Approaches and data needs for modelling the contribution of natural capital to economic production

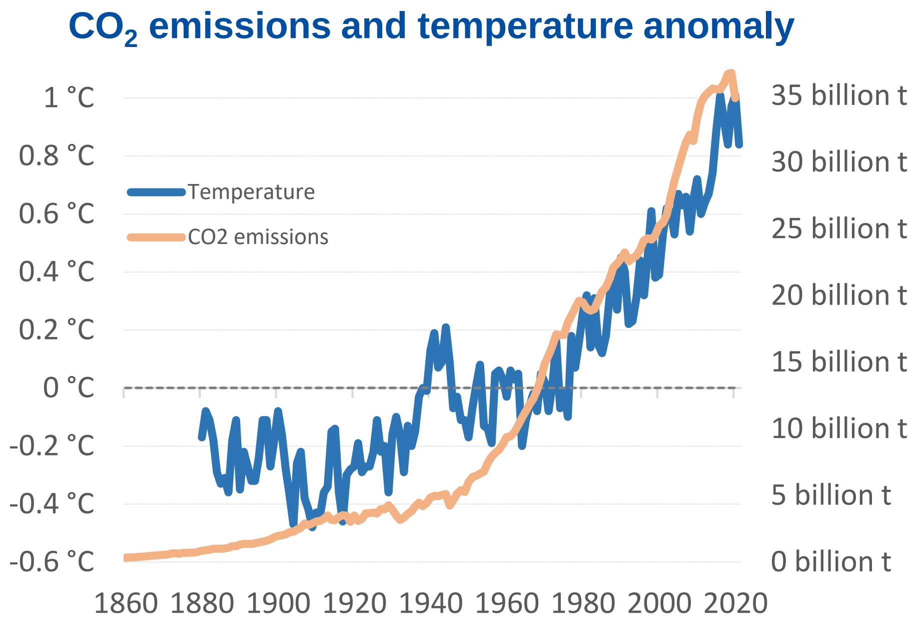
A conceptual framework

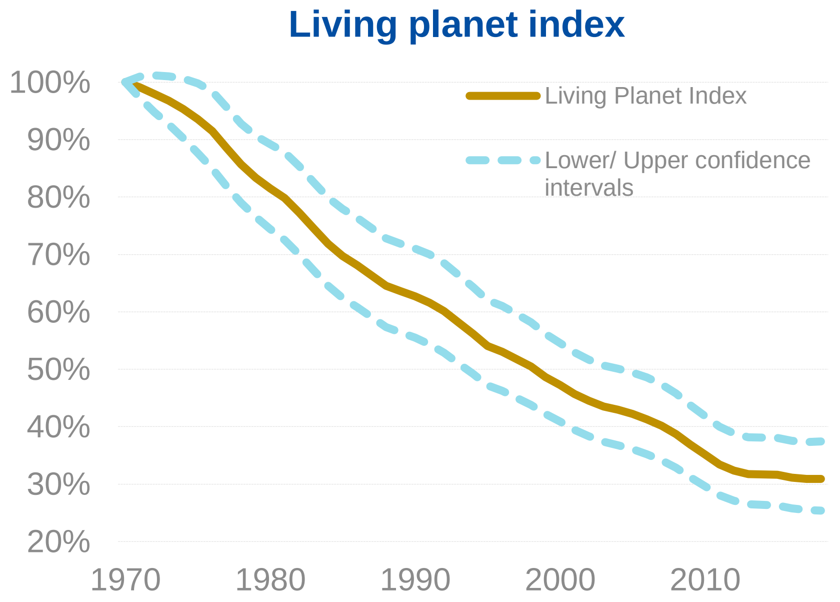
Anna Thum Thysen and Björn Döhring, ECFIN B3

ECFIN – JRC - OGWG Workshop on Natural Capital, 30 November 2023

Motivation

- Climate change, biodiversity loss, policy and geopolitics focus attention on natural capital (NK).
- How will degradation or depletion of NK affect future potential output (Y*)?
    - ➢ Implications for long-term projections of Y* …
    - ➢ … and any tools that use E(Y*), including ECFIN’s macroeconomic surveillance
- Starting point: What can we say about the role of NK in macroeconomic production functions?

