Lecture 12: Sustainable Development

ECON7720: Ecological and Environmental Economics

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Recap of Lecture 11

- Ecosystem services (provisioning, regulating, cultural, supporting) underpin all economic activity.
- Costanza et al. estimated global ecosystem services at US$125–145 trillion/yr, exceeding world GDP.
- The biodiversity crisis (habitat loss, overexploitation, pollution, climate change, invasive species) threatens these services.
- Policy tools: Payments for Ecosystem Services (PES), conservation auctions, biodiversity offsets, Individual Transferable Quotas (ITQs), marine protected areas.

Lecture Outline

1. Part 1: What is sustainable development?
2. Part 2: Notions of sustainability
3. Part 3: Economic development and the environment
4. Part 4: Measuring sustainability

Part 1: What Is Sustainable Development?

What is sustainable development?

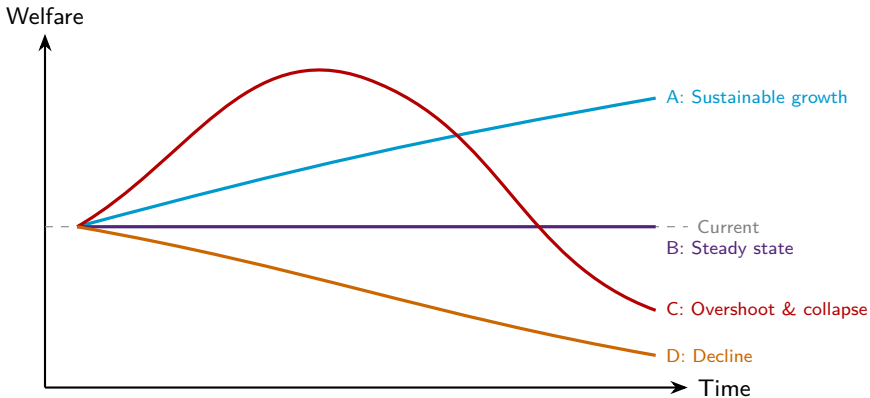
"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

— *Our Common Future*, WCED (1987)

The sustainable path

1. Existence: Does a positive sustainable level of welfare exist?
   - Can the economy sustain a positive standard of living indefinitely, or will resource depletion/degradation eventually undermine production?
2. Magnitude: How does the sustainable level compare with current welfare?
   - Is the sustainable path above or below today's consumption?
   - If below, current welfare is "borrowing from the future."
3. Intergenerational equity: Sensitivity of future welfare to actions by previous generations.

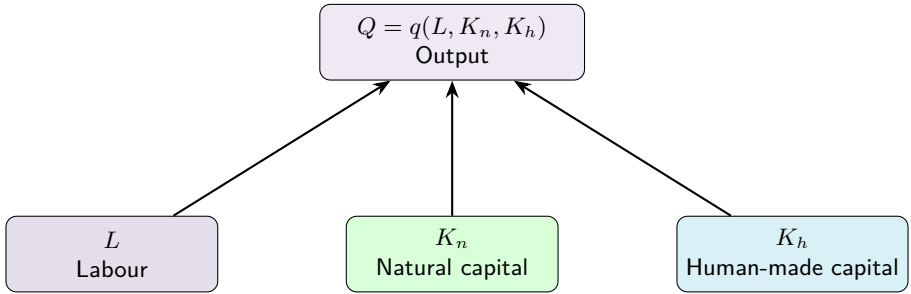
Possible alternative futures



- Path A requires investment in capital to offset resource depletion.
- Path C illustrates the "Limits to Growth" scenario.

The economy's production function

Aggregate production function



- Sustainability requires maintaining the productive capacity of this system over time.

Natural capital (K_n)

Definition

Natural capital comprises all naturally provided assets: water, land, minerals, fish stocks, forests, the atmosphere, genetic material, and ecosystem services.

