CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT:
analysing the linkages with Sustainomics

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WHAT ? is the sustainomics framework and its key elements

WHICH ? are the key issues linking climate change and sustainable development

HOW ? to apply sustainomics to identify practical options
Understanding Sustainomics and its key elements

Sustainable Development will be undermined by Climate Change, especially in Developing Countries

The sustainable development challenge:

• **alleviate poverty**: 1.3 billion people live on less than $1 per day and 3 billion people on less than $2 per day. Top 20% income group uses 86% of resources, while bottom 20% uses under 1.3%
• **food**: 800 million people malnourished today -- food production must double in the next 35 years
• **water**: 1.3 billion people without clean water; 2 billion without sanitation
• **energy**: 2 billion people without electricity
• **healthy environment**: 1.4 billion people exposed to dangerous levels of outdoor pollution and even larger number exposed to dangerous levels of indoor air pollution and vector-borne diseases
• **safe shelter**: many live in areas susceptible to civil strife, environmental degradation, and natural disasters
Ideal Goal:
Sustainable Development

Sustainable development is a process for improving the range of opportunities that will enable individual human beings and communities to achieve their aspirations and full potential over a sustained period of time.

Source: Munasinghe (1992)

Practical Target:
Making Development More Sustainable

‘An approach that will permit sustained improvements in the quality of life at a lower intensity of resource use, thereby preserving for future generations an undiminished or even enhanced stock of productive assets (manufactured, natural and social capital)’

Source: Munasinghe (1992)
Application Framework:

**SUSTAINOMICS**

“*meta-framework for making development more sustainable, which is transdisciplinary, integrative, comprehensive, balanced, heuristic and practical.*”

*Source:* Munasinghe (1994)

Neologism focuses attention on sustainable development and avoids suggestions of disciplinary bias or ‘hegemony’.

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**Key elements of sustainable development and interconnections**

*Source:* Munasinghe [1992]
Figure 1 (a). Elements of sustainable development
(b). Sustainable development triangle supported by the sustainomics framework.
Source: adapted from Munasinghe [1992, 1994]
Main Groups of Actors in Sustainable Development

- Business
- Governance
- Civil Society
- State

All three groups have a vital and balanced role to play

**Optimality-based approaches:**
Maximize welfare (or utility), subject to non-decreasing stock of productive assets (or welfare itself). A simple example of maximization of the flow of aggregate welfare ($W$), cumulatively discounted over infinite time ($t$), is:

$$\text{Max} \int_0^\infty W(C, Z)e^{-rt} dt.$$  

Here, $W$ is a function of $C$ (the consumption rate), and $Z$ (a set of other relevant variables), while $r$ is the discount rate. Side constraints satisfy sustainability needs – e.g., non-decreasing stocks of productive assets (including natural resources).
**Durable development paths:**
Focus mainly on sustaining the quality of life – e.g., by satisfying environmental, social and economic sustainability requirements. They permit growth, but are not necessarily economically optimal. There is more willingness to trade off some economic optimality for the sake of greater safety, in order to stay within critical economic, environmental and social limits.

A simple durability index (D) for an organism or system is its expected lifespan (in a healthy state), as a fraction of the normal lifespan:

\[ D = D(R,V,O,S) \]

specifies durability (D) as a function of resilience (R), vigour (V), organization (O), and the state of the external environment (S) – especially in relation to damaging shocks.

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**“Tunneling” to make development more sustainable:**

*Environmental Risk versus Development Level*

![Diagram showing the relationship between Environmental Risk and Development Level]

Key steps to make development more sustainable

- define development activity (project or policy)
- identify relevant indicators of sustainability (pressure, state, impact: P-S-I)
- assess vulnerability and impacts
- determine remedial response (R)
- modify development activity accordingly

Sustainable Development Assessment
(partial equilibrium analysis at the project level)

1. Economic/Financial Assessment (CBA)
2. Environmental Assessment (EA)
3. Social Assessment (SA)
4. Technical Assessment (TA)
### Incorporating Environmental Concerns Into Decisionmaking