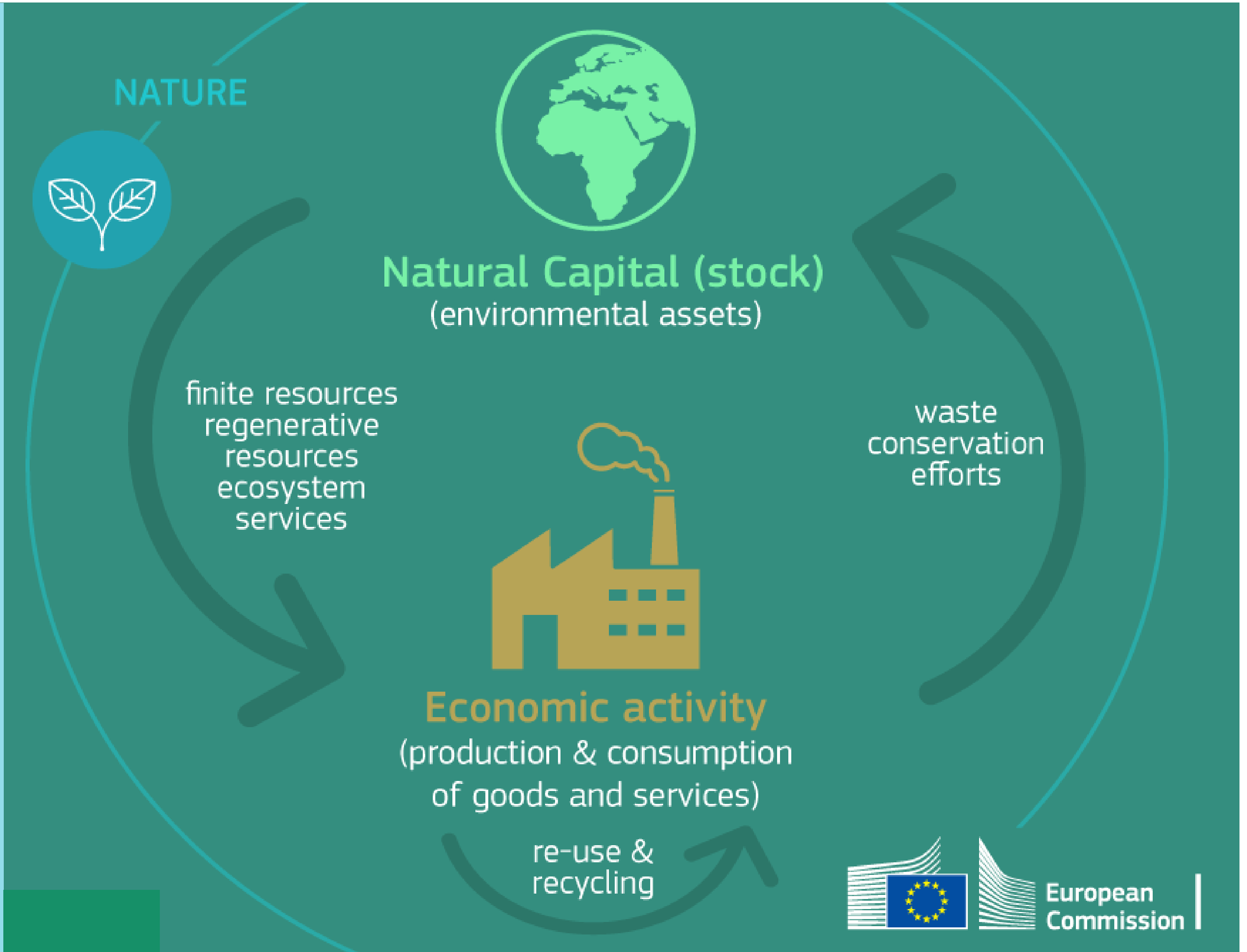




How we understand natural capital

“Natural capital refers to the stocks of environmental assets (including natural resources, ecosystems and a stable climate) that generate flows of goods and services into the economy.”

UN (2020)



European Commission

Outline

- **Different modelling approaches, strengths and (further) requirements**
  1. Aggregate production function with finite and regenerative resources
  2. Extension to the biosphere
  3. Damage functions and Integrated Assessment Models
- **Where to go from here?**
  1. Data needs
  2. Extensions

Modelling approaches

Model 1a: CD production function with resources

$$Y = AK^{a}H^{b}R^{c}$$

With a, b, c > 0

R: finite resources (crude oil, iron ore) and regenerative resources (fish, timber, ...)

Typically, contributions from nature are *implicitly* covered in TFP or K.