- Renewable natural capital (forests, fisheries, freshwater) can regenerate if harvested within sustainable yields.
- Non-renewable natural capital (fossil fuels, minerals) is depleted by extraction; substitutes must be found.
- Environmental sinks (atmosphere, oceans) absorb waste within assimilative capacity; overloading causes degradation.
- Some natural capital is irreplaceable: biodiversity, stratospheric ozone layer, stable climate system.

Human-made capital (K_h)

- Physical capital (K_p): plant, equipment, buildings, infrastructure.
  - Accumulated by devoting part of current production to investment rather than consumption.
- Human capital (K_{hc}): embodied skills and knowledge in the labour force.
  - Education, training, and experience make labour more productive.
- Intellectual capital (K_{ic}): disembodied (codified, transferable) knowledge and technology.
  - The state of technology; accumulated through R&D and innovation.
  - Can offset declining natural capital (e.g., renewable energy replacing fossil fuels).

To what extent can K_h substitute for K_n? This determines the type of sustainability we pursue.

Club of Rome: *Limits to Growth* (1972)

- Meadows et al. (1972) used the **World3** computer model to simulate interactions between population, industrial growth, food production, and resource depletion.
- Base-case prediction: overshoot and collapse by the mid-21st century if trends continued unchanged.
- The report was hugely influential but also controversial:
  - Critics argued it ignored price signals, technological change, and substitution possibilities.
- 2004 update (*Limits to Growth: The 30-Year Update*) confirmed the original trajectories remained plausible.
- The report raised the question of whether economic growth can continue indefinitely on a finite planet.

From MDGs to SDGs

- Millennium Development Goals (2000–2015): 8 goals focused primarily on poverty reduction in developing countries.
  - Notable successes: halved extreme poverty; primary school enrolment reached 91%.
  - Criticisms: top-down; environmental sustainability was only one of eight goals (Goal 7); insufficient integration.
- Sustainable Development Goals (2015–2030): 17 goals, 169 targets; universal.
  - Integrate the "three pillars": economic, social, environmental.
  - Explicitly address inequality, climate, oceans, biodiversity, institutions, and partnerships.
  - Voluntary; progress monitored through national reviews.

The UN Sustainable Development Goals (2015–2030)



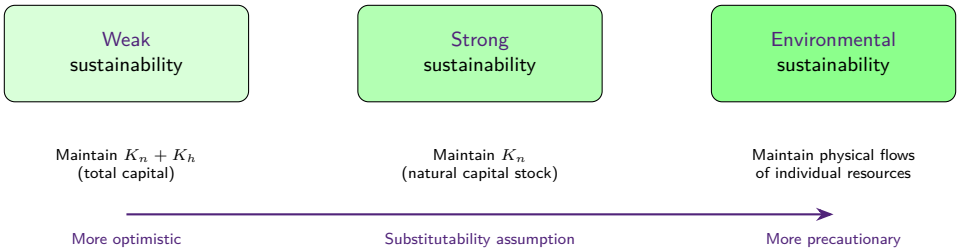
- Progress on one goal can support or hinder others (e.g., energy access vs. climate action).

The tension between growth and sustainability

- Optimistic view: technological progress, substitution, and institutional adaptation can decouple growth from environmental degradation ("green growth").
- Pessimistic view: biophysical limits are real and binding; continued growth on a finite planet will inevitably lead to overshoot ("degrowth" or "steady-state" economy).
- Middle ground: growth is necessary for poverty reduction, but *qualitative* change in the composition and technology of production is essential.
- The debate is ultimately about substitutability:
  - Can human-made capital replace natural capital sufficiently?
  - Are there critical thresholds beyond which natural systems collapse irreversibly?

Part 2: Notions of Sustainability

Three definitions of sustainability



Environmental sustainability

Maintain the physical flows of individual resources, not just the aggregate value.

