Sustainable Development and Climate Change

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- “Sustainable development” was defined in 1987 by the World Commission on Environment and Development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

Aim of paper: to trace the connections between sustainable development (or sustainability) and climate change

Since climate change is the most important externality or external diseconomy affecting output negatively on a global scale, the paper first illustrates in simple economic terms the nature of this externality, and goes on to relate climate change to the concepts of weak and strong sustainability.

Conclusion: only **strong sustainability** that offsets the ongoing deterioration in climatic conditions is consistent with intergenerational equity.

A macroeconomic production function

If Y is total output or real Gross Domestic Product (GDP), K is capital, L labor, T the level of technology, and Q environmental quality, total output in any year can be expressed as

$$Y = f(K, L, T, Q), \qquad (1)$$

where Y varies positively with all the variables in the production function f.

Environmental quality Q is a multidimensional variable that is hard to quantify. It is here replaced by the **atmospheric concentration of greenhouse gases, G**, as a variable that affects negatively not only the level of output, but the quality of life more generally via a rise in global temperature, with its adverse ecological and economic effects that include extreme and potentially catastrophic weather patterns.

If G is a proxy variable for Q, eq. (1) is rewritten as

$$Y = F(K, L, T, G), \tag{2}$$

where $\partial F/\partial K$, $\partial F/\partial L$ and $\partial F/\partial T$ are all positive and $\partial F/\partial G$ is negative.

Writing F_K for $\partial F/\partial K$, etc., and differentiating Y with respect to time t, we obtain

$$dY/dt = F_K(dK/dt) + F_L(dL/dt) + F_T(dT/dt) + F_G(dG/dt). \qquad (3)$$

The growth of output depends positively on the growth of the capital stock, that of the labor force, and on technical change; and negatively on the growth of the stock of greenhouse gases.

Determinants of the growth of K

If I is the rate of gross investment and D the annual depreciation of the capital stock, the growth of the capital stock is given by the accounting identity

$$dK/dt = I - D. \qquad (4)$$

Determinants of the growth of G

Let A be the amount of greenhouse gases that is naturally absorbed within the year by the land biosphere and the surface water of the ocean, as well as by policies such as reforestation.

By analogy with (4), the growth of the stock of greenhouse gases is given by the accounting identity

$$dG/dt = E - A, \quad (5)$$

where E is the rate of emissions.

Substituting (4) and (5) into (3), we obtain

$$dY/dt = F_K (I - D) + F_L(dL/dt) + F_T(dT/dt) + F_G (E - A). \qquad (6)$$

The Kaya (1990) Identity

The level E of emissions can be decomposed by the so-called **Kaya Identity** into

$$E = N \times (Y/N) \times (J/Y) \times (E/J), \qquad (7)$$

where N = population,

Y/N = per capita income (or GDP per capita),

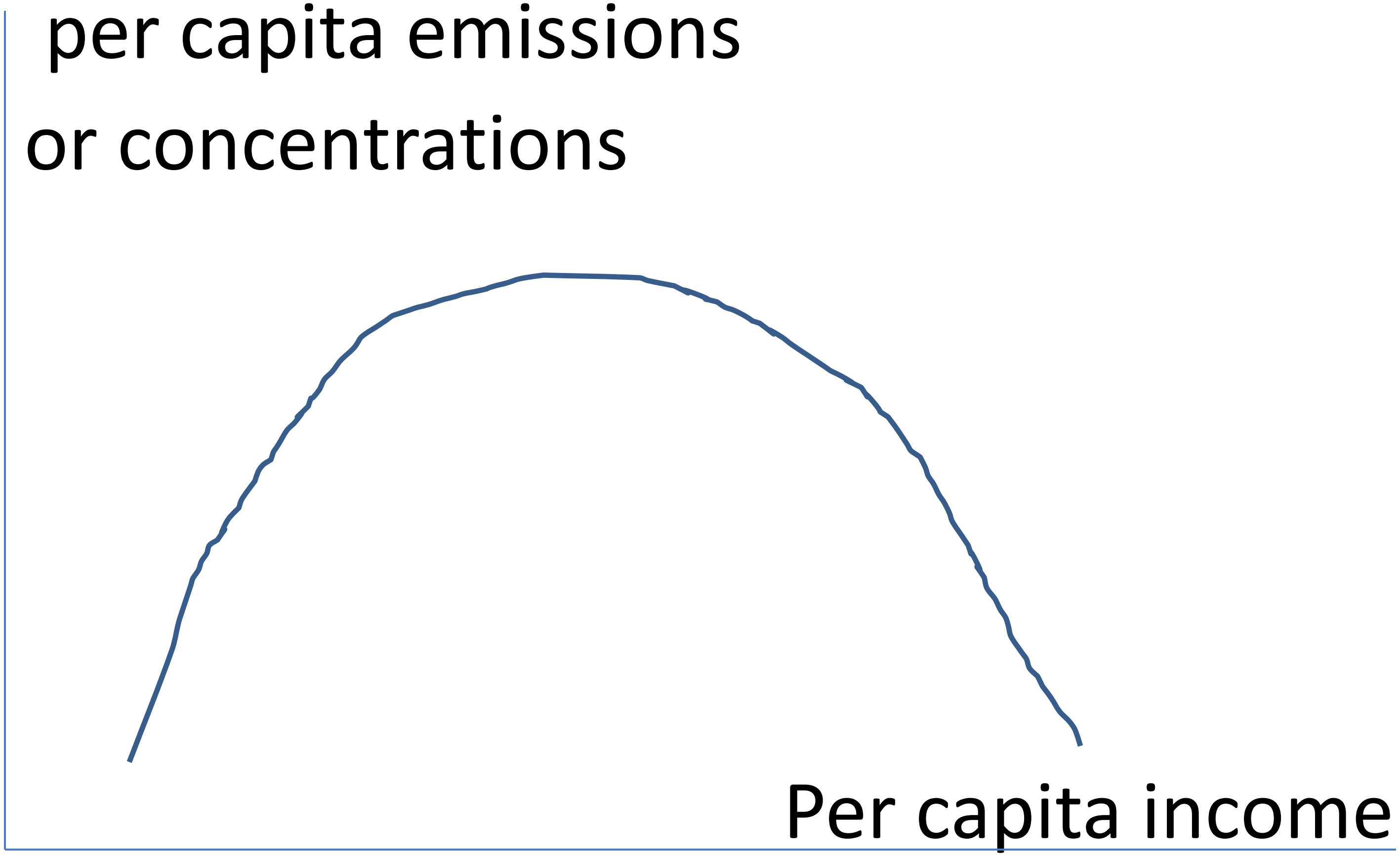
J/Y = the *energy intensity* of GDP measured in joules J of energy per unit of GDP,

