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Environmental sustainability index of Shandong Province, China

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SUMMARY

Since the 1992 Rio Earth Summit, sustainable development has been embraced as an important goal. In order to measure sustainable development, many scientists and researchers have made efforts to establish measurement systems such as the Driving Force State Response (DSR) framework (Hens 1995), the Human Development Index (HDI) (Goeteyn 1996) devised by the United Nations Development Programme, the Sustainable National Income (SNI) developed by Hueting *et al.* (1992) and the Ecological Footprint proposed by Wackernagel and Rees (1996). The environmental sustainability index (ESI) is a composite index, which was created by the World Economic Forum, Yale and Columbia Universities, aggregating data at the national level to measure a country's performance in sustaining a healthy, livable environment. 142 countries have been measured with ESI by 2002. However, it has not yet been documented if it can be applied at a regional level. In this study, we have tried to apply ESI to measure the sustainable development of Shandong in China. 22 indicators and 43 variables were chosen, and results showed the ESI of Shandong was 49, suggesting that Shandong is still far from a position of sustainable development.

INTRODUCTION

An index is a highly aggregated measure that combines indicators that are most important to describe the performance of an institution, regional or economic sector. Indices simplify complex systems, usually to just one number. This can be useful for decision-makers, but if important pieces of information are missing or improperly represented in an index, it can give a false signal. To amend the shortcomings of the GNP/GDP index, several alternative indices have been or are being developed that aim to capture missing dimensions, including the Human Development Index (Goeteyn 1996), Index of

Sustainable Economic Welfare (ISEW) (Daly and Cobb 1989), Sustainable Process Index, and Social Progress Index (Richard 1992).

Environmental sustainability has been increasingly embraced as an important agenda by government agencies worldwide. Since the 1992 Earth Summit, many environmental policy objectives have been formulated in terms of sustainability. The proliferation of these objectives has inevitably spawned considerable discussion, yet actual measurements are generally rare. Therefore, at the international level, political suspicions and data gaps frequently

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conspire to derail even the most modest efforts to compare environmental circumstances of countries. In other words, no single measure of environmental sustainability existed that had the same capacity to guide public policy and attract public attention such as do GNP or the unemployment rate in the economic sphere, until 2000 when a pilot version of ESI was unveiled (WEF 2000). It is necessary to create an ESI in a systematic, transparent and reproducible manner. It should be faithful to the scientific literature as well as relevant to major policy debates. It should be applicable to a wide range of situations and conditions, and should make use of what can actually be measured today, while leaving room for development toward what ought to be measured tomorrow.

The purpose of the ESI consists in developing a composite measure that summarizes environmental performance along multiple axes and that can help decision-makers to choose the best policies for both the environment and the economy. Furthermore, the ESI permits comparative analysis of the levels and determinants of sustainability between countries, helping scholars to better understand the trade-offs and synergies between policies in the environmental and economic realm.

The creators of ESI had applied it to 122 countries by 2001 and 142 countries by 2002 (WEF 2001, 2002). The findings showed that ESI permits cross-national comparisons of environmental progress in a systematic and quantitative fashion and provides a more analytically driven approach to environmental decision-making at national levels. However, it is yet uncertain if it is suitable for use at regional or sub-regional levels. In this paper we have tried to apply ESI in measuring sustainable development in Shandong Province, China, and this feasibility will also be discussed.

METHODOLOGIES OF ESI

The first challenge in measuring environmental sustainability is to define the scope in conceptual terms. Unlike other indicators of 'sustainable development', the developers of the ESI have focused on environmental sustainability, which is a narrower formulation. This choice was made deliberately, based on a conclusion that one

reason for the failure of efforts to measure sustainability is that they seek to fold too many disparate phenomena into the same conceptual umbrella. While they accept the premise that politics, economics and social values are important factors worthy of being sustained, they do not think that there is a sufficient scientific, empirical or political basis for constructing metrics that combine all of them with the environment. Moreover, the environment often becomes overshadowed in 'triple bottom line' analyses and other sweeping sustainability efforts.