<table>
<thead>
<tr>
<th>Environmental Systems</th>
<th>Analytical Tools and Methods</th>
<th>Decisionmaking Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
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<td>Inter-National</td>
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<td>Transnational</td>
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<td>National Macrocon.</td>
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<td>Natural Habitats</td>
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<td>Sectoral Regional</td>
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<td>Land</td>
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<td>Water</td>
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<tr>
<td>Physical, Biological, and Social Impacts</td>
<td>CONVENTIONAL ECONOMIC ANALYSIS</td>
<td>Technical-Engineering Potential Analysis</td>
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</table>

### Physical, Biological, and Social Impacts

- Environmental Systems
- Decisionmaking Structure
- Analytical Tools and Methods
Incorporating Environmental Concerns Into Decisionmaking

Environmental Systems

- Global
- Transnational
- Natural Habitats
- Land
- Water
- Urban, Indus., and Air

Analytical Tools and Methods

- Environmental Assessment
  - Physical, Biological, and Social Impacts
  - Environmental Impact
  - Environmental Valuation
  - Environmental Policy

- Environmental-Economy Interface
  - Resource Efficiency
  - Environmental Accounting

- Conventional Economic Analysis
  - National Accounts

- Decisionmaking Structure
  - Inter-National
  - National Macroecon.
  - Sectoral
  - Subsectoral
  - Project

Simple Two-Dimensional Example of Multi-criteria Analysis (MCA)

- Tradeoff Curve
- Equi-preference Curves
- Feasible set of Options

- CMAX
- BMAX
- Economic Cost
- Biodiversity Loss

A - High
B - High
C - High
The capacity of the ecosystem may become overloaded by the growing socio-economic subsystem (broken lines).

Restructuring Development and Growth

Unsustainable
Sustainable
## Expanded National Income Accounts for SD

### Input-Output Table

<table>
<thead>
<tr>
<th>Activity/Potential Impact</th>
<th>Economic</th>
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<tr>
<td>Macroeconomic and National Accounts</td>
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<td>Distribute of Income</td>
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### Distribution of Environmental Impacts

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## Action Impact Matrix (AIM) for Macro Level SDA

### Simplified Action Impact Matrix (AIM) for Macroeconomic Sustainability Analysis

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### Complementary Measures and Remedies

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### Market Based Measures

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### Non-Market Based Measures

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### Investment Projects

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### Source

Adapted from Munasinghe and Cruz [1994]
Key Issues Linking Climate Change and Sustainable Development: adaptation (and mitigation) in the context of vulnerability, poverty and equity

Future Climate: Key Conclusions

- Climate models up to 2100, project that:
  - Earth’s mean surface temp. rise of 1.4 to 5.8°C; land warmer than oceans
  - sea level rise between 9-88 cm
  - precipitation increases globally, with more heavy precipitation events
  - incidence of extreme weather events rises, e.g., floods, droughts, heat waves
  - stabilization levels between 450 and 1000 ppm of CO₂ will increase temperature and sea level by 1.5 to 9°C and 0.5 to 10 metres.

Note: Future emissions of greenhouse gases and sulfate aerosol precursors depend on population growth, economic growth, technological changes and governance structures. Increase in the atmospheric concentrations of GHGs over the next 100 years, but decreases in sulfate aerosols by 2100.
## Scenarios

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (billion)</td>
<td>5.3</td>
<td>7.0 - 15.1</td>
</tr>
<tr>
<td>World GDP (10^{12} 1990US$/yr)</td>
<td>21</td>
<td>235 - 550</td>
</tr>
<tr>
<td>Per capita income ratio: developed countries to developing countries</td>
<td>16.1</td>
<td>1.5 - 4.2</td>
</tr>
<tr>
<td>Final energy intensity (10^6 J/US$)^a</td>
<td>16.7</td>
<td>1.4 - 5.9</td>
</tr>
<tr>
<td>Primary energy (10^{18} J/US$)</td>
<td>351</td>
<td>514 - 2226</td>
</tr>
<tr>
<td>Share of coal in primary energy (%)^a</td>
<td>24</td>
<td>1 - 53</td>
</tr>
<tr>
<td>Share of zero carbon in primary energy (%)</td>
<td>18</td>
<td>28 - 35</td>
</tr>
</tbody>
</table>

