BEYOND GDP: MEASURING SUSTAINABILITY THROUGH INCLUSIVE WEALTH

Pushpam Kumar
Chief Environmental Economist, UN Environment

UNEP has been recognising this…

Maurice Strong (front left, at the 1972 UN Conference on the Human Environment) sought an alternative to the GDP. *Image: UN Photo/Yutaka Nagata*

Science and Practitioners…

Science

- Kuznets 1941
- Hicks 1948
- Samuelson 1961
- Nordhaus and Tobin 1972
- Daly 1977
- Hartwick 1990
- Timbergen 1992
- Arrow, Dasgupta et al 1995
- Weitzman 1997
- Dasupta and Maler 2000
- Dasgupta 2001, 2009, 2011, 2018

United Nations

- UN development agenda
- Rio+20
- CBD revised Nagoya Strategy 2010
- SEEA revision 2012/13:

Others

- Beyond GDP Conference, Brussels 2007
- Potsdam 2007 G8+5 initiative
- Stiglitz/ Sen/ Fitoussi report Paris 2009
- Ecosystem Capital Accounts fast track project in Europe (2009-2012)

Wealth and Well Being

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The accounting value of an economy's stock of capital goods is its inclusive wealth.

1. If inclusive wealth increases (no matter what the cause of the rise happens to be), social well-being (the well-being of contemporary people and the potential well-being of future generations) increases.
2. Similarly, if inclusive wealth declines (no matter what the cause of the fall happens to be), social well-being declines

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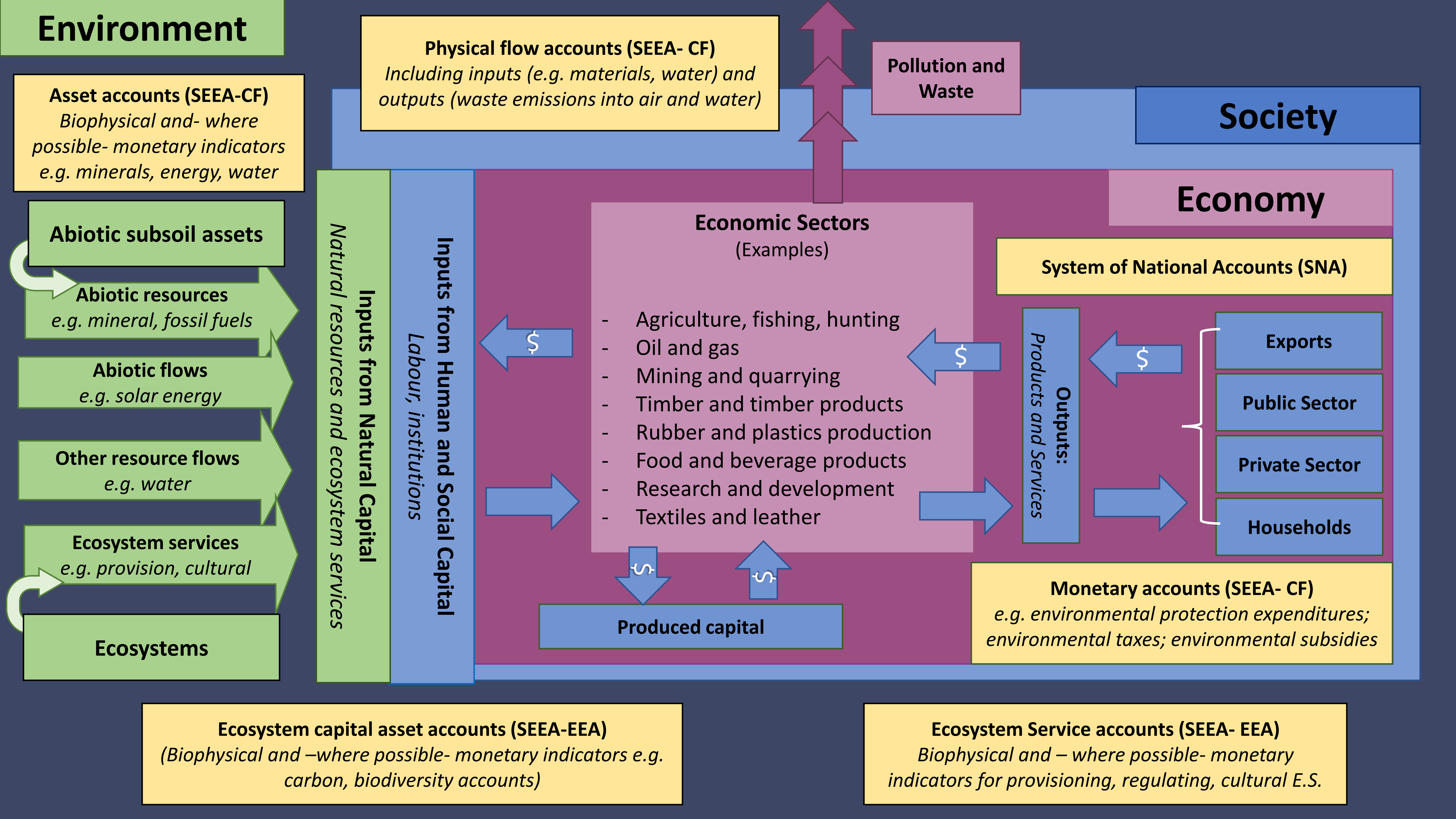
Sustainable management of natural capital for sustainable development and poverty eradication


Environment
Physical flow accounts (SEEA- CF)
Including inputs (e.g. materials, water) and outputs (waste emissions into air and water)
Pollution and Waste
Society
Asset accounts (SEEA-CF)
Biophysical and- where possible- monetary indicators e.g. minerals, energy, water
Abiotic subsoil assets
Abiotic resources
e.g. mineral, fossil fuels
Abiotic flows
e.g. solar energy
Other resource flows
e.g. water
Ecosystem services
e.g. provision, cultural
Ecosystems
Inputs from Natural Capital
Natural resources and ecosystem services
Inputs from Human and Social Capital
Labour, institutions
Economy
Economic Sectors
(Examples)
- Agriculture, fishing, hunting
- Oil and gas
- Mining and quarrying
- Timber and timber products
- Rubber and plastics production
- Food and beverage products
- Research and development
- Textiles and leather
$
$
$
$
$
System of National Accounts (SNA)
Outputs:
Products and Services
Exports
Public Sector
Private Sector
Households
Produced capital
Monetary accounts (SEEA- CF)
e.g. environmental protection expenditures; environmental taxes; environmental subsidies
Ecosystem capital asset accounts (SEEA-EEA)
(Biophysical and –where possible- monetary indicators e.g. carbon, biodiversity accounts)
Ecosystem Service accounts (SEEA- EEA)
Biophysical and – where possible- monetary indicators for provisioning, regulating, cultural E.S.

Inclusive Wealth Index (Adjusted)

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Factors affecting IWI

1. Carbon Damages
2. Oil Capital Gains
3. Total Factor Productivity

Components of IWI

Natural Capital + Human Capital + Produced Capital

Natural Capital

1. Fossil Fuels : Oil, Natural gas, Coal
2. Minerals : Bauxite, Nickel, Copper, Phosphate, Gold, Silver, Iron, Tin, Lead & Zinc
3. Forest resources : Timber & Non-timber forest resources
4. Agricultural Land: Cropland, Pastureland

Human Capital

1. Education
2. Health

Produced Capital

1. Equipment
2. Machineries
3. Roads
4. Others

Natural Capital

Sub-Soil Assets:
(Geological resources)

Minerals, earth elements, fossil fuels, gravel, salts , etc

Non-renewable and depletable

Abiotic Flows:
(linked to geophysical flows)

Solar, wind, hydro, geo-thermal, etc.