Even with the confines of a narrower focus of environmental sustainability, we are dealing with a complicated, multi-dimensional concept. At the most basic level, it is suggested that environmental sustainability can be presented as a function of five phenomena (Table 1):

- (1) State of environmental systems, such as air, soil, ecosystems and water;
- (2) Stresses on such systems in the form of pollution and exploitation levels;
- (3) Human vulnerability to environmental changes in the form of loss of food resources or exposure to environmental diseases;
- (4) Social and institutional capacity to cope with environmental challenges; and
- (5) Ability to respond to the demands of global stewardship by cooperating in collective efforts to conserve international environment resources such as the atmosphere.

Environmental sustainability is defined as the ability to produce high levels of performance in each of these five dimensions in a lasting manner and refers to these dimensions as core 'components'. Scientific knowledge does not permit us to specify precisely what levels of performance are sufficiently high to be truly sustainable, especially on a worldwide scale. Nor are developers expected to identify in advance whether any given level of performance is capable of being sustainable. Establishing the thresholds of sustainability remains an important endeavour, albeit one that is complicated by the dynamic nature of economic factors such as changes in technology over time.

Table 1 Components of Environmental Sustainability Index (Source: ESI Report 2001)

<i>Component</i>	<i>Environmental sustainability of a country</i>
Environmental systems	Sustainable to the extent that its vital environmental systems are maintained at healthy levels, and to the extent that levels are improving rather than deteriorating
Reducing environmental stresses	Sustainable if the levels of anthropogenic stress are low enough to engender no demonstrable harm to its environmental systems
Reducing human vulnerability	Sustainable to the extent that people and social systems are not vulnerable (in the way of basic needs such as health and nutrition) to environmental disturbances; becoming less vulnerable is a sign that a society is on a track to greater sustainability
Social and institutional capacity	Sustainable to the extent that it has in place institutions and underlying social patterns of skills, attitudes and networks that foster effective responses to environmental challenges
Global stewardship	Sustainable if it cooperates with other countries to manage common environmental problems, and if it reduces negative extra-territorial environmental impacts on other countries to levels that cause no serious harm

The basic unit of comparison is a set of 22 environmental sustainability indicators that were identified after a careful review of the environmental literature and are substantiated by statistical analysis. These indicators were deemed the most relevant constitutive elements of the five core components, and therefore are the central element of analysis. In turn, each of the indicators has associated with it a number of variables that are measured empirically. The choice of variables was driven by a consideration of the theoretical logic and relevance of the indicator in question, data quality and country coverage. In general, variables were sought with extensive country coverage, but chosen with narrow coverage if they measured critical aspects of environmental sustainability that would otherwise be lost. Air and water quality, for example, were especially disappointing in their poor country coverage but were included anyway because of their central role in environmental sustainability.

After building up the complete database, countries were selected for inclusion in the index based on the extent of their data coverage. The variables were then standardized by computing a Z-score to make aggregation possible.

$$Z\text{-score}_n = \text{value}_n - \text{mean} / \text{standard deviation}$$

For example, we may standardize the variable 'land area impacted by human activities as a percentage of total land area' of selected nations (Table 2). The first step is to calculate the mean

(38.75) and standard deviation (33.24). The Z score for Albania, for example would then be:

$$Z = 81.19 - 38.75 / 33.24 = 1.28$$

In the same way, the other variables and the 22 indicators were calculated by taking the average of the constituent variables Z scores.

The ESI was then calculated by taking the average of the 22 indicators, converting this to a standard normal percentile (using a Statistics Table, a Statistical Package or the Excel computer program) so as to end up with a number with

Table 2 Land area impacted (percent) in selected nations (original data, ESI Report 2001)

<i>Nation</i>	<i>Land area impacted</i>	<i>Nation</i>	<i>Land area impacted</i>
Albania	81.19	Denmark	91.28
Algeria	2.23	Egypt	4.72
Argentina	32.90	Fiji	5.66
Armenia	57.09	Finland	14.61
Australia	7.07	France	82.83
Austria	46.41	Ghana	23.37
Bangladesh	74.77	Greece	65.65
Belgium	97.88	Iran	13.78
Benin	4.02	Kuwait	27.61
Bolivia	9.31	Malaysia	28.70
Burundi	60.83	Morocco	6.63
Canada	8.51	Netherlands	92.41
Chile	10.27	Singapore	100.00
China	30.06	Saudi Arabia	4.14
Cuba	46.56	USA	31.86