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### The Global Climate of the 21st Century

![Graphs showing CO₂ emissions, CO₂ concentrations, SO₂ emissions, temperature change, and sea level rise](image-url)
Variations of the Earth’s Surface Temperature: 1000 to 2100

- 1000 to 1861, N. Hemisphere, proxy data;
- 1861 to 2000 Global, Instrumental;
- 2000 to 2100, SRES projections

Climate Change

Development

Former Viewpoint

Climate Change

Integrated CC-SD Strategy

Development

Desired Viewpoint (policy relevant)
Radiative Forcing
Climate System

Human Actions Causing GHG Emissions
Atmospheric GHG Emission and Concentration Scenarios

Feedbacks
Climate Change Stresses

Human and Natural Systems

Different Socio-economic Development Paths

Non-climate Stresses

Feedbacks

Climate Domain

Sustainable Development Domain

Atmospheric GHG Emission and Concentration Scenarios

Feedbacks

Climate Change Stresses

Human and Natural Systems

Different Socio-economic Development Paths

Non-climate Stresses

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Human and Natural Systems

Different Socio-economic Development Paths

Non-climate Stresses

Feedbacks
Causes of Development and Change

- **Economic Growth and Consumption**
- **Demographic shifts** (pop. growth and rural/urban transition)
- **Broad Technological Changes**
- **Governance Structures**
  - increased consumption of natural resources and energy
  - inefficient use of technologies and failure to invest in R&D for the technologies of the future
  - institutional and government failures to regulate the use of natural resources and energy
  - policy and market failures, including lack of recognition of the true value of natural resources; failure to appropriate the global values of natural resources to the local level; failure to internalize the social costs of environmental degradation into the market prices of resources; and subsidies that lead to inefficient use of resources and act as barriers to the market penetration of environmentally friendly technologies
**Potential Climate Change Impacts**

- **Climate Changes**
  - Temperature
  - Precipitation
  - Sea Level Rise

- **Human Health**
  - Weather-related Mortality
  - Infectious Diseases
  - Air Quality - Respiratory Illnesses

- **Agriculture**
  - Crop Yields
  - Irrigation Demands

- **Forests**
  - Forest Composition
  - Geographic Range of forests
  - Forest health and productivity

- **Water Resources**
  - Water supply
  - Water quality
  - Competition for water

- **Coastal Areas**
  - Erosion of beaches
  - Inundation of coastal lands
  - Additional costs to protect coastal communities

- **Natural Habitats**
  - Loss of habitat and species

**Adverse Impacts of Climate Change**

- decreased water availability in many water scarce regions, especially in arid and semi-arid lands in the sub-tropics
- reduction in agricultural productivity: (a) in the tropics and sub-tropics for almost any warming, and (b) in mid-latitudes for warming more than a few degrees
- changes in the productivity and composition of ecological systems, with coral reefs and forests being most vulnerable
- increased risk of floods, potentially displacing millions of people, due to sea level rise and heavy rainfall events, especially in small island states and low-lying deltaic areas
- increased incidence of heat stress mortality, and the number of people exposed to vector-borne diseases, such as malaria and dengue and water-borne diseases such as cholera, especially in the tropics and sub-tropics
Climate Change and Ecological Systems

• **Biological systems affected** by changes in climate at the regional scale

• **Structure, functioning of ecological systems altered** and the biological diversity will decrease, especially in niche systems, e.g., alpine and arctic
  - → **forests**, especially tropical and boreal forests are vulnerable due to changes in disturbance regimes (pests and fires), likely to change species composition
  - → **coral reefs** are threatened by increases in temperature, more than increases in sea level - increased mortality
  - → **terrestrial uptake of carbon** will likely diminish over time and forest systems may become a source of carbon

Beneficial Impacts of Climate Change

→ increased agricultural productivity in some mid-latitude regions for increases in warming of up to a few degrees
→ increased water availability in some water-scarce regions, e.g., in some parts of S. East Asia
→ reduced winter mortality in mid- and high-latitudes
→ increase in timber supply (with well managed forests)
Vulnerability to Climate Change