Renewable and non-depletable

Ecosystem Capital:
(linked to ecological systems and processes)

Ecosystems assets (stock):

- Structure and condition

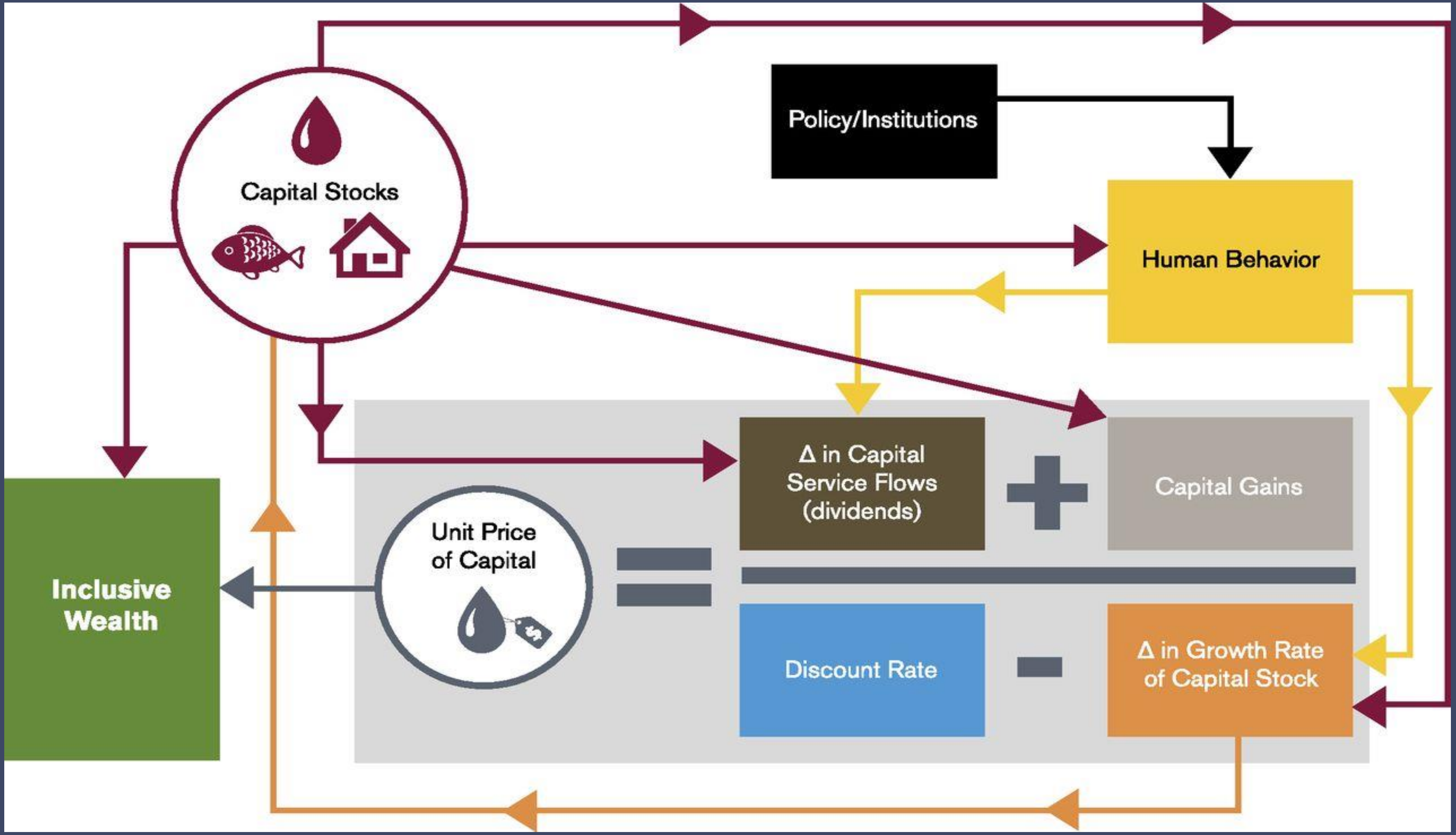
Ecosystems services (flows):

- Provisioning
- Regulation and maintenance
- Cultural services

Renewable and depletable

Source: MAES analytical framework, European Commission (2013)

Inclusive Wealth: Methodological Approach



Adapted from Proceedings of National Academy of Sciences (PNAS) , March 1, 2016.

Methodology and Underpinning of IWR 2018

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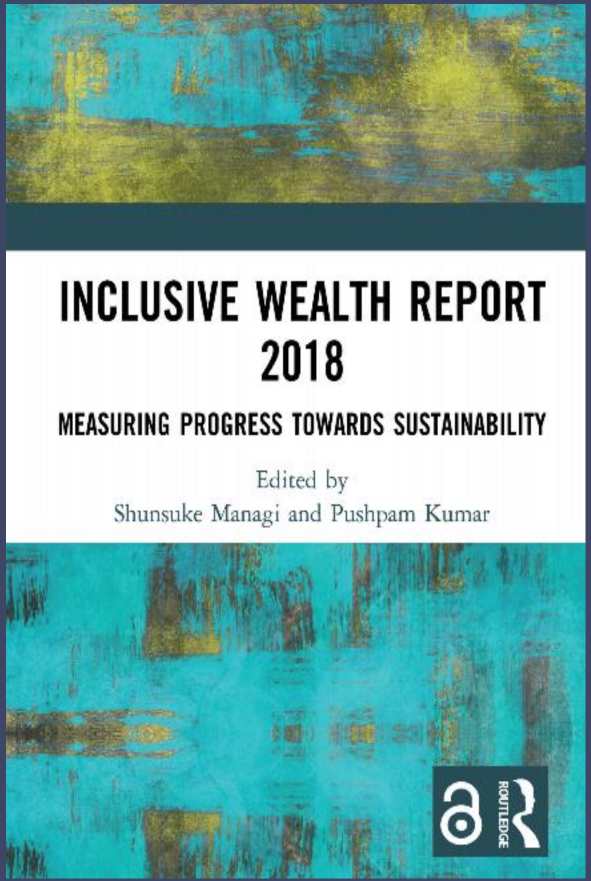
1. Any perturbation to an economy that increases social well-being across the generations raises inclusive wealth as well.

