Environmentally adjusted multifactor productivity: Accounting for natural capital and pollution

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## **EAMFP** – one of six *headline* indicators

Environmental and resource productivity	
Carbon productivity	1. CO <sub>2</sub> productivity (production-based, demand-based)
Resource productivity	2. Non-energy material productivity (production-based, demand-based)
Multifactor productivity	3. Multifactor productivity including environmental services
The natural asset base	
Renewable and non-renewable stocks	4. Natural resource index
Biodiversity and ecosystems	5. Changes in land use and cover
Environmental quality of life	
Environmental health and risks	6. Air pollution (population exposure to PM 2.5)
Economic opportunities and policy responses	
Technology and innovation, environmental goods and services, prices and transfers, etc.	Placeholder – no indicator specified



## MFP is the macroeconomic indicator

- Growth not explained by increasing labour or capital
- A measure of intangibles: Innovation, education, market efficiency, organisational and institutional improvements.
- Adjusted measure of productivity growth:
  - Comprehensive: accounts for multiple factor inputs including the use of natural resources and production of undesirable outputs
  - Highlight environmental concerns in economic policy decisions
  - Insights about more sustainable long-term growth
  - Starting point to analyse green growth



### Growth accounting

- + **Consistent with SNA**; Coherent over time; No need to specify production function
- High data requirements (monetary **and** physical); Susceptible to measurement error; assumes efficiency

## Econometric analysis

- + More flexible data requirements (monetary); Allows hypothesis testing; less susceptible to measurement error
- Need to specify production function; sensitive to estimator and data sample; assumes efficiency
- Data envelopment analysis
  - + Flexible data requirements (monetary or physical); No assumptions on production function or efficiency
  - Highly sensitive to data sample and dimensionality
- Stochastic frontier analysis
  - Flexible data requirements (monetary or physical); allows hypothesis testing; does not assume efficiency; less susceptible to measurement error
  - Need to specify production function; Need to specify the form of the inefficiency Restricted Use - À usage restreint



**Indicators** 

## **GDP** growth + adjustment for pollution abatement

Adjustment for pollution abatement calculated using elasticity of pollution w.r.t. economic growth and pollution emissions

» Elasticities estimated econometrically using a Random Coefficients Model

= Contribution of labour

Calculated using the hourly wage and total hours worked

## + Contribution of produced capital

Calculated using the user cost of capital and total produced capital

- + Contribution of (non-renewable and renewable) natural capital Calculated using the unit rent (or value) and natural capital extraction
- + Environmentally adjusted multifactor productivity (EAMFP) Calculated as a residual. The growth of output (GDP and pollution) which does not come from increasing use of labour, produced capital or natural capital Restricted Use - A usage restreint



## Coverage and data sources 52 countries (OECD + G20) from 1995 to 2018





## Natural capital inputs Additions (in 2023) and exploratory work







Fossil

minerals

# Natural capital inputs Quantity, valuation, methods and sources

#### Domestic extraction in tonnes

- OECD Accounts and CWON 2021 (Rystad Energy, IEA, BP Statistical review, US Energy Information Administration, UN Statistics, US Geological survey, British Geological survey).
- fuels and Unit rent: market prices and plant-level resource-specific extraction costs
  - World Bank commodities price data, Rystad Energy and Wood Mackenzie GEM database (minelevel) : Prices and costs regional average rental rates when specific costs unavailable.

#### • Cropland, pasture land, and (productive) forest land in hectares.

- Definitions and data from FAO
- Cropland unit rent: crop rents (168 crops) per hectare using crop-specific production costs, prices.

Land

- Pasture land unit rent: livestock rents (22 farm animals) per hectare using livestock-specific production costs, prices, intensive rental rate = 2 x extensive rental rate
- Forest land unit rent as the quasi-opportunity cost between cropland and pastureland
  - Crop and livestock production from FAO, FAOTSTAT. Evenson and Fuglie (2010): Export unit value, producer prices and estimated average regional rental. Share of extensive-intensive systems by FAO Global Livestock Environmental Assessment Model. Restricted Use - A usage restricted



**Biological** 

resources

**Ecosystem** 

services

## Natural capital inputs Quantity, valuation, methods and sources

**Non-cultivated timber** in m<sup>3</sup>, forest growing stock to approx. cultivated/non-cultivated FAOSTAT and FAO FRA 2020.

Timber unit rent: export prices, domestic stumpage, production costs.

FAOSTAT and Applied Geosolutions (2015): Prices, costs and estimated average regional rental rates **Marine wild capture fisheries** in tonnes. Includes subsistence, artisanal, recreational, discards and illegally caught fish.

FAO's FishStat, Sea Around Us, and Sumaila (2021): 203 entities, reconstructed total ~1.5 times FAO Fisheries unit rent: Ex-vessel price data, fishing subsidies, fishing costs (by gear type, fleet size, and country)

Sumaila et al. (2007), Lam and Sumaila (2021), Subsidies from OECD, FAO, APEC.

#### Forest ES in hectares (all forest areas).

FAOTSTAT and FAO FRA 2020.

#### • Forest ES unit rent = unit value estimated based on spatially-explicit meta-regresion.

Siikamäki et al. 2021 Meta-analysis. Values statistically significant for NWFP and WSP, not significant for habitat protection, cultural/existence services.