E/J = the *carbon intensity* of energy use measured in emissions of carbon dioxide per joule of energy use.

The Kaya identity shows that emissions will be greater, the greater are population, per capita income, energy intensity and carbon intensity. It may alternatively be written in terms of emissions per capita as

$$E/N = (Y/N) \times (J/Y) \times (E/J). \qquad (7a)$$

A hypothetical EKC



Does an EKC exist for carbon dioxide emissions?

- If this were true with regard to carbon dioxide, economic development would automatically lead to a decline in global emissions without the need for additional policies on the part of the government.

- While the environmental Kuznets curve has been confirmed for some local pollutants such as nitrogen oxides and sulfur dioxide, it fails with regard to greenhouse gases such as carbon dioxide (CO_2). The reduction of the emissions of CO_2 (used here as a shorthand for greenhouse gases) takes the nature of a public good.

Time trends of the components of the Kaya Identity

- Global emissions have risen over time because of the worldwide growth of population and per capita income, both of which expanded by around 80% over the period 1970-2005.

- Greenhouse gas intensity fell much more modestly by around 20% over the same period, so that the net change in emissions between 1970 and 2005 was an increase of 75%.

A.E. Dessler, Introduction to Modern Climate Change (2012)

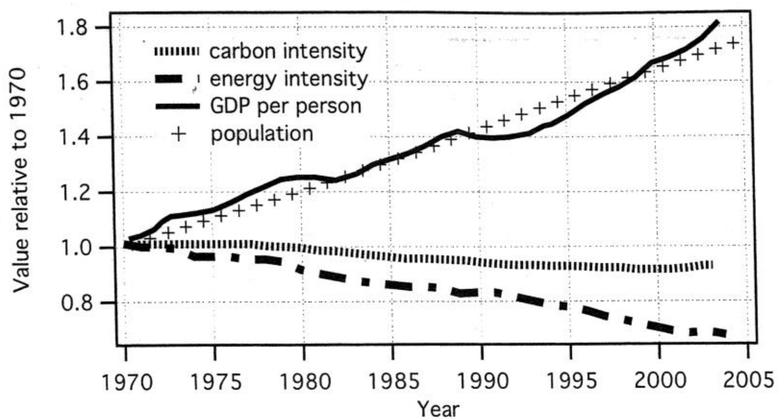


Fig. 8.1 Population, affluence, carbon intensity, and energy intensity for the entire world, relative to values in 1970 (adapted from IPCC, 2007b, Fig. 2).

Intergovernmental Panel on Climate Change (IPCC)

- The Intergovernmental Panel on Climate Change (or IPCC) has published several emissions scenarios based on different assumptions about how the world's ecology and economy might evolve in the course of the 21st century (IPCC, 2000).

Projected rise in the atmospheric concentration of CO_2

- By integrating $dG/dt = E - A$ over time, emissions scenarios are converted by means of carbon-cycle models into time series of the atmospheric concentration of CO_2, starting from a level of 390 ppm (parts per million) in 2010 and reaching levels between 550 and 900 ppm in 2100.
- Even the lower limit of 550 ppm represents twice the atmospheric concentration of CO_2 in pre-industrial times, while the upper limit more than triples that level.