2. Any perturbation that lowers social well-being across the generations reduces inclusive wealth.

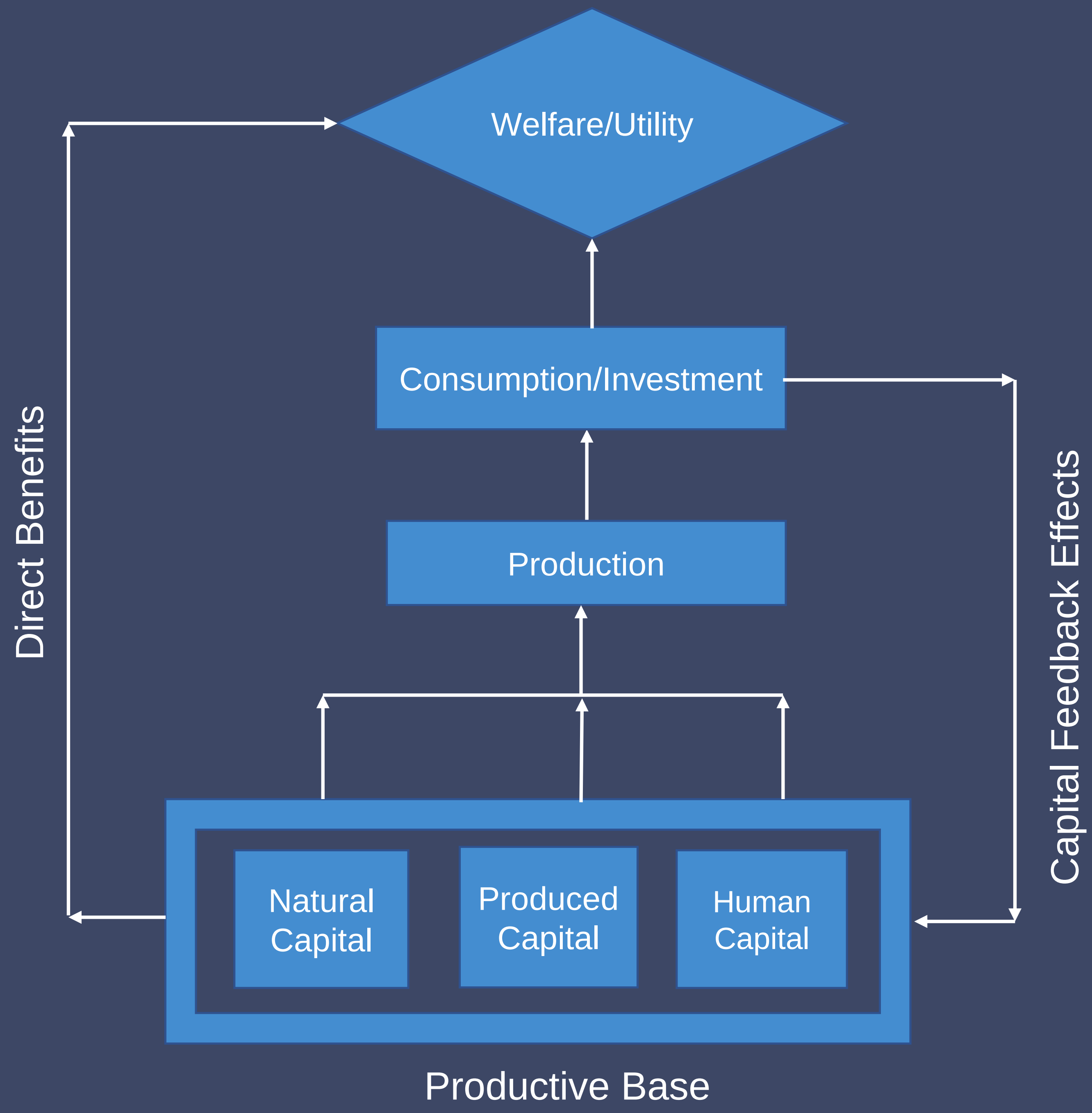
Inclusive Wealth Report

- Building upon earlier two reports (2012 and 2014), IWR 2018 is authored by 46 global authors and experts
- Seven Chapters, 200 pages
- 30 reviewers
- Supervised by Science Panel, Chaired by Sir Partha Dasgupta, Cambridge and Chair, HM Treasury Review of Biodiversity and Economy, UK



Main report:
https://wedocs.unep.org/bitstream/handle/20.500.11822/27597/IWR2018.pdf?sequence=1&isAllowed=y

Executive Summary
https://wedocs.unep.org/bitstream/handle/20.500.11822/26776/Inclusive_Wealth_ES.pdf?sequence=1&isAllowed=y


Welfare/Utility
Consumption/Investment
Production
Natural Capital
Produced Capital
Human Capital
Direct Benefits
Capital Feedback Effects
Productive Base

Equivalence between well-being and wealth

Sustainability can be measured by wealth

- Social well-being

$$V(t) = \int_t^{\infty} U(C(\tau))e^{-\delta(\tau - t)}d\tau$$

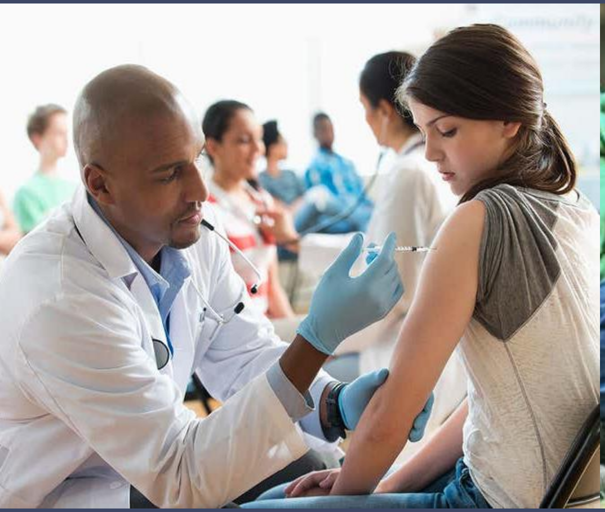
- Consider an economic program M where future flow and stock variables are functions solely of current capital assets, then:

$$V(\boldsymbol{K}(t), M) = \int_t^{\infty} U(C(\tau))e^{-\delta(\tau - t)}d\tau$$

- Define the shadow price of a capital as $p_i(t) \equiv \partial V(t)/\partial K_i(t)$ s.t. a given future dynamics of capitals $\boldsymbol{K}(t)$ and assuming time autonomy, sustainable development is defined by

$$\frac{dV\big(\boldsymbol{K}(t)\big)}{dt} = \sum_i \frac{\partial V\big(\boldsymbol{K}(t)\big)}{\partial K_i(t)} \frac{dK_i(t)}{dt} = \sum_i p_i(t) \frac{dK_i(t)}{dt} \geq 0$$

Human Capital



Education

Stock

$$H = e^{\rho A} * P_{5+edu}$$

- Population of the age of 5 + the average years of the educational attainment or older

Variables	Data sources / assumptions
Educational attainment, A	Barro and Lee (1990, 1995, 2000, 2005, 2010, and 2015)
Population P by age, gender, time	United Nations Population Division (2011)
Interest rate, ρ	8.5% (Klenow and Rodriguez-Clare 1997)
Discount rate, ρ	8.5%
Employment	International Labour Organization (2013); Conference Board (2013)
Compensation of Employees	United Nations Statistics Division (2012); OECD (2013); Feenstra et al. (2013); Lenzen et al. (2013); Conference Board (2013)

Education

Shadow Prices

Conventional method:

$$p_H = \int_0^{T(t)} w e^{-\rho t} dt$$

Frontier analysis:

- Non-parametric estimation of shadow prices with inputs being produced, education, health, and natural capitals. In particular, the model is expressed as
- $P(x) = \{(x, y): x \text{ can produce } y\}$
- $D(x, y; g) = \max_{\beta}\{(y + \beta g) \in P(x)\}$
- Where $x = [K, E, H, N]$ is the input vector, y is output, and g is a directional vector

