Economy*, Vol. 74, No. 2, pp.132-157.
24. Levett, R. (1998). Sustainability Indicators: Integrating Quality of Life and Environmental Protection, *Journal of Royal Statistical Society: Series A*, Vol. 161, No. 3, pp. 291-302.
25. Lindmark, M. (2002). An EKC-pattern in Historical Perspective: Carbon Dioxide Emissions, Technology, Fuel Prices and Growth in Sweden 1870-1007, *Ecological Economics*, Vol. 42, No. 1-2, pp. 333-347.
26. Markandya, A., Golub, A., and Pedroso-Galinato, S. (2006). Empirical Analysis of National Income and SO_2 Emissions in Selected European Countries, *Environmental and Resource Economics*, Vol. 35, No. 3, pp. 221-257.
27. Mederly, P., Novacek, P., and Topercer, J. (2003). Sustainable Development Assessment: Quality and Sustainability of Life Indicators at Global, National, and Regional Level, *Foresight*, Vol. 5, No. 5, pp. 42-49.
28. Perman, R. and Stern, D.I. (2003). Evidence from Panel Unit Root and Cointegration Tests that the Environmental Kuznets Curve Does Not Exist, *The Australian Journal of Agricultural and Resource Economics*, Vol. 47, No. 3, pp. 325-347.
29. Poston, D., Turnbull, A., Park, J., Mannan, H., Marquis, J., and Wang, M. (2003). Family Quality of Life: A Qualitative Inquiry, *Mental Retardation*, Vol. 41, No. 5, pp. 313-328.
30. Rosen, S. (1974). Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition, *Journal of Political Economy*, Vol. 82, No. 1, pp. 34-55.
31. Rosen, S. (1979). Wages-based Indexes of Urban Quality of Life. In: *Current Issues in Urban Economics*. Edited P. Mieszkowski and M.S. Baltimore, Maryland: Johns Hopkins University Press.
32. Shafik, N. (1994). Economic Development and Environmental Quality: An Econometric Analysis, *Oxford Economic Papers*, Vol. 46, No. 4, pp. 757-773.
33. Stretesky, P.B., Johnston, J.E. and Amey, J. (2003). Environmental Inequality: An Analysis of Large-scale Hog Operations in 17 States, 1982-1997, *Rural Sociology*, Vol. 68, No. 2, pp. 231-252.
34. Tang, C.S. and Zhou, S. (2012). Research Advances in Environmentally and Socially Sustainable Operations, *European Journal of Operational Research*, Vol. 223, No. 3, pp. 585-594.
35. Valadbigi, A. and Ghobadi, S. (2010). Sustainable Development and Environmental Challenges, *European Journal of Social Science*, Vol. 13, No. 4, pp. 542-548.
36. Welsch, H. (2002). Preferences over Prosperity and Pollution: Environmental Valuation Based on Happiness Surveys, *Kyklos*, Vol. 55, No. 4, pp. 473-494.
37. Witte, A.D., Sumka, H.D. and Erekson, H. (1979). An Estimate of a Structural Hedonic Price Model of the Housing Market: An Application of Rosen's Theory of Implicit Markets, *Econometrica*, Vol. 47, No. 5, pp. 1151-1173.
38. Wu, P.-I. (1998). Economic Development and Environmental Quality: Evidence from Taiwan, *Asian Economic Journal*, Vol. 12, No. 4, pp. 395-412.

Appendix



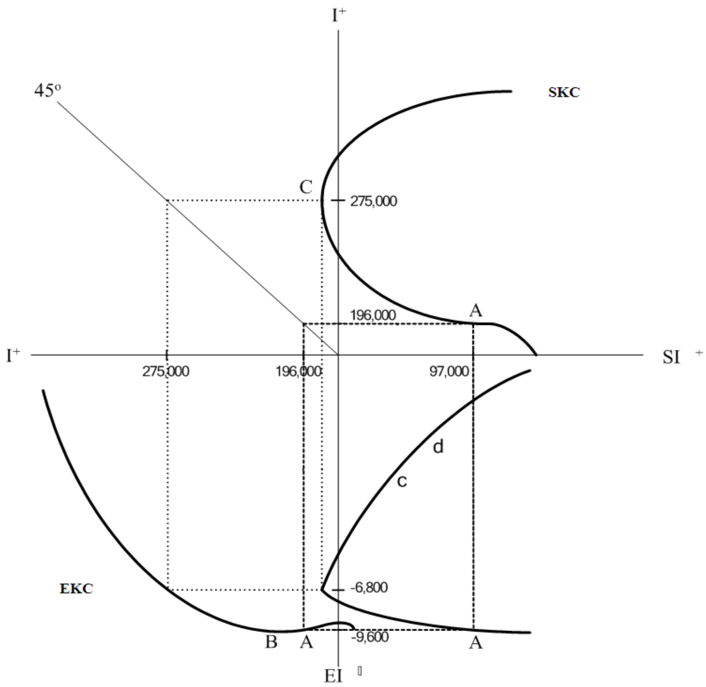
(A) Three-ring circus model (Levett, 1998)





(B) Russian doll model (Levett, 1998) **(C) Night owl model**

Fig. 1. Conceptual frameworks of sustainable development



Notes: A: corresponding points of mean disposable income of all samples – NT 196,000 dollars. B: Turning points of EKC is about NT 215,000 dollars. C: Turning points of SKC is about NT 215,000 dollars.