#### • Mangroves ES in hectares.

Global Mangrove Watch database

Mangroves ES unit rent = unit value modelled on spatially distributed averted flood damages to people and property.

Beck et al. 2021



# $\begin{array}{c} \underline{\text{GHGs:}}\\ \text{CO}_2, \, \text{CH}_4,\\ \text{N}_2\text{O}\\ \text{NF}_3, \, \text{SF}_6 \end{array}$

Air pollutants: SOx, NOx,

PM<sub>10</sub>, CO,

NMVOC, BC,

NH<sub>3</sub>

Cost of pollution abatement not directly observable, estimated econometrically
Ideally expenditure data would be used, but limited availability.

## Econometric estimation

- Elasticities statistically significant for CO<sub>2</sub>, NOX, NMVOC and SF<sub>6</sub>.
- Random Coefficient Model, allows heterogeneity in both the intercept and covariates
- Robustness tests for choice of estimation method and tests for significance for country-specific variation.
- Possible reverse-causality but no suitable instruments found to date for all pollutant covariates.

# Results: Identification of sources of growth (1996-2018)



\*based on TED data; blue: OECD; purple: Prospective members; black: Partner countries

- **EAMFP growth** is the main source of output growth for most countries.
- The contribution of **natural capital** to output growth is smaller, on average, than the contribution of conventional inputs.
- Once **pollution** is included as an output, many countries show important downward **adjustments to** conventional **GDP growth**.
- Produced capital is an important source of income growth for many non-OECD member countries
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**Results:** 

- The contribution of **non-renewable** natural capital is **higher** than that of **renewables**, both in frequency and magnitude.
- The contribution of renewable natural capital is likely underestimated; improved **data availability** and more systematic reporting are needed.
- The 'net' contribution of natural capital may be low when contributions cancel out each other.
- These indicators measure the sources of growth. They are **not sustainability indicators**.

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Data Indicators

Reporting





Increase of CO<sub>2</sub> emission in fast growing economies



- NMVOC plays an important role in most countries, showing a smaller adjustment for advanced economies in relative terms.
- N<sub>2</sub>O adjustment from abatement may reflect the changing relative contribution of agriculture to income growth.
- **SF**<sub>6</sub> adjustment to output growth is the smallest among the undesirable outputs included. Restricted Use - À usage restreint



#### 



- Method
  - Growth accounting: Substitutability of natural capital, returns to scale, perfect competition
  - Estimation of shadow prices of pollution
- Partial coverage
  - Natural capital inputs: freshwater, soil and other mineral types (e.g. rare earths),
  - Undesirable outputs: water emissions, waste (litter), nutrients, biodiversity loss
- Interpretation
  - The growth accounting framework does not provide information on the level of pollution emissions or the quantity of natural capital used by a country, but on the increasing or decreasing (change) dependency of economic growth on the environment. It informs on the trajectory of a country's management of resources but not on its absolute dependency, nor on its sustainability.
  - The interpretation of the contribution of renewable natural capital inputs needs to be qualified according to the **extraction source** (cultivated vs non-cultivated)
  - Valuation from the producer's perspective. Insofar externalities are not reflected in producer's costs, the contribution of natural capital to output growth is biased downwards



# Gain experience from the use of indicators

- OECD country reviews
- Countries' own use (adaptations of the framework to country specifics, e.g. additional natural capital inputs or undesirable outputs depending on priorities and data availability)

# Future expansions/updates

- Improve pollution valuation
- Revisit measurement along the work of the OECD EG Natural Capital for SNA update
  - Accounting for ownership and depletion of natural resources
  - Accounting of biological resources
  - Treatment of renewable energy assets
  - Valuation of mineral and energy resources
- Improve updating frequency

# Thank you!

Website:http://oe.cd/eamfpOECD paper:https://doi.org/10.1787/9096211d-en

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# **EXTRA**



- Growth accounting at the aggregate economy level
- Start with a transformation function:

 $H(Y,R,L,K,S,t) \geq 1$ 

Log-differentiation yields:







\*based on TED data; blue: OECD; purple: Prospective members; black: Partner countries

- Several countries rely significantly on extraction of non-renewable natural capital.
- **Fossil fuel** extraction contributes more and for more countries to income growth than minerals
- Oil is the main contributor, followed by brown and hard coal, and natural gas.
- Copper and iron ore contribution to growth is noticeable for a handful of countries.



Contribution of each renewable natural inputs growth to pollution-adjusted GDP growth



- Forests are important sources of income growth through non-cultivated timber and productive forest land.
- Changing sources of income growth observed among land types
- Strong negative contribution of marine capture fisheries, suggests sustainable resource management techniques are required to maintain growth rates over the long run.
- Overall, ecosystem services play a minor role in the generation of income. Watershed protection from forests is the ecosystem service with the largestreomtribution to output growth.



- **3** Renewable energy resources
- Solar PVWind
- Hydro

Unit rent and electricity production

- Electricity prices, levelised cost of electricity (LCOE), transmission and distribution share
- IEA World Energy Statistics,
- IEA World Energy Prices
- IRENA Cost of technology

## Findings (49/52 countries):

- Unit rents and the **contribution** of renewable energy sources to income growth **turns** strictly **positive over time**. Driven by decreasing technology costs, turning renewable energy profitable in several countries.
- Contributions vary significantly by resource
- In a few instances, the renewable energy contribution overtakes fossil fuels' contribution to income growth