- The most restrictive criterion: each resource flow must be maintained separately.
- Example: a fishery must be harvested at or below the maximum sustainable yield; a mineral must not be depleted faster than substitutes are developed.
- Maintaining the *value* of an aggregate is not sufficient if individual critical resources are degraded.
- Practical challenges:
  - Difficult to monitor all individual resource flows.
  - May be economically costly; may conflict with efficiency.
  - But may be necessary for ecological resilience, i.e., keeping ecosystems above the thresholds beyond which they collapse irreversibly.
- Associated with Goodland (1995) and the ecological economics tradition.

Strong sustainability

The value of the stock of natural capital should not decrease, regardless of changes in human-made capital.

- Assumes natural and human-made capital are largely complements, not substitutes.
- Emphasises critical natural capital: natural assets for which no adequate substitute exists.
  - Biodiversity, the ozone layer, a stable climate, fertile topsoil, freshwater systems.
- Once critical thresholds are crossed, degradation may be irreversible.
- Policy implication: safe minimum standards, precautionary principle, non-negotiable environmental constraints.
- Associated with ecological economics tradition (Daly, 1996; Costanza et al., 1997).

Weak sustainability

The total value of all capital ($K_n + K_h$) should not decline over time.

- Assumes natural and human-made capital are substitutable: running down K_n is acceptable if K_h increases by at least as much.
- Example: depleting an oil reserve is sustainable if the rents are invested in education, infrastructure, or technology.
- The substitutability assumption may be too strong for some forms of natural capital (e.g., biodiversity, climate stability).
- Associated with the neoclassical growth tradition (Solow, 1974; Hartwick, 1977).

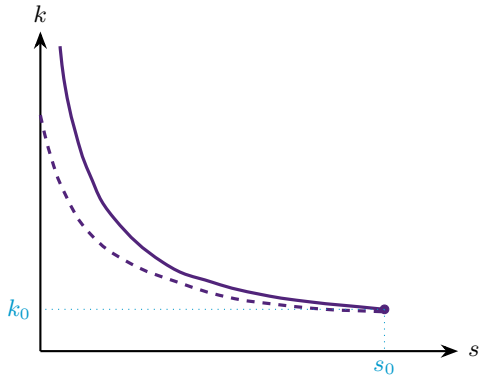
Hartwick's Rule (1)

If all scarcity rent (marginal user cost $\times$ quantity extracted) from depleting non-renewable resources is invested in reproducible capital, a constant level of consumption can be maintained in perpetuity.

- Scarcity rent $= P - MC$ (marginal user cost) for each unit extracted.
- The rule ensures the total capital stock does not change: $\Delta K_h + \Delta K_n = 0$.
- If the value of total capital is declining, the allocation is not sustainable under weak sustainability.
- Assumptions:
  - Perfect substitutability between K_n and K_h.
  - Constant returns to scale.
  - No population growth (or sufficient productivity growth).

Hartwick's Rule (2)

- The economy starts at (k_0, s_0) with a large resource stock and little capital.
- The solid curve shows the efficient and egalitarian path: as s is depleted, all rents are invested in k.
- Along this path, consumption remains constant across generations.



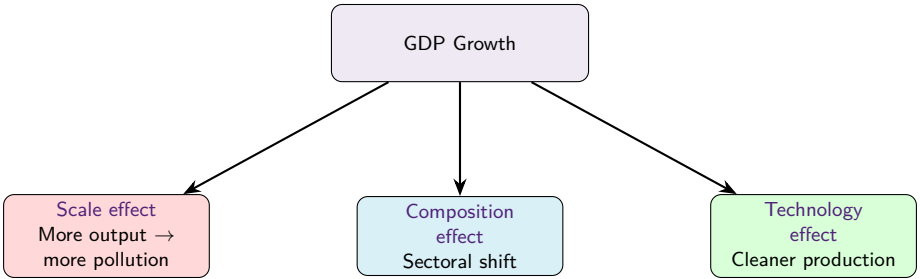
Source: Asheim (2013)

Part 3: Economic Development and the Environment

Growth vs development

- Economic growth: increases in aggregate output, typically measured by GDP.
  - A country's GDP can grow while per-capita welfare stagnates (if population grows faster).
- Economic development: increases in per-capita output *and* broader measures of well-being.
  - Includes improvements in health, education, institutional quality, and environmental quality.
- Growth is *necessary but not sufficient* for development.
- The environmental question: does economic growth inevitably degrade the environment, or can growth be "green"?