Fig. 2. Indirect relationship of aggregate environmental index and aggregate social index – "three ring circus" model

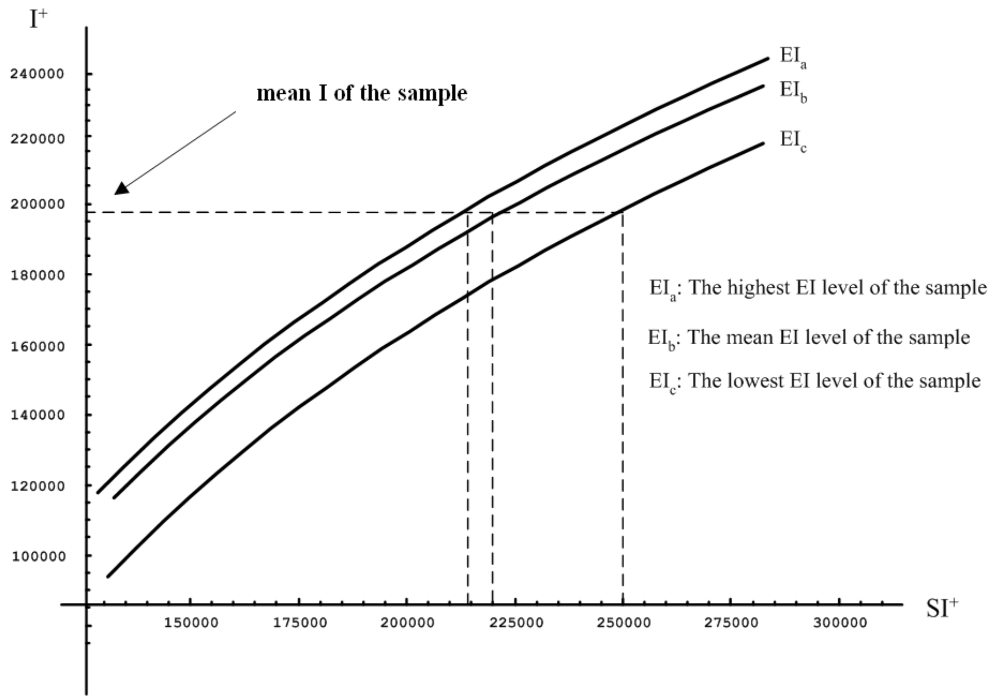


Fig. 3. Direct relationship between aggregate environmental index and aggregate social index – "Russian doll model"

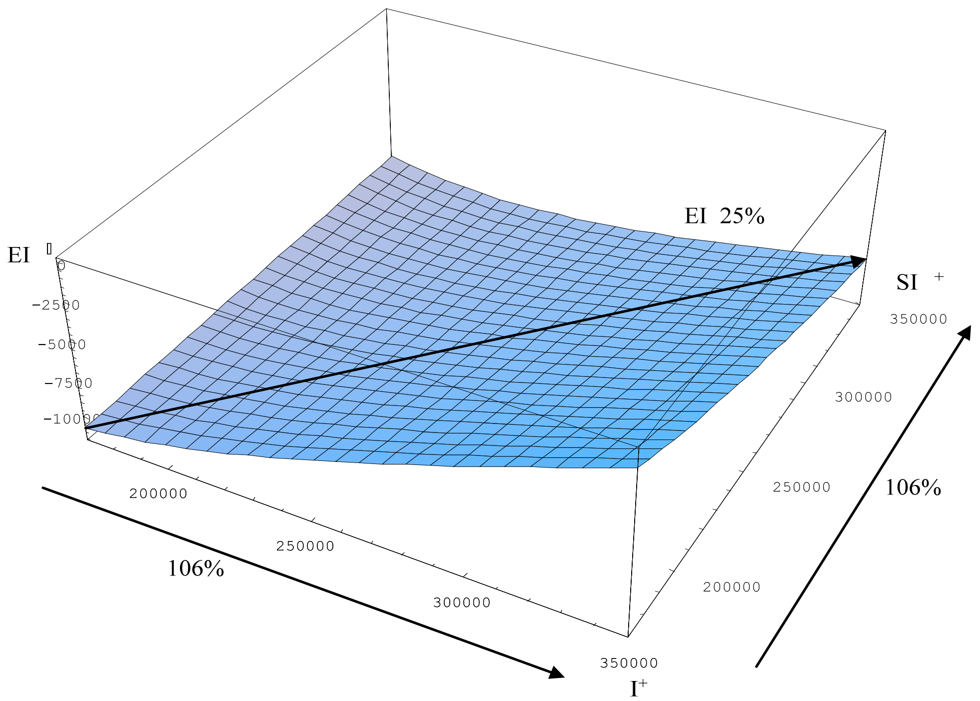


Fig. 4. Relationship among aggregate environmental, aggregate social, and economic index of sustainable development – "night owl model"