Table 3 ESI and component values for Shandong

City	ESI	Environmental systems	Environmental stresses and risks	Human vulnerability	Social and industrial capacity	Global stewardship
Jinan	59.4	50.5	61.1	47.0	72.6	70.0
Qingdao	60.5	57.3	55.4	45.8	78.0	68.7
Zibo	51.5	44.9	59.9	68.5	39.8	50.5
Zaozhuang	39.0	55.9	42.4	29.5	25.6	41.0
Dongying	45.1	46.2	50.4	56.8	35.4	37.2
Yantai	55.0	58.3	44.3	47.6	59.0	64.8
Weifang	49.8	47.7	53.2	64.6	42.5	41.0
Jining	38.9	40.7	41.0	15.9	42.3	50.5
Taian	52.7	45.6	59.3	56.9	63.7	37.2
Weihai	59.3	50.9	62.1	53.0	61.8	68.7
Rizhao	56.2	67.3	59.7	43.4	54.6	56.0
Laiwu	46.5	52.0	56.3	43.2	50.8	37.2
Linyi	49.3	72.4	55.3	40.8	43.3	37.2
Dezhou	50.8	43.7	31.6	69.7	48.4	60.0
Liaocheng	40.6	30.0	12.2	84.9	46.6	37.2
Binzhou	45.0	42.1	44.1	53.1	52.9	32.0
Hezhe	38.6	34.4	23.2	44.6	45.3	46.7
Average for Shandong	49.5	49.4	47.9	50.9	50.3	49.1

greater intuitive understanding which does not assume that the highest and lowest observed average in the data set corresponds to maximum and minimum levels of environmental sustainability. Rather, a more reasoned assumption would be that the figures represent a range of estimates of an actual distribution that is in fact wide.

To establish the ESI for Shandong, this study used 22 core indicators, aggregated into five components (Environmental Systems, Reducing Environmental Stresses, Reducing Human Vulnerability, Social and Institutional Capacity and Global Stewardship). Each indicator contains 1 to 4 variables from a total of 43 underlying variables (information on variables can be obtained from the author).

In summary, the ESI methodology is as follows:

- Collect data;
- Make variables comparable where necessary by dividing by population, income or populated land area.
- Take log values of highly skewed variables.
- Set substantive thresholds where appropriate.

- Standardize variables to permit aggregation.
- Calculate 22 indicators by averaging underlying variables.
- Calculate ESI average for the 22 indicators and calculate standard normal percentile (5 components calculated in same way).

RESULTS AND DISCUSSION

ESI was calculated for each city of Shandong Province (Table 3). The top cities in the league table were Qingdao (60.5), Jinan (59.4) and Weihai (59.3), and the bottom cities were Heze (38.6), Jining (38.9), and Zhaozhuang (39). Correlations of the ESI and selected comparative measures were analysed, and showed that the ESI was significantly correlated with the ecological footprint ($p = 0.007$), GDP per capita ($p = 0.017$) and GDP growth rate ($p = 0.037$). However, no significant correlation between ESI and population density was found (Table 4). Comparison was performed between ESI and other measures among the cities ranked at the top, medium and bottom levels (Table 5). ANOVA analysis showed significant differences for ESI, GDP per capita

and ecological footprint between the top, medium and bottom groups.

The results of the ESI for Shandong appear intuitively plausible, although there are some anomalies that are discussed below. Since the ESI was established to shed light on the debate over the relationship between economic growth and environmental protection, one of the original motivations for this study was to test whether the ESI could be applied at the level of region or sub-region, and thus make it possible to provide a scientifically theoretical basis for decision-making. To do so, the authors have compared ESI with GDP per capita (Shandong Statistical Yearbook 1999), GDP growth rate (Shandong Statistical Yearbook 1999), ecological footprint (Cui et al. 2004) and population density (Shandong Statistical Yearbook, 1999) (Tables 4, 5).

The relationships between the ESI and the ecological footprint are very strong, and GDP per capita and GDP growth rate are also significantly correlated with the ESI. However, population density, in spite of common complaints about its impact on the environment, is in general not consistently associated with poor environmental performance. These results suggest that densely populated regions are not inevitably subject to pollution damage and natural resources shortage.

In general, the top ranks have higher per capita income, faster economic growth and a larger ecological footprint; while the bottom ranks have lower per capita income, slower economic growth and a smaller ecological footprint.