How does GDP growth affect the environment?



Net environmental impact = scale + composition + technology

The scale effect

- Holding technology and composition constant, a larger economy produces more pollution and resource extraction.
- Doubling GDP roughly doubles total emissions/waste (in the absence of other changes).
- This is the mechanism behind the "Limits to Growth" concern: if the scale effect dominates, growth is inherently unsustainable.
- Empirically, the scale effect is powerful:
  - Global material extraction grew from 27 Gt (1970) to 92 Gt (2017).
  - Global CO_2 emissions grew from 22 Gt (1990) to 37 Gt (2023).
- But the scale effect can be offset by composition and technology effects.

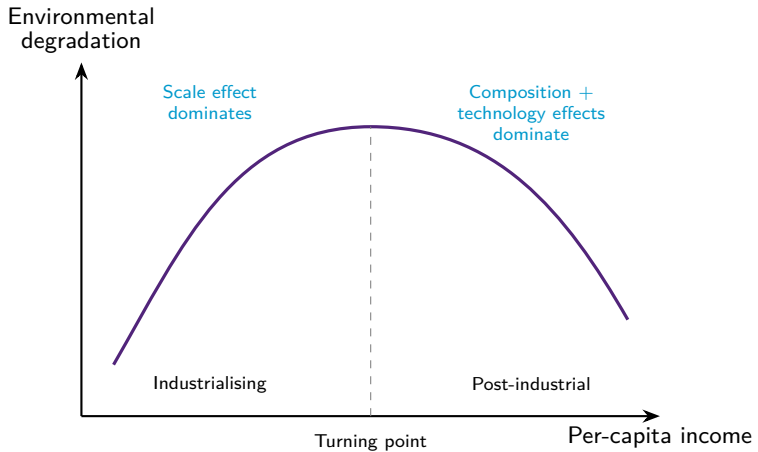
The composition effect

- As economies develop, the sectoral mix changes:
  1. Agriculture → Manufacturing → Services
- Early industrialisation: shift from agriculture to heavy manufacturing increases pollution intensity.
- Later development: shift from manufacturing to services decreases pollution intensity per unit of GDP.
- Example (share of GDP in services):
  - Low-income countries: ∼45%
  - High-income countries: ∼70%
- But globalisation complicates this: rich countries may outsource pollution-intensive production to developing countries.

The technology effect

- Technological progress makes production cleaner per unit of output.
- Examples:
  - SO_2 emissions per kWh of electricity have fallen $>$90% in OECD countries since 1970.
  - LED lighting uses $\sim$85% less energy than incandescent bulbs.
  - Internal combustion engine efficiency has doubled since 1975.
- Technology can be induced by:
  - Rising resource prices (scarcity-driven innovation).
  - Environmental regulation (Porter hypothesis).
  - R&D investment and knowledge spillovers.
- The rebound effect (Jevons' paradox): efficiency gains may increase total resource use if they lower effective prices.
- Net impact depends on whether the technology effect outpaces the scale effect.

