Sustainable Energy Efficiency Index: A case Study of SAARC countries

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Outline

- World Energy Outlook
- Energy Sector of Pakistan
- Significance of the Study
- Objectives of the Study
- Methodology
  - Data
  - Variables
  - Sustainable Energy Efficiency Index
  - Data Envelopment Analysis
  - Malmquist Productivity Index
- Results & Discussion
Projected Global Energy demands to grow by 33% higher by 2040.

- OECD
- Non-OECD

Major role players: India, China, Africa, the Middle East & South-East Asia.

- Reduction in annual growth rate.

- 17% of the global population – remain without electricity.

- Energy-related Carbon emissions projected to be 16% higher by 2040, increasing at the rate of 2.4% per year since 2000.
World total energy Consumption by fuel in 2014

- Oil: 32.57 (33%)
- Natural Gas: 23.71 (24%)
- Coal: 30.03 (30%)
- Nuclear Energy: 4.44 (4%)
- Hydro Electricity: 6.8 (7%)
- Renewable: 2.5 (2%)
Energy Sector of Pakistan

- Total Primary Energy Consumption: 38.8 MTOE

- Fuel contribution:
  - Natural Gas: 43.2%
  - Oil: 29%
Significance of the Study

- Climate Summit in Paris (COP21)

- Pakistan: a minor contributor but a worst victim of Climate Change.

- Contributes 0.8% of total global GHG emission and 0.5% of total Carbon emission.

- Widening Deficit in supply and demand of energy
Objectives of the Study

- **Overall Objective:**
  - Analyze the role of energy sector in Environmental degradation and Economic growth

- **Explicit Objectives:**
  - Develop Sustainable Energy Efficiency Index
  - Estimate Scale efficiencies
  - Analyze the patterns of change in efficiencies over time
  - Policy formulation
The present study is based on the secondary source of data consisting annual observations on SAARC countries for the years 2004–2007.

**INPUT:** Energy use per capita (E)

**OUTPUT:** Gross Domestic Product per capita (GDP) & CO₂ emissions per capita (C)

**SOURCE:** World Development indicators
Variables

- Energy use in kg of oil equivalent per capita
- GDP per capita (current US$)
- CO₂ emissions (metric tons per capita)
Energy Sustainability Index

- **Energy sustainability**: A guarantee that the energy resources are preserved for the coming generations.

- **Methods for assessing Energy Sustainability**
  - Aspect of Sustainability
  - Type of data Employed
  - Time Span
Measuring Efficiency

- Uni-dimensional Methods:
  - Performance Indicators

- Multi-dimensional Methods:
  - Frontier Approaches
    - Stochastic Frontier Analysis
    - Corrected Ordinary Least Squares
    - Data Envelopment Analysis
    - Malmquist Productivity Index
  - Parametric Approaches
  - Non-Parametric Approaches
Non-Frontier Approaches

- Linear Programming
- Econometric Methods
- Growth Accounting Equation
- Divisia Index
- Exact Index
- Tornqvist Index

Parametric Approaches

Non-Parametric Approaches
Energy efficiencies obtained using the output oriented models estimated such that for the given levels of energy input:

- maximizes the economic growth
- minimizes the carbon emissions at the same time.
Methods Employed in Study

Which:
- Data Envelopment analysis
- Malmquist Productivity Index

Why:
- Incorporate multiple inputs and outputs
- Does not require functional form
- Variables can have different units of measurements
- Provide direct comparison by the means of peers
Data Envelopment Analysis

- Introduced by Farrell (1957)
- Estimate productivity efficiency taking into account all the inputs.
- Based on linear programming for assessing the relative efficiency of DMUs.
  - **DMU**: Decision Making Units that operates a production process that converts inputs into outputs.
A basic DEA model assumes $K$ inputs and $M$ outputs on each of $N$ DMUs.