Resulting rise in average temperature

- The atmospheric concentrations of CO_2 produced by the different emissions scenarios are then fed into climate change models to calculate the projected radiative forcing. The ensuing rise in average global surface temperature by the end of the 21st century ranges between 1.8 and 3.6 ^{o} C (compared to the increase of 0.7 ^{o} C experienced in the 20th century).

The consequences of the projected rise in average temperature are reflected in the negative partial derivative $\partial F/\partial G$ of the production function

$Y = F(K, L, T, G)$.

Impacts will vary widely across latitudes and climate zones.

N. Stern's warning in the *Stern Review*

- "With 5-6 ^{o} C warming, models that include the risk of abrupt and large-scale climate change estimate a 5-10 % loss in global GDP, with poor countries suffering costs in excess of 10%. The risks, however, cover a very broad range and involve the possibility of much higher losses" (Stern, 2007, p. 161).

In addition to the purely economic effects of climate change, Stern takes into account three additional factors that multiply the possibilities of adverse effects: the direct "non-market" impacts on the environment and human health, the scientific evidence that amplifying feedback in the climate system can cause it to be more responsive to greenhouse gas emissions than was previously thought, and the disproportionate burden these may have on poor countries.

"Putting these three additional factors together would increase the total cost of BAU climate change to the equivalent of around a 20% reduction in current per-capita consumption, now and forever".

Climate change and the sustainability of output

- Sustainable development, or "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" can alternatively be defined as non-declining per capita economic welfare.
- It can be made more precise by analyzing the composition of a society's aggregate **capital stock**, and seeing how it changes over time in response to ecological and economic trends.

Weak sustainability

Weak sustainability assumes that all types of capital – natural, produced and human – are inherently substitutable, so that any depletion of natural capital (the climate, agricultural land, biomass, fisheries, national parks, the ozone layer, unpolluted air and water, fossil fuels, and so on) can be compensated for by appropriate increases in human capital (skilled labor, an educated population, scientists and engineers, managerial staff) or in produced or physical capital (factories, machines, buildings, infrastructure of various types).

Strong sustainability

Strong sustainability holds that no other type of capital can substitute for natural capital. Global warming leads to the degradation of the climate, an essential or “critical” form of natural capital, and thus clearly violates the strong sustainability criterion. Proponents of strong sustainability argue that natural capital is a *complement* and not a *substitute* for other forms of capital.

Strong sustainability and intergenerational equity

- According to the ethical perspective of intergenerational equity, future generations are entitled to a climate (and related standard of living) comparable to the present one. This calls for the mitigation of the emission of greenhouse gases (GHGs) and preliminary steps toward adaptation to the global warming that will occur even if the emission of GHGs were to come to an immediate end.

As shown by the differential form of the production function (2),

$$dY/dt = F_K(dK/dt) + F_L(dL/dt) + F_T(dT/dt) + F_G(dG/dt) \quad (3)$$

a buildup of greenhouse gases represented by $dG/dt > 0$ would lead to a fall in output unless compensated for by capital accumulation, labor force growth, or technical progress. According to the criterion of weak sustainability, the harmful effects of greenhouse gases and the resulting loss of natural capital can be neutralized by means of capital accumulation.

Strong sustainability implies $dG/dt \leq 0$

The harmful effects on welfare due to the growth of G go beyond the negative effects on output given by F_G (dG/dt), and suggest the superiority of the strong sustainability criterion. For this purpose, expression (3) for the growth of output,

$$dY/dt = F_K(dK/dt) + F_L(dL/dt) + F_T(dT/dt) + F_G(dG/dt),$$

should be made subject to the constraint

$$dG/dt \leq 0 . \qquad (8)$$

In light of (5), an alternative way of writing the inequality constraint

$$dG/dt \leq 0 \quad (8)$$

is

$$A \geq E, \quad (8a)$$

which stipulates that the natural and policy-induced absorption of greenhouse gases should exceed or equal the level of emissions.

Safe minimum standards and the precautionary principle

- Two other principles are consistent with and complement strong sustainability, although neither has been rigorously defined. The adoption of **safe minimum standards** can guard against the uncertainty and potential harm surrounding long-term environmental outcomes. Sustainable development is also consistent with the adoption of the **precautionary principle** advanced in Article 15 of the 1992 Rio Declaration on Environment and Development: "Where there is a threat of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation".

- Stern also maintains that “the global environmental and ecological system, which provides us with life support functions such as stable and tolerable climatic conditions, cannot be substituted” (Stern, 2007, p. 48).

Final thought

If sustainable development is to be more than a popular slogan or a passing fad, it should be firmly anchored in the concept of “strong sustainability”, which implies that neither technical change nor any other form of capital can substitute for natural capital, particularly in the form of climatic conditions.

Thank you for your attention