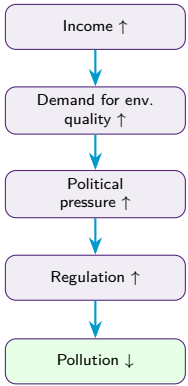
The Environmental Kuznets Curve (EKC)



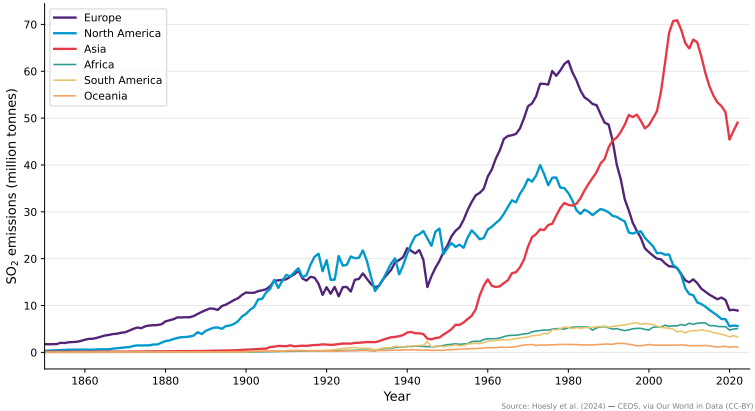
- The EKC hypothesises an inverted U-shaped relationship between per-capita income and environmental degradation.

EKC: The underlying mechanism

- Environmental quality is a normal good: as incomes rise, people demand more environmental quality.
- At **low incomes**, growth and basic needs come first, so pollution rises with industrialisation.
- At **higher incomes**, citizens demand cleaner air and water, governments respond with regulation, and firms adopt cleaner technologies.
- Preferences can translate into change through regulation or through market demand for greener products, but neither channel is automatic.



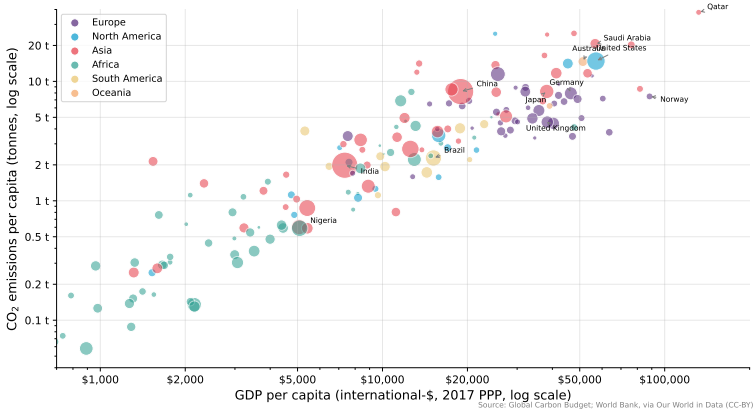
EKC: Evidence FOR — SO_2 emissions by world region



Interactive version: ourworldindata.org/grapher/so-emissions-by-world-region-in-million-tonnes

- EKC evidence is strongest for local, short-lived pollutants like SO_2, CO, and lead, where direct health effects trigger regulation as incomes rise (Grossman & Krueger, 1995).

EKC: Evidence AGAINST — CO_2 emissions vs GDP per capita



Interactive version: ourworldindata.org/grapher/co2-emissions-vs-gdp

- EKC evidence is weakest for global, long-lived pollutants like CO_2, where no turning point has been observed at current income levels.

Trade and environment: Pollution haven hypothesis

- Pollution haven hypothesis (PHH): differences in environmental regulation create a comparative advantage for pollution-intensive industries in countries with lax standards.
- Trade liberalisation $\Rightarrow$ pollution-intensive production shifts to developing countries $\Rightarrow$ global pollution does not decrease, it relocates.
- This would explain why rich countries appear to reduce pollution (composition effect) while global pollution continues to rise.
- If the PHH holds, the EKC for rich countries is partly an artifact of trade, they have "exported" their pollution.

