Comprehensive environmental performance index (CEPI): an intuitive indicator to evaluate the environmental quality over time

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Abstract

Current environmental indicators assess environmental quality, but no single indicator measures the overall environmental performance of a country, state, or region in an easy and intuitive methodology. This paper provides a simple but informative indicator known as the Comprehensive Environmental Performance Index (CEPI) for 48 Asian countries for the period from 1996 to 2020. The CEPI represents a step toward clarity by combining six different indicators (Ecological Footprint, Environmental Quality, environmental vulnerability, environmental sustainability, adjusted net savings, and pressure on nature) data into one indicator. Contrary to other indices, the CEPI does not use complex mathematical procedures but is designed for simplicity, which facilitates understanding and applying economics to professionals and laymen. We adopt PCA (Principal Component Analysis) to maximize ease of understanding. In addition to Raw CEPI, which gives equal weightings to its components, we build weighted CEPI and show that the two indices behave similarly to the Asian data.

1. Introduction

Over the past few decades, the pursuit of higher growth and economic development has been a central goal of government policies. However, to achieve greater growth, natural resources are needed, which has a negative impact on the environment. Therefore, the achievement of sustainable development and continuous improvement of the current quality of life at a lower intensity of resource utilization without jeopardizing future generations has received more global attention than ever before, particularly considering global warming, climate change, and other environmental problems are getting increasingly serious. Understanding and forecasting changes in environmental quality is a crucial topic for policymakers in charge of environmental policies. The Environmental Kuznets Curve (EKC) is a hypothesis widely used in the Environmental Economics literature for modeling the growth path of the environment empirically. The EKC hypothesis is that there is an inverted U-relation between environmental degradation and per capita income. In other words, environmental degradation is projected to increase with income to a certain extent, after which a higher per capita income will improve environmental quality. Many studies have focused on the contrast between the short run and long-term effects of economic growth, although the research on economic development and environmental deterioration is misleading. Specifically, the notion is that, despite short-term environmental degradation, long-term economic expansion can enhance environmental quality. The Environmental Kuznets Curve is the name given to this phenomenon (EKC). However, mixed evidence exists for this feature of economic growth and the environment. For example, by considering different countries and groups of countries different empirical work reported contrasting outcomes on the validity of EKC (Lindmark 2002, Lantz and Feng 2006, Caviglia-Harris et al 2009, Narayan and Narayan 2010, Song et al 2013, Onafowora and Owoye 2014, Apergis 2016, Sencer Atasoy 2017, Nasir et al 2019). One can argue that potential differences exist between developed
and developing countries. However, such disagreement would be simplified as the empirical evidence indicates significant differences, even within developed and developing sectors (Tamazian et al 2009, Tamazian and Bhaskara Rao 2010, Jalil and Feridun 2011, Chang 2014, Abbasi and Riaz 2016, Javid and Sharif 2016, Solarin et al 2017, Shahbaz et al 2018, Zakaria and Bibi 2019, Ahmed et al 2021, Khan and Yahong 2022). At the same time, it is necessary to carry out a detailed analysis, specific to the economy concerned, before drawing a conclusion on ecological consequences of economic growth.