**Constant Return to Scale (CRS) Model**
- Introduced by Charnes, Cooper and Rhodes (1978)
- Based on the Radial minimization of all inputs and maximization of all outputs.
- Assumes an environment of Constant return to scale.
- Provides an estimate of Technical efficiency
Variable Return to Scale (VRS) Model
- Introduced by Banker et al. (1984)
- Provides estimates of the Pure Technical Efficiency.
- Impose a convexity constraint on the CRS model

Scale Efficiencies:

\[
\text{Scale Efficiency} = \frac{TE_{CRS}}{TE_{VRS}}
\]
Malmquist Productivity Index (MPI)

- Introduced by Fare et al. (1994, 1996)
- Measures Productivity Growth as the weighted sum of the sectoral rates
- Assumes the inputs are explicitly known and efficiently allocated among the sector.
- Output Based MPI is given as:

\[ M_0(t, t+1) = \left[ \frac{D^t_0(x^{t+1}, y^{t+1})}{D^t_0(x^{t}, y^{t})} \cdot \frac{D^{t+1}_0(x^{t+1}, y^{t+1})}{D^{t+1}_0(x^{t}, y^{t+1})} \right]^{1/2} \]
MPI > 1 indicates Positive TFP growth

MPI can be represented as the geometric mean of the effect of the technological change.

\[ M = \text{TE} \times \text{TC} \]

Where TE = Technical efficiency

TC = Average Technological Change over Time.
Results & Discussion

- Descriptive Analysis
- Energy Sustainable Index
- Patterns of Change in efficiencies
Energy Use Per Capita
Carbon Emission per capita

CO2 Emissions per capita

Mean

Year
GDP per capita

![GDP per capita graph showing growth over years for different countries such as Bangladesh, Bhutan, India, Srilanka, Maldives, Nepal, and Pakistan. The graph illustrates the economic growth and disparity among these countries over time.]
# Efficiency Summary for 2004

<table>
<thead>
<tr>
<th>Country</th>
<th>CRS Efficiency</th>
<th>VRS Efficiency</th>
<th>Scale Efficiency</th>
<th>Peers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bhutan</td>
<td>1</td>
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<tr>
<td>India</td>
<td>0.345</td>
<td>0.356</td>
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<tr>
<td>Srilanka</td>
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<td>0.62</td>
<td>0.954</td>
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<tr>
<td><strong>Mean Efficiency</strong></td>
<td><strong>0.754</strong></td>
<td><strong>0.764</strong></td>
<td><strong>0.978</strong></td>
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# Efficiency Summary for 2005

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<tr>
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<tr>
<td>Bangladesh</td>
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<td>India</td>
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## Efficiency Summary for 2006

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<td>Bangladesh</td>
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<td>Bhutan</td>
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<td>India</td>
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<td>Pakistan</td>
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<tr>
<td>Mean Efficiency</td>
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## Efficiency Summary for 2007

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<td>India</td>
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<tr>
<td>Pakistan</td>
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<td>Mean Efficiency</td>
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<td>0.793</td>
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</table>
## Patterns of Change in Efficiency (2004–2007)

<table>
<thead>
<tr>
<th>Country</th>
<th>Technical Efficiency Change, TE</th>
<th>Technological Change, TC</th>
<th>VRS Technical Efficiency Change</th>
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<td>0.959</td>
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<td>1.085</td>
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<td>Srilanka</td>
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<td>1.056</td>
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<tr>
<td>Mean Efficiency Change</td>
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<td>1.039</td>
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<td>1.001</td>
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</tr>
</tbody>
</table>
Conclusion

- **Year-wise Energy Sustainability Indices**
  - Most Efficient Countries: Bhutan, Maldives
  - Least Efficient Countries: Pakistan, India

- **Change in Productivity over time**
  - MPI suggests an overall positive change (1.02%) in TE of the region.
  - An increase in Technological Change (1.04%)
  - Region is more inclined toward Technological improvement rather than Technical improvements.
- MPI reveals progress in terms of environmental related energy efficiency for the whole region except Bangladesh.
- India and Srilanka have shown highest progress in this regard.
- The highly efficient Maldives owes it efficiency to the Technology.
Policy recommendations

- SAARC countries need to divert towards technical efficient paradigm for a sustainable economic growth.
- Pakistan has a long struggle ahead in energy-environment-growth nexus.
- Pakistan needs to adapt the policies by its peer indicated by the analysis.
- The energy sector of Pakistan needs institutional reforms to increase the energy efficiency via technological achievements.
Thank You