Trade liberalisation and environmental quality

- Copeland & Taylor (2004) decompose the environmental impact of trade into the familiar three effects:
  1. Scale effect: trade increases output → more pollution (negative).
  2. Composition effect: countries specialise according to comparative advantage → pollution may increase or decrease depending on specialisation pattern.
  3. Technique effect: trade raises incomes → demand for regulation rises → cleaner technologies adopted (positive).
- Net effect is ambiguous and depends on:
  - Whether countries specialise in clean or dirty industries.
  - The strength of income-induced demand for regulation.
  - The presence and enforcement of environmental policy.
- Free trade agreements increasingly include environmental provisions (e.g., USMCA-ex NAFTA, EU trade agreements).

Globalisation and sustainability

- Globalisation amplifies both opportunities and risks for sustainability:
- Opportunities:
  - Diffusion of clean technologies (e.g., solar panels manufactured in China deployed globally).
  - Higher incomes in developing countries $\rightarrow$ demand for environmental quality.
  - International environmental agreements (Paris, Montreal).
  - Global supply chain standards (Environmental, Social, and Governance—ESG; Taskforce on Nature-related Financial Disclosures—TNFD).
- Risks:
  - Increased material throughput (scale effect).
  - Pollution leakage via trade.
  - Race to the bottom in governance-weak countries.
  - Transport emissions from global supply chains.

Degrowth and beyond-GDP perspectives

Is infinite growth on a finite planet possible?

- Degrowth: a school of thought (primarily ecological economics) arguing that wealthy nations should deliberately *reduce* GDP to stay within planetary boundaries.
- Key argument: "green growth" (decoupling GDP from environmental impact) has not been achieved at the scale needed, especially for GHGs.
- Counter-arguments:
  - GDP growth enables poverty reduction in developing countries.
  - Innovation (driven by growth) is needed for clean technologies.
  - Political feasibility: no electorate has voted for degrowth.
- Middle ground: focus on what grows (services, wellbeing, clean energy) rather than whether GDP grows. Measure progress with inclusive wealth indicators, not GDP alone.

Part 4: Measuring Sustainability

Why GDP is inadequate

- Gross Domestic Product measures the market value of final goods and services produced in an economy.
- Problems as a measure of well-being:
  1. Counts remediation as gain: money spent cleaning up pollution or after natural disasters *increases* GDP.
  2. Ignores natural capital depreciation: GDP counts the revenue from mining and logging but not the loss of the resource stock.
  3. Ignores inequality: per-capita GDP can rise while poverty increases.
  4. Ignores non-market production: unpaid household work, volunteer activities, ecosystem services not counted.
  5. Ignores environmental externalities: pollution costs are not subtracted from output.

From GDP to NDP

Net Domestic Product

$$\text{NDP} = \text{GDP} - \text{Depreciation of produced capital}$$

- NDP subtracts the wearing out of physical capital (buildings, machinery, infrastructure).
- A step in the right direction: recognises that some output merely replaces worn-out capital, not a net gain.
- But NDP still ignores the depreciation of natural capital.
- Green GDP (Environmentally Adjusted NDP):

$$\text{Green GDP} = \text{NDP} - \text{Depreciation of natural capital} - \text{Pollution damage costs}$$

- China experimented with Green GDP in 2004 but abandoned it when results showed growth was much lower than official figures (Li & Lang, 2010).

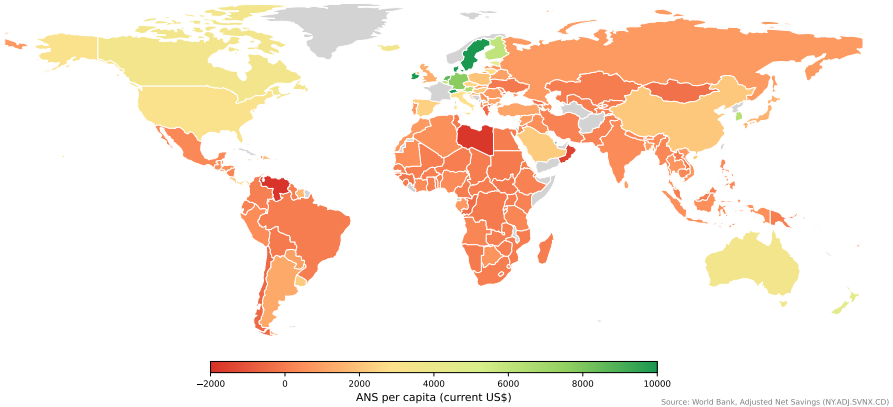
Adjusted Net Savings (ANS)