According to the BP PLC Global Energy Statistical Study, Asian economies’ emissions more than quadrupled from 3.4 gigatons to 7.4 gigatons between 2000 and 2008. The rate of increase in emissions has moderated during the last few years. Between 2008 and 2018, China’s emissions are expected to climb at a rate of roughly 2.6 percent, according to BP. Since 2011, carbon dioxide emissions have dropped, reaching their lowest point in 2020. According to historical norms, there have been the biggest reductions in both energy demand and carbon emissions since World War II. Last year, CO2 emissions fell by more than 2 Gt, returning to levels last seen in 2011. To put it another way, assuming carbon emissions continue to fall at the same rate as last year over the next 30 years, global carbon emissions will have dropped by over 85% by 2050 (Statistical Review of World Energy Globally Consistent Data on World Energy Markets and Authoritative Publications in the Field of Energy 2021). Figure 1 shows the trends in carbon dioxide (CO2) emissions, methane emissions (ME), and nitrous oxide (NO) emissions in Asian economies. Figure 2 shows the trends in the under-analysis economies’ Ecological Footprints (EFP) and Load Capacity Factor (LCF). Figure 3 compare the demand and supply of the environment. As indicated that the Asian region is facing the problem of ecological deficit as the demand for environment in this Asian region exceeds the biocapacity of the environment. Given that Asian economies have been emitting greenhouse gases in tandem with significant economic growth, and the biocapacity is insufficient to meet the demand for environment it’s intriguing to investigate the environmental consequences of growth by developing an intuitive indicator, the CEPI (Comprehensive Environmental Performance Index), for evaluating a country’s environmental quality. As a result, the primary goal of this study is to develop the CEPI using the Principal Component Analysis (PCA) weighting approach.

The remaining paper is organized as next section conclude the outcomes of previous studies done to trace the impact of different macroeconomic dimensions on environmental quality by taking different indicators.
Section 3 provide the estimates about the construction of Comprehensive Environmental Performance Index. The final section reserved to conclude and present policy recommendations.

By constructing the CEPI for the 48 Asian economies, the research aims to give an intuitive environmental indicator. The study is unique in that it creates very first time a Comprehensive Environmental Performance Index (CEPI) for 48 Asian economies by taking six different dimensions of Environment. To do so, we used PCA (Principal Component Analysis) to generate the CEPI. Table A1 in the appendix provided the list of Asian countries.

To start the work with a quick summary of the current indicators and their inadequacies. The CEPI is then introduced, along with an explanation of how indicators are created to produce raw scores and efficiency ratings that are used to assess a country’s environmental quality. To demonstrate how the index has performed over different economic periods, we review 48 Asian economies environmental and economic history from 1996 to 2020, including the CEPI results for each year.

### 2. Existing literature on environmental quality indicators

Economic growth is the main goal of macroeconomic policy, especially after the 2nd World War (Raworth, Doughnut, 2017). The same applies to Asian economies. The impact of economic growth on the environment is an important aspect that has attracted the attention of the world over the past decades. Several studies have explored the effects of economic growth on environmental degradation in this setting, with an emphasis on the idea of EKC. According to EKC, economic growth and environmental degradation have a U-shaped negative relationship. Economic expansion adds to environmental degradation in the near run. When the country’s income rises, however, this ratio reverses and economic growth begins to slow, which is good for the environment. Following the initial contributions of (Grossman et al 1991) to the relationship between growth and the environment in the context of EKC, there are few studies that have investigated experimentally with this relationship. Different studies explore the affiliation of different economic indicators by using different proxies for environment. The results heavily dependent upon the indicator of environment employed. The summary of the existing indicators and their impact on environment is reported in table 1.

| Author                                             | Proxy                                      | Findings                                |
|-----------------------------------------------------|--------------------------------------------|-----------------------------------------|
| (He 2006, Ghosh 2010, Esteve and Tamarit 2012,      | Carbon Dioxide Emission, Sulfur Dioxide    | Mixed Findings on the existence of EKC  |
| Fosten et al 2012, Sephton and Mann 2013, Shahbaz  | Emission, Methane Oxide Emission           |                                         |
| et al 2018, Nasir et al 2019)                      |                                            |                                         |
| (Javid and Sharif 2016, Aydin et al 2019, Charfeddine | Ecological Footprint                       | Mixed Findings on the shape of EKC      |
| and Kahia 2019, Destek and Sarkodie 2019, Dogan     |                                            |                                         |
| and Inglesi-Lotz 2020, Usman and Jahanger 2021)    |                                            |                                         |
| (Xu et al 2022)                                    | Load Capacity Factor                       | Mixed Findings                          |
| (Fakher 2019)                                      | Ecological Footprint, Pressure on Nature,  |                                         |
|                                                    | Adjusted net Savings, Environmental       |                                         |
|                                                    | Quality, Environmental Sustainability,    |                                         |
|                                                    | Environmental Vulnerability                |                                         |