Health

Stock

- Only the **longevity effect** of health capital is measured (not direct utility and productivity effects)
- Expected utility:

$$\Pr(H)\, U(C)$$

- Thus, Marginal health = $\frac{d\Pr(H)}{dH} U(C)$
- VSL *per se* is not the value of life; the amount people would be willing to spend to reduce the number of expected deaths by 1
  - $0 = dU = \frac{\partial U}{\partial C} dC + \frac{\partial U}{\partial \Pr(H)} \mathrm{dPr}(H)$

  →MWTP for risk reduction in monetary terms=$-\frac{dC}{d\Pr(H)} = \frac{U(C)}{\Pr(H)U'(C)}$
  - VSL= $\frac{\Pr(H)}{d\Pr(H)}$MWTP=$\frac{U(C)}{d\Pr(H)U'(C)}$

$f(t)$	density of age of death
$F(t) = \sum_{a=0}^{t} f(a)\,; S(t) = 1 - F(t)$	cumulative distribution of age of death
$f(t \mid t \geq a) = \frac{f(t)}{[1 - F(a)]}$	conditional density of age of death given survival to age a
$m(a) = \lim_{\Delta t \to 0} \frac{\Pr(t < a + \Delta t \mid t \geq a)}{\Delta t} = \frac{f(a)}{[1 - F(a)]}$	Mortality hazard rate
$M(t) = \sum_{0}^{t} m(s)$	Cumulative mortality hazard rate
$f(t \mid t \geq a) = \frac{f(t)}{[1 - F(a)]} = -\frac{\dot{S}(t)}{S(a)} = \frac{m(t)S(t)}{S(a)} = m(t)e^{-\int_a^t m(u)du} = m(t)e^{M(a) - M(t)}$	
$H(a) = \sum_{t=a}^{100} f(t \mid t \geq a)V(a,t)$	health capital of an individual of age a
$V(a,t) = \sum_{u=0}^{t-a} (1 - \delta)^u$	(compound) discount factor
$H = \sum_{a=0}^{100} H(a)P(a)$	total health capital of a country

Deriving shadow prices by frontier analysis

- Previous measurement of health capital (longevity) is based on the assumption that MWTP to reduce the risk of death (VSL) is common for all the age groups, which may overestimate its shadow price
- As an alternative method, *frontier analysis* is a non-parametric estimation of shadow prices with inputs being inclusive wealth
- In particular, we assume a production-possibility set P, with input vector x (produced, education, health, and natural capitals), output y (GDP), and a directional vector $g = g_y$ with $g \in \Re^M$. Formally,

$$P(x) = \{(x, y) : x \text{ can produce } y\}$$
$$D(x, y; g) = \max_{\beta}\{\beta : y + \beta g_y \in P(x)\}$$

Deriving shadow prices by frontier analysis

- The input functions are used to generate following quadratic function formula:

$$D(x,y;1) = \alpha_0 + \sum_{n=1}^{3} \alpha_n x_n + \beta_1 y + \frac{1}{2}\sum_{n=1}^{3}\sum_{n=1}^{3} \alpha_{n,n'} x_n x_{n'} + \frac{1}{2}\beta_2 y^2 + \sum_{n=1}^{3} \delta_n x_n y$$

- The DDF, in accordance with Färe et al. (2005), Kumbhakar and Lovell (2000), Tamaki et al. (2017), can conduct these estimates using the stochastic function approach based on the following:

$$0 = D(x,y;1) + \epsilon$$

$$D(x,y;1) = D(x,y+\alpha,1) + \alpha \rightarrow -\alpha = D(x,y+\alpha;1) + \epsilon$$

Deriving shadow prices by frontier analysis

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- By setting $g = 1$, we can derive the revenue function for each unit with the DDF as follows:

$$R(x,p) = \max_{y}\{py : D(x,y;1) \geq 0\}$$

- where p is the price of the output, set equal to 1 in this case. By solving the revenue maximization problem and using our parameterization of DDF, the shadow price of health capital can be obtained as:

$$P = -\frac{\partial D(x,y;1)/\partial x_{health}}{\partial D(x,y;1)/\partial y} = -\frac{\alpha_1 + \sum_{n=1}^{3} \alpha_{n,l} x_n + \delta_1 y}{\beta_1 + \beta_2 y + \sum_{n=1}^{3} \delta_n x_n}$$

Produced Capital

Produced capital

Stock (Perpetual Inventory Method):

$$K(t) = K(0)(1-\delta)^t + \sum_{\tau=1}^{t} I(\tau)(1-\delta)^{t-\tau}$$

where the initial capital stock $K(0)$ is estimated by assuming steady state of capital-output ratio; $0 = \dot{K}/y = (I - \delta K)/K - \gamma$ ➔ $\frac{K}{y} = \frac{I/y}{\delta+\gamma}$

Shadow Prices:

- As the unit of account is $, there's no conversion (assuming $U_C = F_K$).

Variables	Data sources / assumptions
Investment, I	United Nations Statistics Division (2013a)
Output, y	United Nations Statistics Division (2013a)
Depreciation rate, δ	4% (as taking the country average from Feenstra et al. (2013))
Capital lifetime	Indefinite

Natural Capital




Agricultural land

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Stock:

- Cropland/pastureland area available for country i in year j

Shadow prices:

- Rental price/ha for country i in year j: $\mathrm{RPA_{ij}} = \left(\frac{1}{A}\right) \sum_{k=1}^{159} R_{ik} P_{ijk} Q_{ijk}$
- NPV of rental price/ha: $Wha_{ij} = \sum_{\tau=t}^{\infty} \frac{\mathrm{RPA_{ij}}}{(1+\mathrm{r})^{\tau}}$ and taking year average

Variables	Data sources / assumptions
Quantity of crops produced, Q	FAO (2015)
Price of crops produced, P	FAO (2015)
Rental Rate, R	Narayanan et. al. (2012)
Harvested area in crops, A	FAO (2015)
Discount rate, r	5%
Permanent cropland/pastureland area	FAO (2015)

Forest: Timber benefits

- **Stock**
  - Timber density * total forest area * % of total volume commercially available
  - Excluding cultivated forest (regarded as manufactured capital
- **Shadow prices:**

$$P * R$$

  - P: Weighted average price of industrial round-wood and fuelwood, converted from current to constant prices by country-specific GDP deflator
  - R: regional rental rates for timber by Bolt et al. (2002) (assumed to be constant)
  - Average price over the entire study period (1990 to 2010)

Variables	Data sources / assumptions
Forest stocks	FAO (2015; 2010; 2006; 2001; 1995)
Forest stock commercially available	FAO (2006)
Wood production	FAO (2015)
Value of wood production	FAO (2015)
Rental rate, R	Bolt et al. (2002)
Forest area	FAO (2015)