- Vulnerability is a function of three factors
  - degree of climate change
  - sensitivity of sector/system to climate change
  - adaptive capacity

Developing Countries are the Most Vulnerable to Climate Change

- Impacts disproportionately on the poorest countries and poorest persons within countries, who have contributed least GHG emissions: exacerbates inequities in health status and access to adequate food, clean water and other resources.
- Net effects negative in most developing countries, but mixed for developed countries for a warming of up to a few degrees Centigrade.
  - A warming of greater than a few degrees Centigrade is likely to result in net effects becoming negative for most countries
Why Developing Countries Are More Vulnerable:

a) Impacts are worse

<table>
<thead>
<tr>
<th>Closer to margin of tolerance</th>
<th>Coastal vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>for temperature and precipitation changes (more drought- and flood-prone areas)</td>
<td>49 out of 50 countries with shore protection costs due to climate change above 0.5% of GDP are less developed countries</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vulnerable economic structure</th>
<th>Poorer nutrition and health infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larger share of the economy in climate sensitive sectors, such as agriculture</td>
<td>and therefore higher losses of human life</td>
</tr>
</tbody>
</table>

b) Lower capacity to adapt

<table>
<thead>
<tr>
<th>Availability of technology</th>
<th>Institutional capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Know-how and education</td>
<td>Financial capacity</td>
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</tbody>
</table>
Crop Yield Change

Percentage change in average crop yields for the climate change scenario. Effects of CO₂ are taken into account. Crops modeled are: wheat, maize and rice.

Jackson Institute, University College London / Goddard Institute for Space Studies / International Institute for Applied Systems Analysis

Evidence of yearly extreme weather-related losses: 1950-99

(a)
People at Risk from a 44 cm Sea-level Rise by the 2080s
Assuming 1990s Level of Flood Protection

Vector (insect)-borne Diseases

<table>
<thead>
<tr>
<th>Disease</th>
<th>Vector</th>
<th>Population at risk (millions)</th>
<th>Present distribution</th>
<th>Likelihood of altered distribution with warming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaria</td>
<td>mosquito</td>
<td>2,100</td>
<td>(sub)tropics</td>
<td>✔ ✔</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td>water snail</td>
<td>600</td>
<td>(sub)tropics</td>
<td>✔ ✔</td>
</tr>
<tr>
<td>Filarialis</td>
<td>mosquito</td>
<td>900</td>
<td>(sub)tropics</td>
<td>✔</td>
</tr>
<tr>
<td>Onchocerciasis (river blindness)</td>
<td>black fly</td>
<td>90</td>
<td>Africa/Latin America</td>
<td>✔</td>
</tr>
<tr>
<td>African trypanosomiasis (sleeping sickness)</td>
<td>tsetse fly</td>
<td>50</td>
<td>tropical Africa</td>
<td>✔</td>
</tr>
<tr>
<td>Dengue</td>
<td>mosquito</td>
<td>unavailable</td>
<td>tropics</td>
<td>✔ ✔</td>
</tr>
<tr>
<td>Yellow fever</td>
<td>mosquito</td>
<td>unavailable</td>
<td>tropical South America &amp; Africa</td>
<td>✔</td>
</tr>
</tbody>
</table>

Likely ✔
Very likely ✔ ✔

Co-Benefits: Adaptation to Both Natural and Forced Climate Change

- **Many sectors vulnerable** (e.g., water resources and agriculture) to natural climate variability, e.g., floods and droughts associated with ENSO events
- **Identify technologies, practices and policies** that can reduce the vulnerability of sectors to natural climate variability, and can increase adaptive capacity as well as resilience to long-term climate change - examples:
  - better infrastructure design (e.g., bridges, roads, buildings)
  - incorporate modern scientific forecasts of ENSO events into sector management decisions
  - integrated multi-sector watershed management and appropriate water pricing policies
  - elimination of inappropriate agricultural subsidies

Mitigation and Burden Sharing

UNFCCC and Kyoto Protocol confirm that developed (Annex 1) countries must take lead in mitigation efforts:

- main contributors to GHG emissions
- greater financial and technical capability
Some Applications of Sustainomics to Identify Practical Options

Avoiding “dangerous anthropogenic intervention with climate system”

Source: Adapted from IPCC 1996c, Figure 5.10
SD and Macro/Sectoral Policies

- Macro/sectoral (economywide) policies are designed mainly to revive economies, boost growth, alleviate poverty, etc.
- They can have good social and environmental impacts -- e.g., economywide liberalization and market-based reforms will improve efficiency of natural resource use.
- However, growth can combine with economic imperfections to cause social and environmental damage.