World Bank definition

$$
\begin{aligned}
\text{ANS} = {} & \text{Net national savings} \\
& + \text{Education expenditure (human capital investment)} \\
& + \text{R\&D expenditure (intellectual capital investment)} \\
& - \text{Depletion of energy, minerals, and forests} \\
& - \text{Pollution damage } (CO_2,\ PM_{2.5})
\end{aligned}
$$

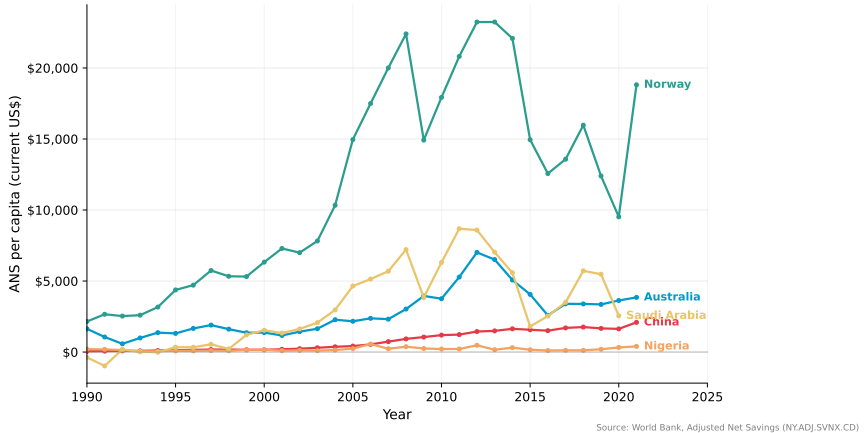
- ANS $= \Delta$(total capital stock): change in the value of all of a nation's capital.
- ANS $> 0 \Rightarrow$ the economy is weakly sustainable: total wealth is not declining.
- ANS $< 0 \Rightarrow$ the economy is depleting its capital base: unsustainable.

ANS: Global patterns



- Limitations: does not capture all natural capital depreciation (e.g., biodiversity, soil); valuation of education as "investment" is crude; does not distinguish critical from substitutable natural capital.

ANS: Temporal trends by country



- China and Norway consistently above the sustainability threshold; Saudi Arabia volatile due to oil price swings; Nigeria dips below zero when resource rents are consumed rather than invested.

Other measures of sustainability

- **Human Development Index (HDI):** combines longevity, education, and income (GNI per capita). Ranges 0–1; Australia ≈ 0.95. Multidimensional but excludes environmental quality.
- **Gross National Happiness (GNH):** Bhutan's 9-dimension framework (well-being, time use, community, culture, health, education, environment, living standard, governance). 148 indicators. Context-specific but highlights: what we measure shapes what we prioritise.
- **Inclusive Wealth Index (IWI):** total value of produced + human + natural capital at shadow prices. A nation is sustainable iff IWI per capita is non-declining. Many countries show rising GDP but declining natural capital.
- **Ecological Footprint:** area of productive land/water (gha/cap) needed to support consumption. If footprint $>$ biocapacity $\Rightarrow$ ecological deficit. Global overshoot: humanity uses $\sim$1.7 Earths.
- **Genuine Progress Indicator (GPI):** adjusts personal consumption for inequality, non-market contributions (household work), and environmental costs. In many countries, GPI has stagnated since the 1970s while GDP kept growing (Daly & Cobb, 1989).

Appendix

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