Forest: Non-timber benefits

Shadow prices:

$$\sum_{\tau=t}^{\infty} \frac{PQ_\tau \gamma}{(1+r)^\tau}$$

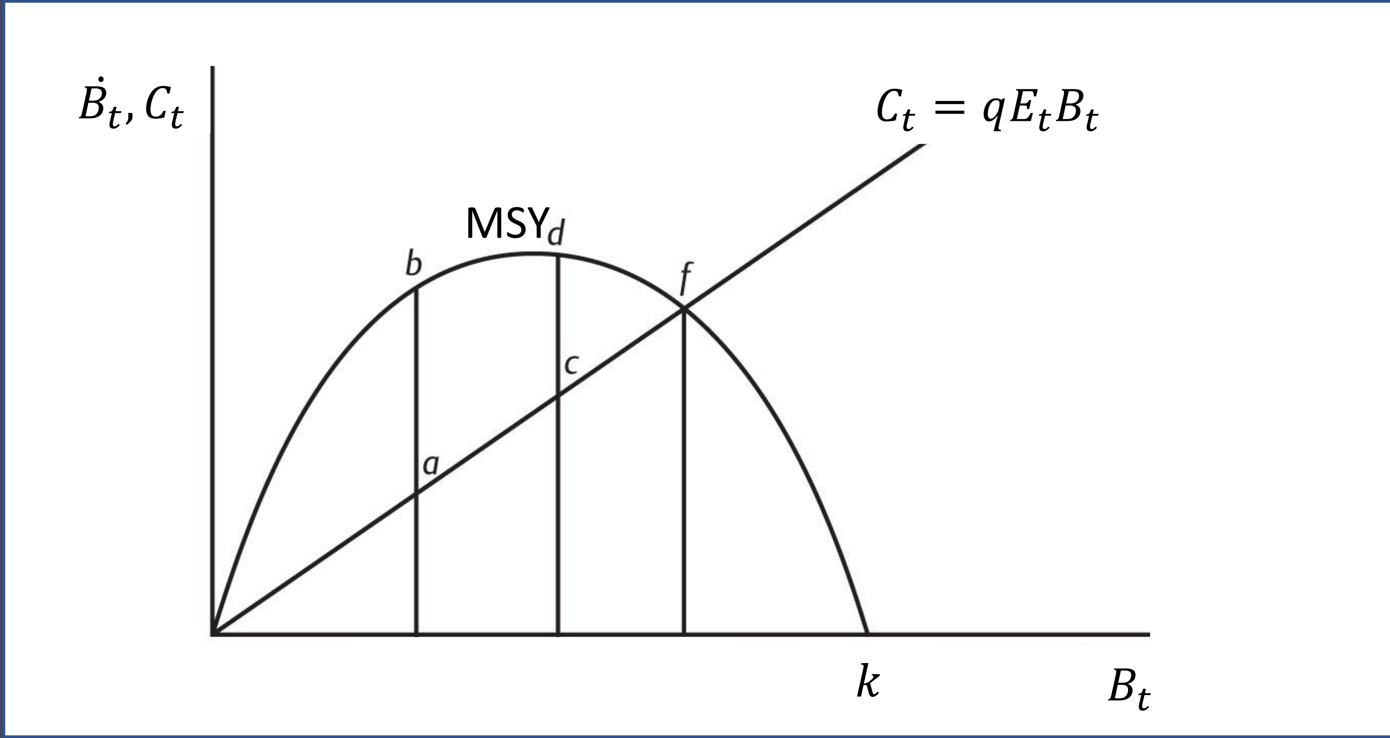
Variables	Data sources / assumptions
P: forest ecosystem service benefit to social well-being	ESVD: van der Ploeg and de Groot (2010) weighted the corresponding values by the share of each forest type in the total forest of the country
Q: total forest area in the country under analysis, excluding cultivated forest	FAO (2015)
γ: fraction of the total forest area which is accessed by individuals to obtain benefits	10% (World Bank 2006)
Discount rate, r	5%

Fisheries

Stock

Following the Gordon-Schaefer model of fishery biomass stock

$$B_{t+1} - B_t = rB_t\left(1 - \frac{B_t}{k}\right) - C_t$$



Fisheries

According to Froese et al. (2012) and Kleisner et al. (2013), the status of fishery is determined by the following criteria:

Status of fishery	Code	Year	C/C_{max}	C/MSY
Developing	D	Year of landing < year of max. landing AND landing is < or = 50% of max. landing OR year of max. landing = final year of landing	0.1 – 0.5	0.2 – 0.75
Exploited	E	Landing > 50% of max. landing	> 0.5	> 0.75
Overexploited	O	Year of landing > year of max. landing AND landing is between 10-50% of max. landing	0.1 – 0.5	0.2 – 0.75
Collapsed	C	Year of landing > year of max. landing AND landing is < 10% of max. landing	< 0.1	< 0.2
Rebuilding	R	Year of landing > year of post-max. min. landing AND post-max. min. landing < 10% of max. landing AND landing is 10-50% of max. landing		

Fisheries

Stock: B_t

Shadow prices: $P * R$

Variables	Data sources / assumptions
C_t: catch of each country's economic exclusive zone (EEZ) for the period of 1950-2010	seaaroundus.org only evaluate the stock that has a catch record for at least 20 years and which has a total catch in a given area of at least 1000 tons over
P: Shadow prices	Species-specific market prices, average for 1990-2014.

Fisheries

- Stock dynamics: $B_{t+1} - B_t = rB_t\left(1 - \frac{B_t}{k}\right) - C_t$
  - Production is known to be proportional to effort and stock, i.e., $C_t = qE_tB_t$, so that if effort (number of vessels; labor input) is known, as well as catchability coefficient q and C_t, then B_t can be estimated (Yamaguchi et al. 2016).
  - But effort data are sparse. Since there is no reliable data on r and k for most fish stocks, we follow Martell and Froese (2013) in developing an algorithm to randomly generate feasible (r, k) pairs from a uniform distribution function.
  - The likelihood of the generated (r, k) pairs are further evaluated by using Bernoulli distribution to ensure that the estimated stock meets the following assumptions:
    - it has never collapsed or exceeded the carrying capacity, and
    - the final stock lies within the assumed range of depletion.
  - In a case where the value of r and k are not obtainable, the stocks are simply estimated according to the following rules:
    - If year > year of max catch, then $B_t = 2C_t$; otherwise, $B_t = (2 \times C_{max}) - C_t$

Fossil fuels

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- Stock of coal, natural, gas, and oil
  - $S(t-1) = S(t) + Extraction(t)$,
- Shadow prices: $P * R$

Variables	Data sources / assumptions
S: reserve	U.S. Energy Information Administration (2015)
Extraction	U.S. Energy Information Administration (2015)
P: prices	BP (2015) • Coal: averaged prices from U.S, northwestern Europe, Japan coking, and Japan steam • Natural gas: averaged prices from EU, UK, US, Japan, and Canada • Oil: averaged prices of Dubai, Brent, Nigerian Forcados, and West Texas Intermediate • adjusted for inflation before averaging over time using the U.S. GDP deflator
R: rental rates	Narayanan et al. (2012)

Metals and minerals

- Stock of bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin, and zinc
  - $S(t-1) = S(t) + Extraction(t)$,
- Shadow prices: $P * R$

Variables	Data sources / assumptions
S: reserve	U.S. Geological Survey (2015), *Mineral Commodity Summaries* and/or *Minerals Yearbook*
Extraction	U.S. Geological Survey (2015)
P: prices	U.S. Geological Survey (2015)
R: rental rates	Narayanan et al. (2012)

Adjustments

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1. Carbon Damages

obtain the total global carbon emissions

- Fuel consumption and cement (Boden et al. 2011)
- Global deforestation (FAO (2013) on the changes in annual global forestland). Taking the average carbon release/ha of 100 tonnes of carbon (Lampietti and Dixon 1995)

derive the total global damages

- The damages per tonne of carbon released to the atmosphere are estimated at US$50 (Tol 2009), which is constant over time

allocate the global damages to the countries

- The distribution of damages as a percentage of the corresponding regional and global GDP (Nordhaus and Boyer 2000)