The existing literature provide contrasting and inconclusive results regarding the impact of macroeconomic variables on environmental quality. So, it is important to derive an inclusive and comprehensive indicator to measure environmental quality of the Asian countries.
3. Construction of comprehensive environmental performance index (CEPI)

Despite recent developments in environmental science, many people are still uninformed about the theory of the background environment and the confusion caused by the abundance of economic statistics in the media. Furthermore, many people are unable to properly evaluate their country’s current environmental performance and compare it to historical performance. In other words, they cannot situate current performance in a historic context. This problem is caused by several factors, including:

- The number of environmental statistics used by businesses and governments, their quality and potential differences in media coverage.
- An absence of historic background needed to portray and deliver the environmental movements.
- An absence of context regarding alternative statistics, for instance not all statistics are unit created equal, with some clearly being a lot of necessary and consequential than others.
- Results heavily affected with the nature of the proxies taken to do the analysis with environmental quality.
- There is no single indicator of environment that consider both demand and supply side factors of environmental quality.

The Comprehensive Environmental Performance Index (CEPI) is designed to resolve these issues. Although structurally easy, the CEPI could be a powerful Environmental indicator that clearly measures the performance of the economy’s all primary segments: households, firms, government, and available geographical area. The CEPI includes variables that influence all sectors simultaneously:

- Ecological Footprints Index (EFPI)
- Environmental quality index (EQI)
- Environmental vulnerability Index (EVLI)
- Environmental Sustainability Index (ESI)
- Adjusted Net Savings Index (ANSI)
- Pressure on Nature Index (PONI)
- the Methane emissions

Data their descriptions and sources are summarized in table 2.

Note that after selecting the weights for the indicators of environmental quality the environmental quality index is defined as follows:

\[
CEPI = \frac{\sum_{i=1}^{n} W_i \cdot \text{Value}_i}{\text{Max Value} - \text{Min Value}}
\]  

In this stage, we applied PCA to the six indicators of environment (EFPI, EQI, EVLI, ESI, ANSI, PONI) to compute their weights in the overall index. Table 3 shows the main component composition and normalized weights for each dimension for Asian economies over the period of 1996 to 2020. The final column shows that PCA determines the maximum EFPI weight (0.37), followed by ESI (0.27), Environmental Quality (0.17), ANSI...
From this information, Environmental sustainability, and ecological footprint are the most important dimensions in explaining the level of environmental performance of Asian economies.

Regarding the structure of the main components, we found that the first and most important components, which accounted for 41 percent of the total data change (Table 3), contributed equally across all three dimensions. As previously explained, this needs to be maintained to ensure that all three dimensions measure the same latent structure, which is interpreted as the degree of environmental quality. It shows that in most cases only the first component accounts for more than 90% of the total variation in the causal variable. Therefore, a strategy that uses only the first major component can be a good approach to assessing the dimensions and levels of environmental quality. In the last section of Table 3, cumulative variances for CEPI are provided, expressing the changes in the indices that are explained by the relevant dimensions. The first component of the environmental quality dimension, ecological footprint index, accounts for 23% of the total differences in this dimension (see Table 3). The second component adds the 21% information. The third, fourth, fifth, and sixth components, on the other hand, increased environmental performance information by 17 percent, 15%, 15%, and 9%, respectively. The correlation matrix of the different dimensions of environmental performance are reported in Table A2 in appendix.

