Environmentally adjusted multifactor productivity: Accounting for renewable resources and ecosystem services

Session 3

OECD Network on Agricultural Total Factor Productivity and the Environment

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Why EAMFP?

- **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**

How to measure EAMFP?
Extended measurement framework

Data Indicators Reporting

Indicators

GDP growth + **adjustment for pollution abatement**

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

» *Elasticies 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

Natural capital inputs
Additions and exploratory work

Data Indicators Reporting

22 +3 Natural capital inputs

14 Non-renewable

- **4** Fossil fuels
  - Hard coal
  - Soft coal
  - Natural gas
  - Crude oil
- **10** Minerals
  - Copper
  - Gold
  - Iron ore
  - Lead
  - Nickel
  - Silver
  - Tin
  - Zinc
  - Phosphate
  - Bauxite

8 +3 Renewable

- **3** Land types
  - Cropland
  - Pasture land
  - Forest land
- **2** Biological resources
  - Non-cultivated timber
  - Marine capture fisheries
- **3** Ecosystem services
  - Forest ES: Non-wood forest products
  - Forest ES: Watershed protection
  - Mangroves ES: Coastal protection
- **3** Renewable energy resources
  - Solar
  - Wind
  - Hydro

Natural capital inputs
Details on valuation and data sources

Data Indicators Reporting

Quantity, valuation (producer's perspective), methods and sources

Fossil fuels and minerals

- 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).
- Unit rent: market prices and plant-level resource-specific extraction costs
  - World Bank commodities price data, Rystad Energy and Wood Mackenzie GEM database [1300 mines]: Prices and costs regional average rental rates when specific costs unavailable.

Land

- **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.
- **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 pasture land
  - 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.

Natural capital inputs
Details on valuation and data sources

Data Indicators Reporting

Quantity, valuation (producer's perspective), methods and sources

Biological resources

- **Non-cultivated timber** in m³, 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), Fisheries Economic Research Unit at UBC: Ex-vessel prices, fishing costs and estimated average regional rental rates. Subsidies from OECD, FAO, APEC.

Ecosystem services

- **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 with machine learning on 600 studies from 53 countries, all continents and all forest biomes. 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 distritbuted averted flood damages to people and property.
  Beck et al. 2021: process-based storm and hydrodynamic models applied to Global Human Settlement layer dataset and Penn World Tables.

Air emissions
Pollution abatement as output

Data Indicators Reporting

Valuation (producer's perspective) and method

GHGs: CO_2, CH_4, N_2O NF_3, SF_6

Air pollutants: SOx, NOx, PM_{10}, CO, NMVOC, BC, NH_3

- Cost of pollution abatement not directly observable, estimated econometrically
- Elasticities statistically significant for CO_2, NOX, NMVOC and SF_6.
- Estimation follows Cárdenas Rodríguez et al. (2018)
  - 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.

Data sources
52 countries (OECD + G20) from 1995 to 2018

Effective output

Pollution	12	GHGs: CO2, CH4, N2O Air pollutants: SOx, NOx, PM10, CO, NMVOC, BC, NH3, NF3, SF6
GDP		

Inputs

Labour		Hourly wage, hours worked
Produced capital		User cost of capital, capital stock
Natural capital	22	Unit rent, extraction
EAMFP		Calculated as residual