Adjustments

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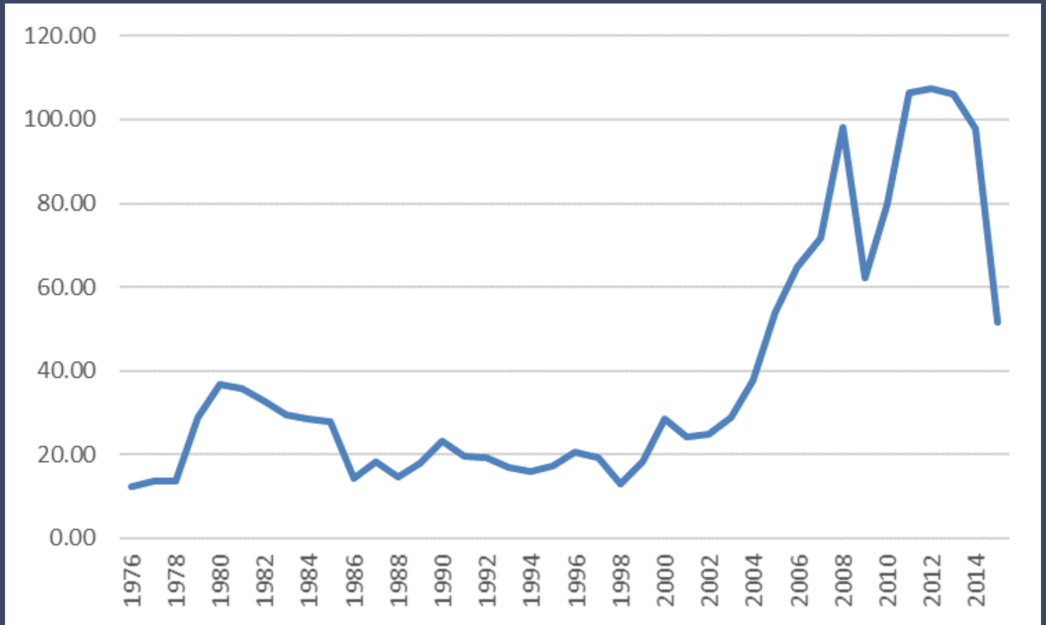
2. Oil Capital Gains

- If oil price increases, oil-rich nations enjoy an increase in wealth
- Conversely, importing-countries may have fewer investment opportunities due to higher oil prices, so oil capital losses are distributed to consuming countries
- An annual increase of 3% in the rental price of oil is assumed (following the annual average oil price increase during 1990-2014



Natural Capital is on decline!

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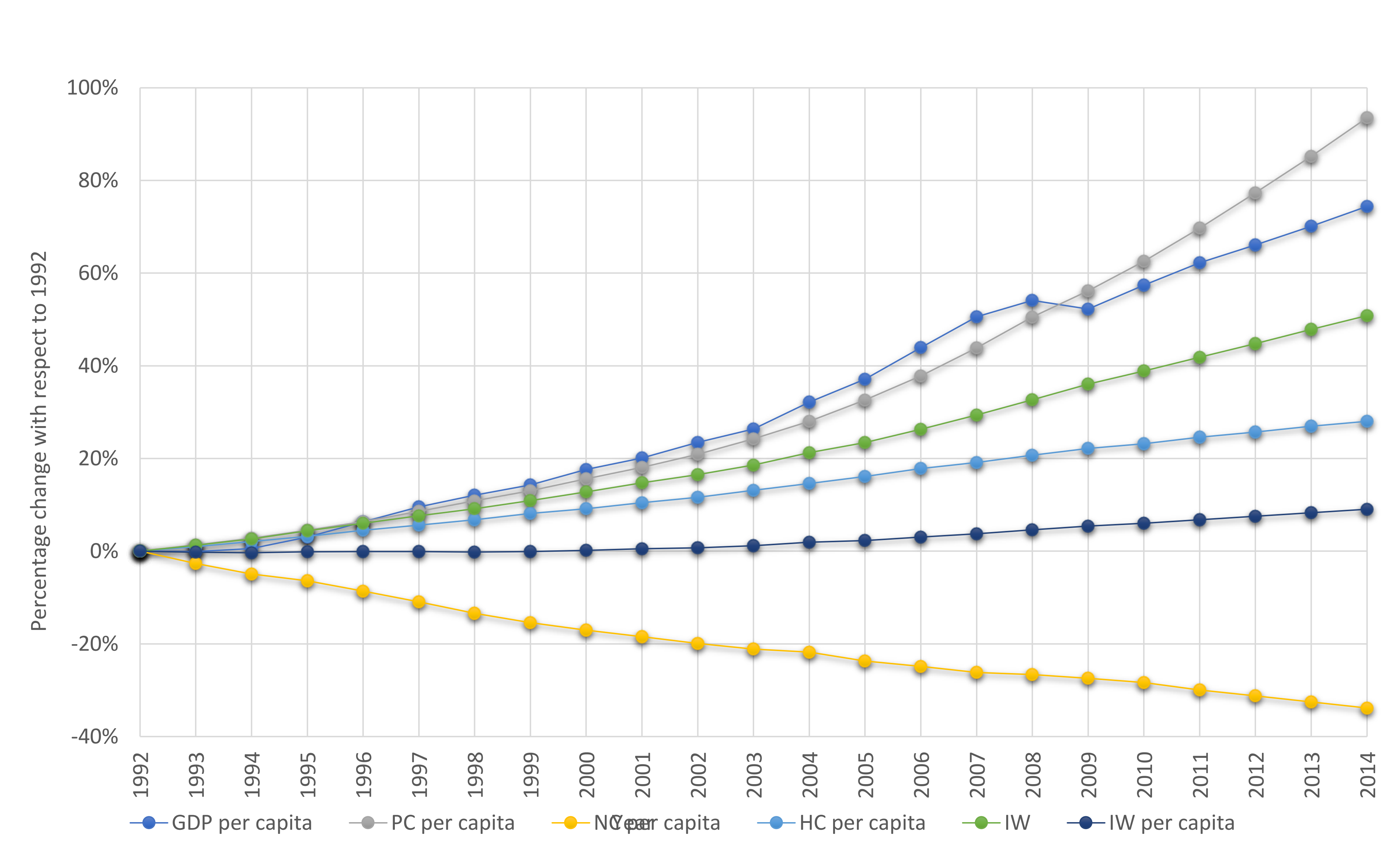
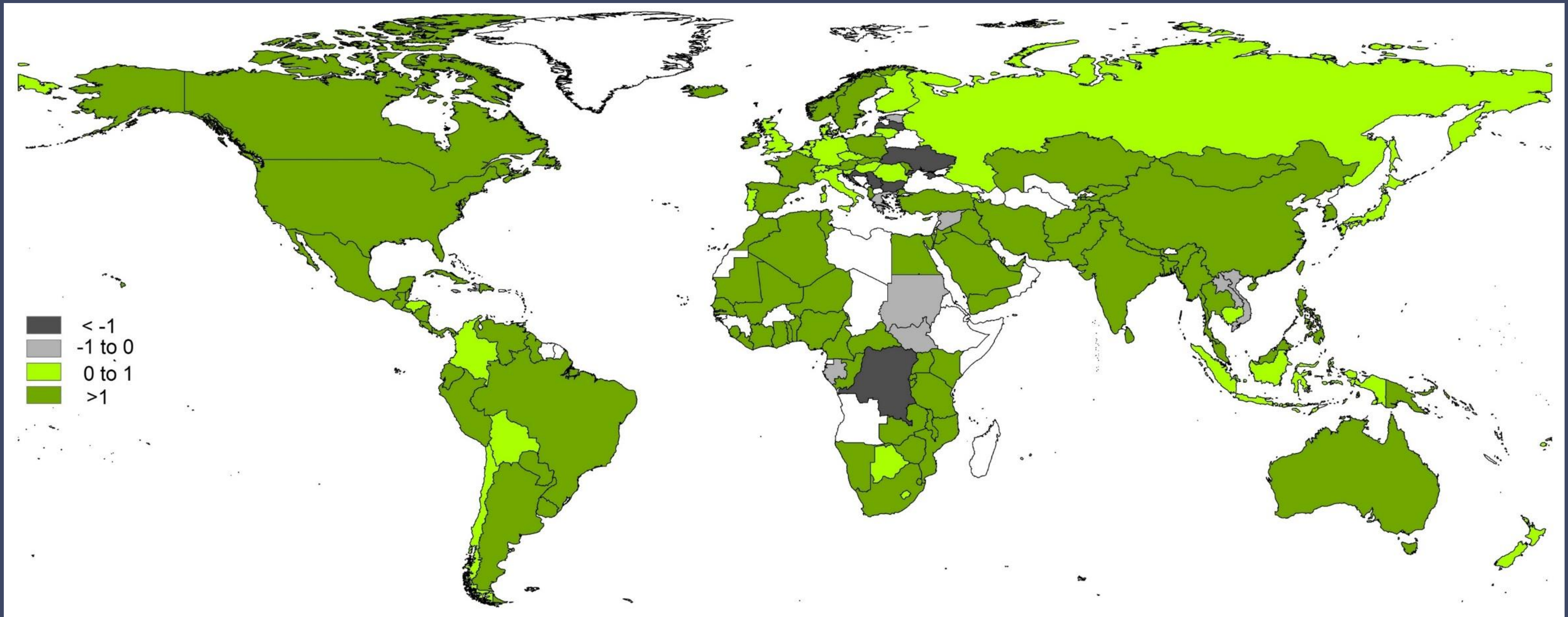