Table 3. Comprehensive Environmental Performance Index (CEPI). Principal Component Estimates.

| Variables | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 | Normal weights |
|-----------|-----|-----|-----|-----|-----|-----|---------------|
| EFPI      | 0.73| 0.17| −0.06| −0.26| 0.37| 0.47| 0.37          |
| EQI       | 0.23| 0.67| −0.06| 0.06| 0.10| −0.67| 0.17          |
| EVLI      | 0.16| 0.60| 0.15| 0.48| −0.26| 0.53| 0.09          |
| ESI       | 0.54| 0.17| −0.32| −0.03| 0.74| 0.12| 0.27          |
| ANSI      | 0.28| 0.31| −0.41| 0.78| 0.15| −0.07| 0.14          |
| PONI      | 0.04| 0.12| 0.83| 0.26| 0.45| −0.10| 0.03          |
| Eigenvalues | 2.05| 1.67| 0.86| 0.30| 0.10| 0.04| Source Own Construction |
| Cumulative Variances | 0.23| 0.44| 0.61| 0.76| 0.91| 1.00| Source Own Construction |

(0.14), EVLI (0.09), and PONI (0.03). From this information, Environmental sustainability, and ecological footprint are the most important dimensions in explaining the level of environmental performance of Asian economies.

Regarding the structure of the main components, we found that the first and most important components, which accounted for 41 percent of the total data change (Table 3), contributed equally across all three dimensions. As previously explained, this needs to be maintained to ensure that all three dimensions measure the same latent structure, which is interpreted as the degree of environmental quality. It shows that in most cases only the first component accounts for more than 90% of the total variation in the causal variable. Therefore, a strategy that uses only the first major component can be a good approach to assessing the dimensions and levels of environmental quality. In the last section of Table 3, cumulative variances for CEPI are provided, expressing the changes in the indices that are explained by the relevant dimensions. The first component of the environmental quality dimension, ecological footprint index, accounts for 23% of the total differences in this dimension (see Table 3). In the structure of environmental quality, the second component adds the 21% information. The third, fourth, fifth, and sixth components, on the other hand, increased environmental performance information by 17 percent, 15%, 15%, and 9%, respectively. The correlation matrix of the different dimensions of environmental performance are reported in Table A2 in appendix.

In contrast to ecological footprint and environmental quality, environmental vulnerability, environmental sustainability, adjusted net savings and pressure on nature give some of its information to the second component, so that this dimension not only contributes to the overall index through the first main component, but also adds additional information through the second component and becomes relevant for the second component of the overall Index.

Ranking of Asian countries based on their CEPI scores for the year of 2020 are reported in Table 4 and Figure 4. Based on CEPI scores for the year 2020 Qatar having the highest position according to Comprehensive environmental performance index and Timor Leste showing the lowest position among the 48 Asian economies. Overall, the developed Asian economies showing better environmental performance as compared to the low-income Asian economies.
4. Conclusion and policy recommendations

Environmental Performance is an important part of economic development. The right of policy makers to use environmental services to prevent environmental damage should be a priority. However, efforts to measure environmental performance are still inadequate and incomplete. Environmental performance is a multi-dimensional concept that cannot be captured precisely by individual indicators but is determined by a much larger set of indicators than some of the indicators accounted for in the existing work. The nature of environmental performance is complex and heterogeneous. An inclusive ecosystem must promote the growth and development of the most vulnerable groups in society. That is, they are most affected by ecosystem constraints.

Existing indicators for environmental performance are questionable because they provided inconclusive results. This paper proposes a one-step PCA to measure the level of environmental performance index for Asian countries or region. This method is statistically good for indexing and reliable for large amounts of data. We measure Comprehensive Environmental Performance using a composite index for 48 Asian economies, using six causal variables as determinants of environmental performance for the period from 1996–2020. This index can be compared across countries and over time. In particular, our index states that the level of environmental performance is determined by maximizing the ecological absorption and reproductive capacity of the nature and minimizing the greenhouse gas emissions. Our main contributions are to create a comprehensive index for environmental performance that covers both Supply and demand information of eco system.

As our assessment shows, environmental quality and ecological footprint are the most important dimension in determining environmental performance of Asian economies. The index is useful for explaining the determinants of environmental performance and its contribution to economic growth and development. Our index is easy to interpret and calculate. We believe that more detailed information on various dimensions in the form of disaggregated greenhouse emissions data, frequency of use, ecological footprint, Load Capacity Factor information, environmental vulnerability, sustainability, pressure on nature, and adjusted net savings can be useful for a more accurate assessment of environmental performance, leading to policy recommendations.