Problem
- Economic expansion often interacts unfavourably with pre-existing imperfections, to cause social and environmental harm.
  - Policy distortions
  - Market failures
  - Institutional constraints

Remedy
- Introduce complementary measures to remove imperfections and reduce the vulnerability of society and the environment directly -- without reversing economywide reforms and affecting economic growth prospects.
In low growth economy with demand $D_0$, environmental degradation $Q_0$ is below the safe limit even at subsidised price $P_s$.

Macroeconomic reforms stimulate growth of demand to $D_1$ and environmental degradation $Q_1$ greatly exceeds safe limit.
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Macroeconomic reforms stimulate growth of demand to $D_1$ and environmental degradation $Q_1$ greatly exceeds safe limit.

Successive increases in resource price ($P_{en}$ and $P_{ec}$) will reduce environmental degradation to $Q_{en}$ and $Q_{ec}$ (within safe limit).

In low growth economy with demand $D_0$, environmental degradation $Q_0$ is below the safe limit even at subsidised price $P_s$.

Macroeconomic reforms stimulate growth of demand to $D_1$ and environmental degradation $Q_1$ greatly exceeds safe limit.

Successive increases in resource price ($P_{en}$ and $P_{ec}$) will reduce environmental degradation to $Q_{en}$ and $Q_{ec}$ (within safe limit).
MCA of Hydroelectric Projects

Figure 11. Average generation costs (AVC), biodiversity index (BDI), and number of resettled people (RE) by hydroelectric project. All indices are per kWh per year. Numbers of people resettled and the biodiversity index are scaled for convenience (by the multipliers $10^{-5}$ and $10^{-9}$ respectively). The values at the top of the graph indicate the annual energy generation in gigawatt hours (GWh).

Source: CEB (1987); CEB (1988); Meier and Munasinghe (1994)

Three dimensional MCA of sustainable development indicators for various hydropower options.
Source: Morimoto, Munasinghe and Meier [2000]
Developing Country Strategies
- Develop Fast (reduce vulnerability)
- Adapt (reduce impact damage)
- Mitigate (earn FX through JI etc.)
- Combine above options

Concluding Thoughts on Climate Change and Sustainable Development
- CC policies must be integrated with SD strategies
- Adaptation and vulnerability reduction is critical for developing countries (avoid adverse CC and globalisation impacts)
- Mitigation is the main obligation of industrial countries
The way forward towards Sustainable Development is by making existing development patterns more sustainable -- using the Sustainomics approach for balanced consideration of economic, environmental and social elements. In particular, maintaining and accumulating Manufactured, Natural and Human capital is vital.

Some Issues to be Explored in the Case Studies

1. Designing models and sub-models that better balance and integrate the economic, social and environmental aspects;
2. Incorporating approaches based on both optimality and durability, identifying the circumstances under which these viewpoints would be appropriate, and reconciling potential conflicts;
3. Linking the global/transnational, macroeconomic/regional/sectoral, and local/project impacts;
4. Developing methods to identify win-win situations, where development could be made more sustainable, unambiguously;
5. Developing methods to resolve situations involving trade-offs among different objectives of sustainable development;
6. Exploring the linkages among poverty, equity and climate change;
7. Testing assessment methods and associated indicators of sustainable development at the global/transnational, macroeconomic/regional/sectoral, and local/project.
Postscript: Learning from the past

“The law locks up both man and woman
Who steals the goose from off the common
And lets the greater felon loose
Who steals the common from the goose.”

19th Century Verse,
England.