Growth in IWI absolute terms

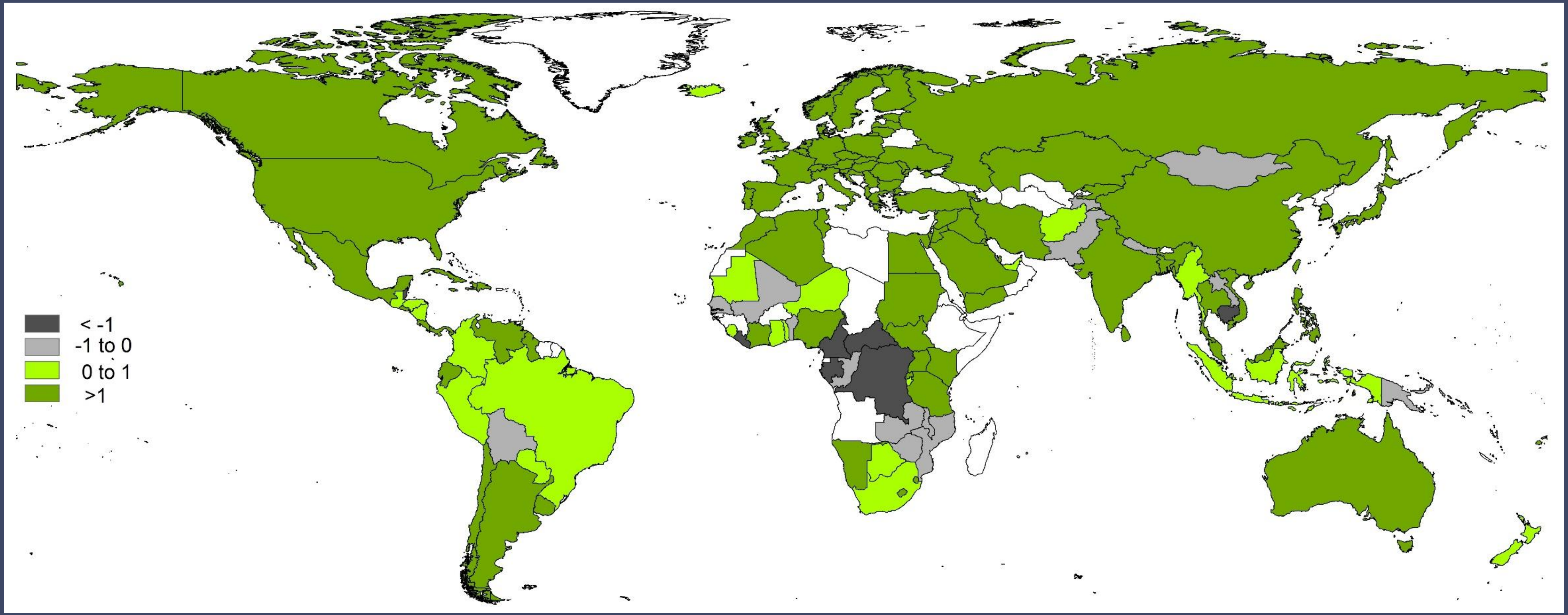
- 135 of the 140 countries (> 96%) experienced a positive annual average growth rate in IWI (in absolute terms)