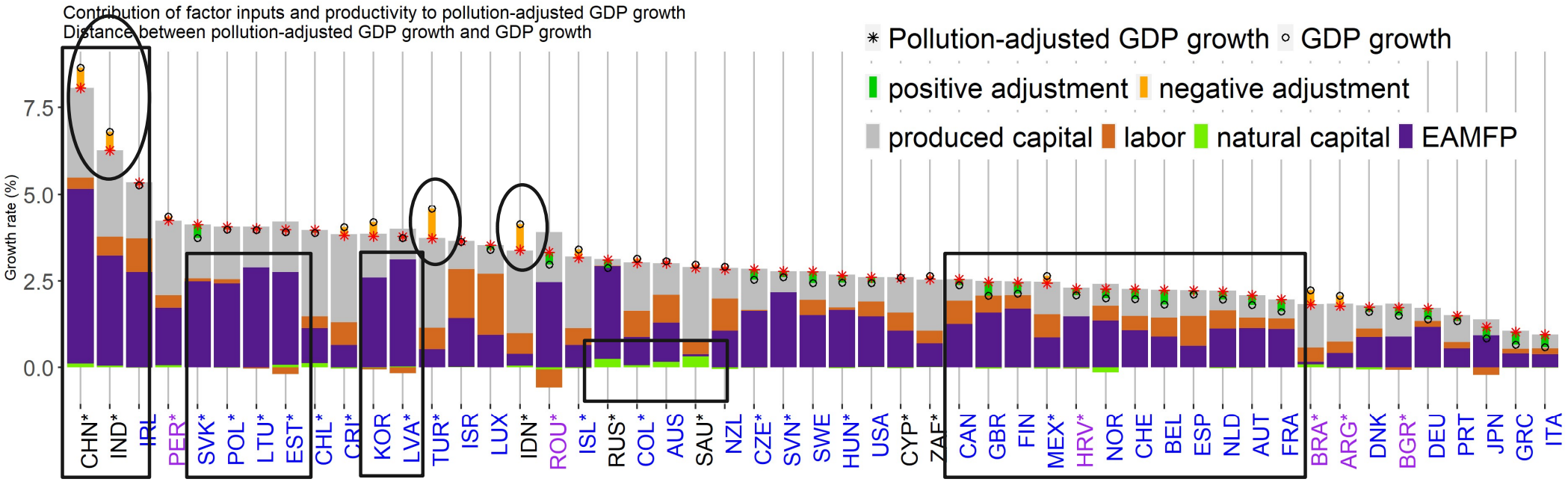
- **OECD Air Emissions Accounts**
- OECD Greenhouse Gas Emissions by Source
- OECD Air Emission by Source
- UNFCCC GHG inventories
- European Monitoring and Evaluation Programme (EMEP/CEIP)
- PRIMAP-hist
- Emissions Database for Global Atmospheric Research (EDGAR)

- **OECD Productivity Database**
- **OECD National Accounts**
- Total Economy Database
- WB World Development Indicators
- IMF World Economic Outlook

- **OECD Natural Resource Accounts**
- WB Changing Wealth of Nations (CWON) 2021
- FAO Forest Resource Assessment 2020
- FAOSTAT

Results:

Identification of sources of growth (1996-2018)



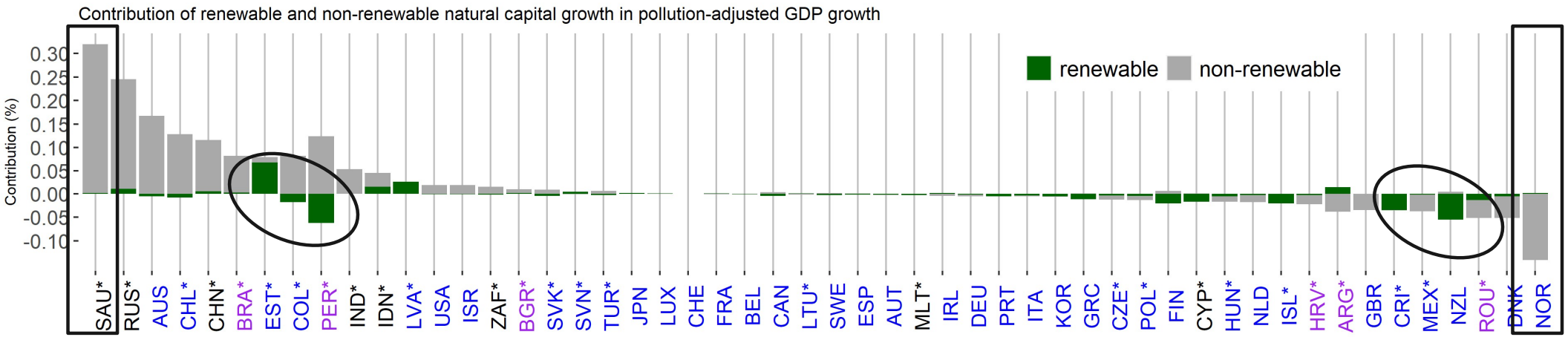
*based on TED data; blue: OECD; purple: Prospective members; black: Partner countries

- **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

Results:

Natural capital sources of growth

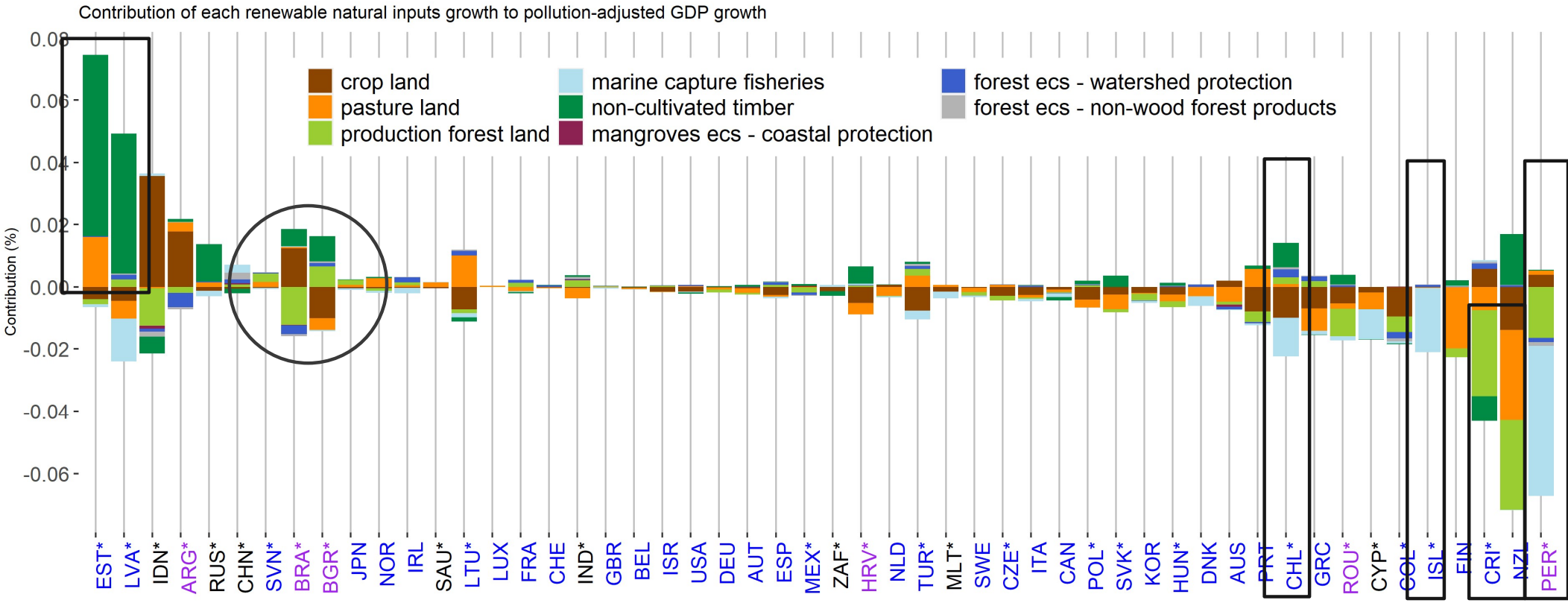
Data Indicators Reporting



- The contribution of **non-renewable** natural capital is **more prevalent** than that of **renewable**, 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 (Peru).
- These indicators measure the sources of growth. They are **not sustainability indicators**.

Results:

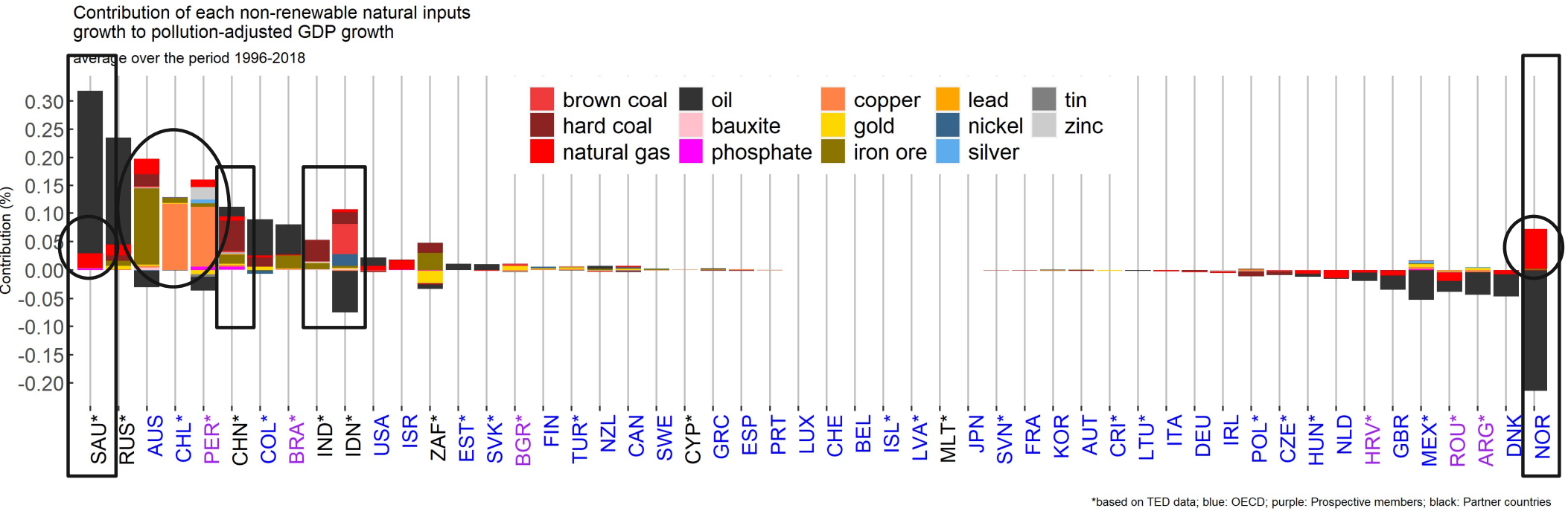
Renewable natural capital sources of growth



- Forests are important sources of income growth through **non-cultivated timber** resources and the **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 largest contribution to output growth.

Results:

Non-renewable natural capital



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- Several countries rely significantly on extraction of non-renewable natural capital.
- **Fossil fuel** extraction contributes more and for more countries to income growth than metals and 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.

Annex: Exploratory work
Renewable energy resources

Data Indicators Reporting

3 Renewable energy resources

- Solar
- Wind
- 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

Preliminary findings:

- 32/52 countries included (due to data availability)
- 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 some instances, the renewable energy contribution overtakes fossil fuels' contribution to income growth

Next steps

Data Indicators Reporting

- **Paper on ONE (ENV/EPOC/WPEI(2022)10)**
  - Initial discussion at JWPAE
  - Discussion at OECD Working Party on Environmental Information
  - Comments by end-January 2023, annex on Renewable Energy forthcoming
  - CSSP and WP1 for information
  - Update of dataset in OECD statistical portal
- **Gain experience from the use of EAMFP-related 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)

Thank you!

http://oe.cd/eamfp

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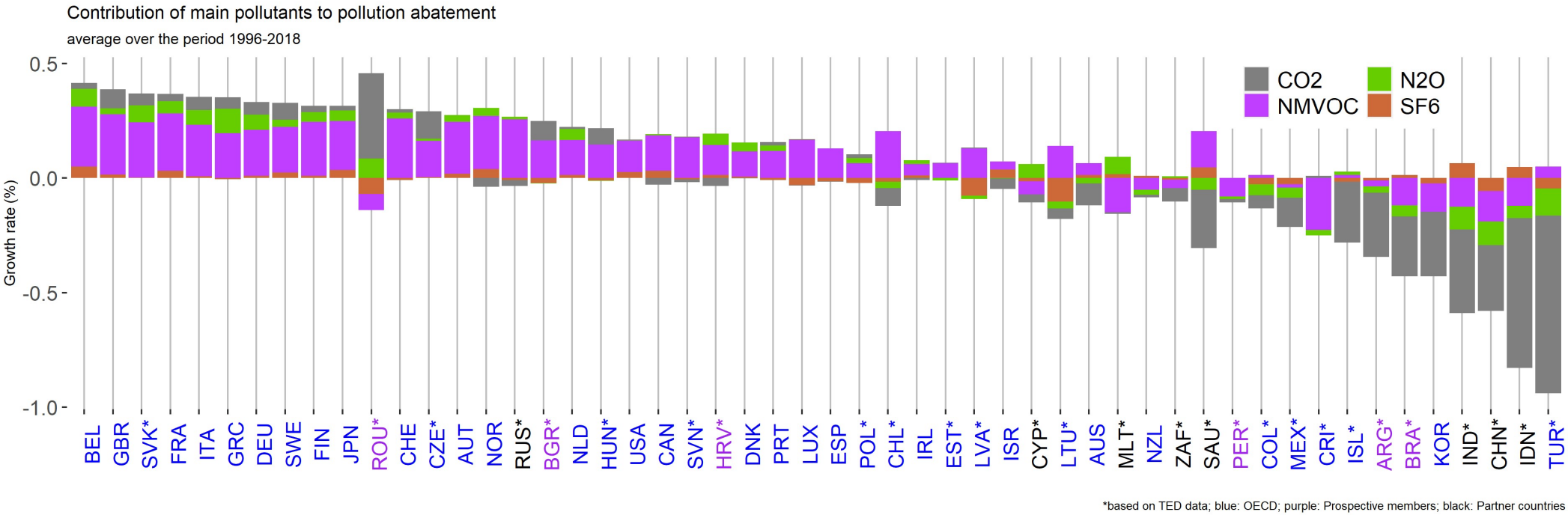
Results:

Adjustment for air pollution abatement

Data Indicators Reporting



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- Increase of **CO_2** emission in fast growing economies
- NMVOC plays an important role in most countries, showing a smaller adjusment for advanced economies in relative terms.
- **N_2O** emissions arise partly from fertilizer use. Changes in the adjustment from abatment can reflect the relative contribution of agriculture to income growth.
- **SF_6** adjustment to output growth is the smallest among the undesirable outputs included.

Limitations

- **Partial coverage of inputs and outputs**
  - Natural capital inputs: soil, freshwater, 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 environmental services. It informs on the trajectory of a country's management of resources but not on its absolute dependency.
  - The interpretation of the contribution of renewable natural capital inputs needs to be qualified according to the **extraction source** (cultivated vs non-cultivated resources)
  - The cost of inputs and the value of outputs is calculated from the **producer's perspective.** Insofar externalities are not fully reflected in producer's costs, the contribution of natural capital to output growth is well below the total value of the environment.

Annex A: Exploratory results (32 countries)

Renewable energy

Hydro-electricity, onshore wind and solar PV (99% of electricity from renewable resources)

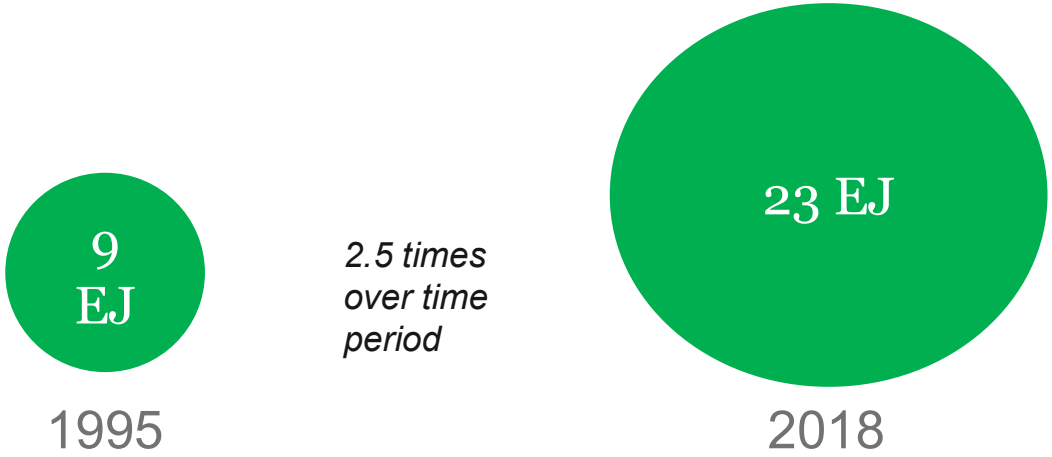
Methodology

Unit rent

Increseangly positive, country dependant

Prices

Production costs (LCOE), transmission and distribution costs

Learning curve up, costs down

Quantity