Table 4 Correlation between the ESI and selected comparative measures for 1998 (Source: Shandong Statistical Yearbook 1999)

Measure**	Correlation with ESI	Significant*
Ecological footprint	0.93	0.007
GDP per capita (ppp)	0.80	0.017
GDP growth rate	0.74	0.037
Population density	-0.014	0.914

*Correlation is significant at the 0.05 level

However, when we analyse different ranking groups, the results are not entirely consistent. For example, within the top group: Weihai has the highest income, fastest economic growth and a larger footprint in the province, but it only ranks third behind Qingdao and Jinan. In contrast, Qingdao, although its income, economic growth and footprint are all lower than Weihai and Jinan, ranks first. How can we explain this and why can it happen? If we take the more comprehensive condition of each city into account, we may have an answer. Qingdao, as a coastal city with a solid economic foundation, pays more attention to environmental protection; Jinan, as the capital of the province, has higher per capita income than Qingdao but it also has a much bigger ecological footprint and its ESI is not so very different from Qingdao. However, Weihai, as an economic development region, pays more attention to economic development than environmental pro-

Table 5 Comparison of ESI with other measures among the cities ranking top, middle and bottom (Source: Shandong Statistical Yearbook 1999)

City	ESI	GDP/Capita (US\$)	GDP growth (US\$)	Ecological footprint	Population density (per km ²)
Qingdao	60.5	1451	12.8	1.26	1444
Jinan	59.4	1794	13.1	1.36	1648
Weihai	59.3	2605	15.2	1.32	1435
Weifang	49.8	1120	11.0	1.22	1195
Linyi	49.3	562	11.2	1.21	1521
Zaozhuang	39.0	799	9.4	1.13	1892
Jining	38.9	800	11.0	1.15	1452
Heze	38.6	301	2.0	1.12	1196
Sign. Differ	0.000	0.035	0.042	0.003	0.776

Note: Exchange rate US\$ to RMB¥: 1 to 8.3

tection, and so has more per capita income, faster economic growth and a low ESI. This suggests that, when it comes to making fundamental policy choices having to do with environmental sustainability and economic performance, there is no significant trade-off. The choices appear to be distinct and separable. This is consistent with the ‘Porter hypothesis’ that suggests that high levels of environmental protection are compatible with high levels of economic growth, and may even encourage the innovation that supports growth (Porter and Van der Linde 1995; Esty and Porter 2000). The other groups (middle and bottom ranks) almost have similar situations that need further discussion.

On the other hand, comparison of the ESI of Shandong with those of China and other selected countries in 2001 (Table 6) show that the ESI of Shandong was higher than that of China (ranking 97 in the world) and Belgium (ranking 73 in the world), the same as Israel and much lower than Finland (ranking first in the world) and Japan (ranking 22 in the world). Because of political, economic, social and natural uncertainty, we cannot define exact scores of sustainability but define them between 0 and 100, and suggest that the closer to 100, the higher the sustainability. The average ESI in Shandong was 49.5, suggesting that Shandong was still close to an unsustainable situation.

CONCLUSIONS

According to the above analysis, the characteristics of the ESI of Shandong Province are consistent with those of the ESI created by the World Economic Forum (WEF 2000). Therefore, the ESI, although not perfect, can be applied at regional and local levels. The ESI permits cross-national, regional or sub-regional comparisons of environmental progress in a systematic and

Table 6 Comparison of Shandong’s ESI with selected countries (Source: ESI Report 2001)

Region/Countries	ESI
Shandong	49.5
China	37.6
Belgium	44.1
Finland	80.5
Japan	60.6
Israel	49.5

quantitative fashion, and has proven to be a surprisingly powerful and useful measure of the underlying conditions, current societal performance and capacity for future policy interventions that determine long-term environmental trends. Most cities in Shandong are still far from sustainable development and not all cities are on a truly sustainable path. The ESI will be helpful to highlight opportunities for improvement and where best practices might be found.

Economic conditions affect, but do not determine, environmental conditions. Comparisons of the ESI with measures of economic performance suggest that decisions of how vigorously to pursue environmental sustainability and economic growth are in fact two separate choices. The ESI thus enables:

- Identification of issues where national or regional environmental results are above or below expectations;
- Policy tracking to identify areas of success or failure;
- Benchmarking of environmental performance;
- Identification of best practices; and
- Investigation into interactions between environmental and economic performance.

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