Average annual growth rate of Inclusive Wealth Index (%), 1990-2014

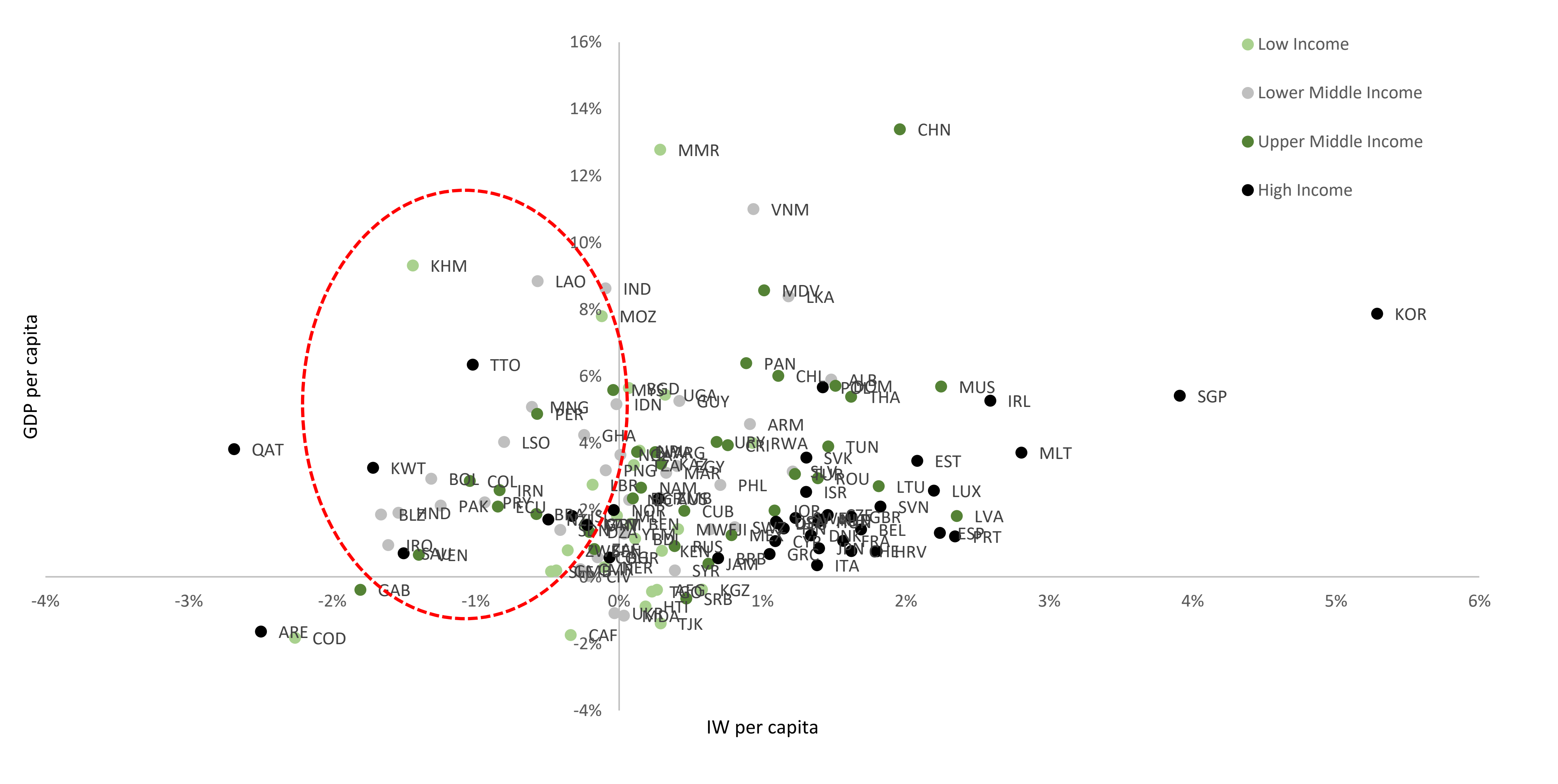
Growth in IWI per capita

- 84 percent countries assessed in IWR 2018 present a positive IWI (per capita)



Growth in Inclusive Wealth per capita considering adjustments

Many countries with + GDP growth, - IW, questioning sustainability



Growth rate in GDP per capita and growth rate in IW per capita, 1990-2014

Happiness and inclusive wealth go together

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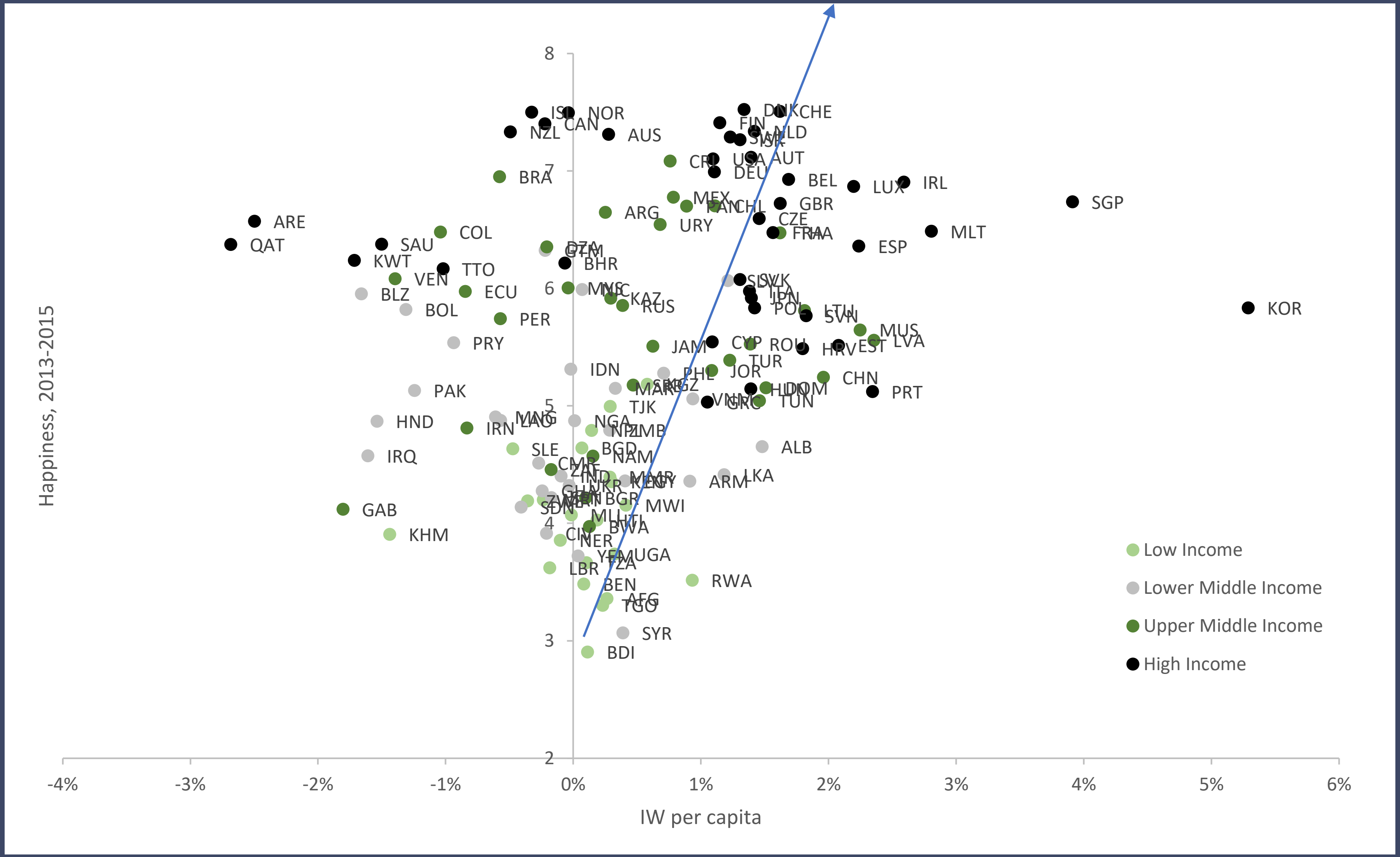

Compiled from *World Happiness Report 2016 update*

Top 10 – not necessarily 'rich' nations!

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IWI Ranking	Country	Average growth per head During 1992-2014
1	Republic of Korea	33.0%
2	Singapore	25.2%
3	Malta	18.9%
4	Latvia	17.9%
5	Ireland	17.1%
6	Moldova	17.0%
7	Estonia	16.0%
8	Mauritius	15.5%
9	Lithuania	15.2%
10	Portugal	13.9%

Many rich nations are in the bottom 10

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IWI Ranking	Country	Average per head Inclusive Wealth during 1992-2014
140	Qatar	-40.4%
139	United Arab Emirates	-35.2%
138	Iraq	-30.6%
137	Kuwait	-29.7%
136	Venezuela (Bolivarian Republic of)	-27.4%
135	Saudi Arabia	-26.2%
134	Syrian Arab Republic	-19.5%
133	Democratic Republic of the Congo	-19.2%
132	Iran (Islamic Republic of)	-16.5%
131	Belize	-15.0%

Great demand and support from countries

China
Nigeria
India
Kazakhstan
Ethiopea
Canada
SriLanka

THANK YOU

Pushpam Kumar
Chief Environmental Economist, UN Environment
pushpam.kumar@un.org