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| Table 4. CEPI Based Ranking of Asian Countries. |
|-----------------------------------------------|
| Country        | Rank | Country     | Rank |
|----------------|------|-------------|------|
| Qatar          | 1    | Vietnam     | 25   |
| UAE            | 2    | Bhutan      | 26   |
| Kuwait         | 3    | Uzbekistan  | 27   |
| Bahrain        | 4    | India       | 28   |
| Oman           | 5    | Azerbaijan  | 29   |
| Brunei         | 6    | Georgia     | 30   |
| South Korea    | 7    | Armenia     | 31   |
| China          | 8    | Indonesia   | 32   |
| Saudi Arabia   | 9    | Lao PDR     | 33   |
| Russia         | 10   | Sri Lanka   | 34   |
| Singapore      | 11   | Philippines | 35   |
| Kazakhstan     | 12   | Syria       | 36   |
| Turkmenistan   | 13   | Turkey      | 37   |
| Taiwan         | 14   | Kyrgyzstan  | 38   |
| Israel         | 15   | Maldives    | 39   |
| Japan          | 16   | Pakistan    | 40   |
| Mongolia       | 17   | Nepal       | 41   |
| Iran           | 18   | Tajikistan  | 42   |
| Cyprus         | 19   | Bangladesh  | 43   |
| Malaysia       | 20   | Afghanistan | 44   |
| Lebanon        | 21   | Cambodia    | 45   |
| Iraq           | 22   | Myanmar     | 46   |
| Thailand       | 23   | Yemen       | 47   |
| Jordan         | 24   | Timor-Leste | 48   |
Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: https://doi.org/https://databank.worldbank.org/source/world-development-indicators.

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Conflict of interest

The corresponding author states that there is no conflict of interest associated with this manuscript.

Human and animal rights

No human or animal harmed to do this research.

Consent to publish

I agreed to publish the paper in the journal of environmental science and Pollution Research.

Material and data required

All the data is obtained online from world development indicators and Global footprint network. You can easily access the data from the link provided https://databank.worldbank.org/source/world-development-indicators, https://data.footprintnetwork.org/.

Ethical approval and consent to participate

Not Applicable

Author’s contribution

Nazia Latif: Complete writing, Data analysis, Software working, Econometric modelling, and methodology.

Author’s position

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Appendix

Table A1. List of Asian Countries.

| Country          | Region                    |
|------------------|---------------------------|
| Afghanistan      | Timor-Leste               |
| Syria            | Uzbekistan                |
| Tajikistan       | Vietnam                   |
| Yemen            | Armenia                  |
| Bangladesh       | Azerbaijan                |
| Bhutan           | China                     |
| Cambodia         | Georgia                   |
| India            | Indonesia                 |
| Kyrgyzstan       | Iran                      |
| Lao PDR          | Iraq                      |
| Magnolia         | Jordan                    |
| Myanmar          | Kazakhstan                |
| Nepal            | Lebanon                   |
| Pakistan         | Malaysia                  |
| Philippines      | Maldives                  |
| Sri Lanka        | Russian federation        |
| United Arab Emirates |           |

Source: Own Elaboration

Table A2. Correlation Matrix.

| Variables | EFPI | EQI | EVLI | ESI | ANSI | PONI |
|-----------|------|-----|------|-----|------|------|
| EFPI      | 1    |     |      |     |      |      |
| EQI       | 0.05 | 1   |      |     |      |      |
| EVLI      | −0.08| 0.20| 1    |     |      |      |
| ESI       | 0.89 | 0.06| 0.03 | 1   |      |      |
| ANSI      | −0.31| 0.02| −0.79| 1   |      |      |
| PONI      | 0.27 | 0.36| 0.45 | 0.78| −0.26| 1    |

Source: Own Elaboration

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