Some applications in the literature

- Brandt et al. (2014, 2017), **Cardenas Rodriguez et al (2018)**: adjustment of TFP for natural capital inputs in a Cobb-Douglas function
- Galiano-Bastarrica et al (2022); Blampain et al (2023): Difficulties with estimating CD function in practice.

European Commission

Model 1b: generalisation to CES

$$Y = \left[(1-\gamma)(AK^{a}H^{1-a})^{\frac{\sigma-1}{\sigma}} + \gamma(A_R R)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

With γ a share parameter and σ the elasticity of substitution between the bundle of produced capital / human capital and the resource R.

A and A_R are levels of input-saving technology for capital/labor (TFP) and resources ('resource productivity').

Alternative specifications are possible, e.g. a CES for K&R nested in a CD function.

Some applications in the literature

- Hassler et al (2021): focus on substitutability
- ECFIN simulations of gas disruption with Global Multicountry Model
- More disaggregated in CGE models e.g. of the energy sector

Model 2: extension to the biosphere

$$Y = AS^{\beta}K^{a}H^{b}R^{c}$$

This formulation follows Dasgupta (2021) chapter4*

S^{β}: service flows from the biosphere (S) (e.g. soil regeneration, pollination)

$dS(t)/dt = G(S(t)) – R(t) – Y(t)/a_z$

The evolution of S depends on natural regeneration (G), resources (R) taken out and waste deposited (Y/a_z)

Applications in the literature

- **JRC (e.g. La Notte et al 2022)** has studied individual ecosystem services (e.g. flood prevention, pollination)
- No macroeconomic work we are aware of so far [but cf. model class 3 below]

Model class 3: Integrated assessment models

Feedback loop from economic activity with pollution as an unintended output → negative impact on NK → damage to economic output (‘Damage Function’).

$$Q = YE[1 - \Lambda]$$ and $$E = \frac{1}{1 + (\frac{W}{W_H})^2}$$

E (0<E<1) represents stylised damages to output as a function of pollution (W);
Λ stands for mitigation efforts

- Damage functions are typical in climate IAMs; similar approach to NK in its infancy (Hackett and Moxnes 2015; **Bastien-Olvera and Moore 2021**)
- Very large bio-physical models with an economy module (e.g. GCAM, IMAGE, …, overview in Harfoot et al 2013).
- CGE models with ecosystem services and feedback loops (e.g. Banerjee et al 2017, **Johnson et al 2023**).

Overview of the three model classes

Model class	Strengths	Challenges
1a. Cobb-Douglas (CD) with resources *1b. Constant Elasticity of Substitution (CES) with resources*	- Straightforward formulation - Visualising the importance of NK - CD widely used in resource economics	- Measurement of resources (non-monetized/non-produced capital) - Calibration substitutability; CD's $\sigma=1$ may be hard to justify (input essential if $\sigma \leq 1$) - Interpretation contribution of NK: can imply over-harvesting or land conversion beneficial for the env.
2. CD extended to the biosphere	- Account for critical enabling systems (water etc) and tipping points/planetary boundaries	- Difficult to measure ecosystem services - Interdisciplinary cooperation needed
3. Integrated Assessment Models (IAM)	- Explicit coverage of feedback loops - Well established (climate modelling)	- Difficult to measure damages - Further development of macro-economic core in env. IAMs

Not discussed in this paper but for future work: natural capital in the utility function

Photo: T. Swinnen

Where to go from here?

European Commission

Data

We have:

Traded resources in I/O tables (Comext, FIGARO)

Material flow accounts (**ESTAT**)

Ecosystems accounts (UN, **ESTAT, JRC**)

Natural capital stocks (**WB-CWON**)

We need:

More complete coverage of natural assets

Compatibility with national accounts

Resource flows (material flow accounts)
- fill data gaps
- values in addition to volumes
- add countries of origin

Ecosystem services
- Widen the coverage
- 25 SEEA categories; ESTAT so far covers 9
- Leg. proposal has 7 more (EP wants more).

Non-traded natural assets
- Outside the NA boundaries…
- … but still crucial for economic production

Variation of NK stocks
- useful alongside GDP
- extend coverage

European Commission

Data (cont'd)

Quality

- Official statistics (ideally)
- Experimental statistics as a stepping stone
- Academic estimates as first approximation

Coverage

- EU Member States for all
- Imports, exports, country of origin for traded resources
- For planetary boundaries: global
- Time series

Integration with SNA

- Need to go beyond SNA conceptual boundaries
- Compatibility with I/O tables as far as possible

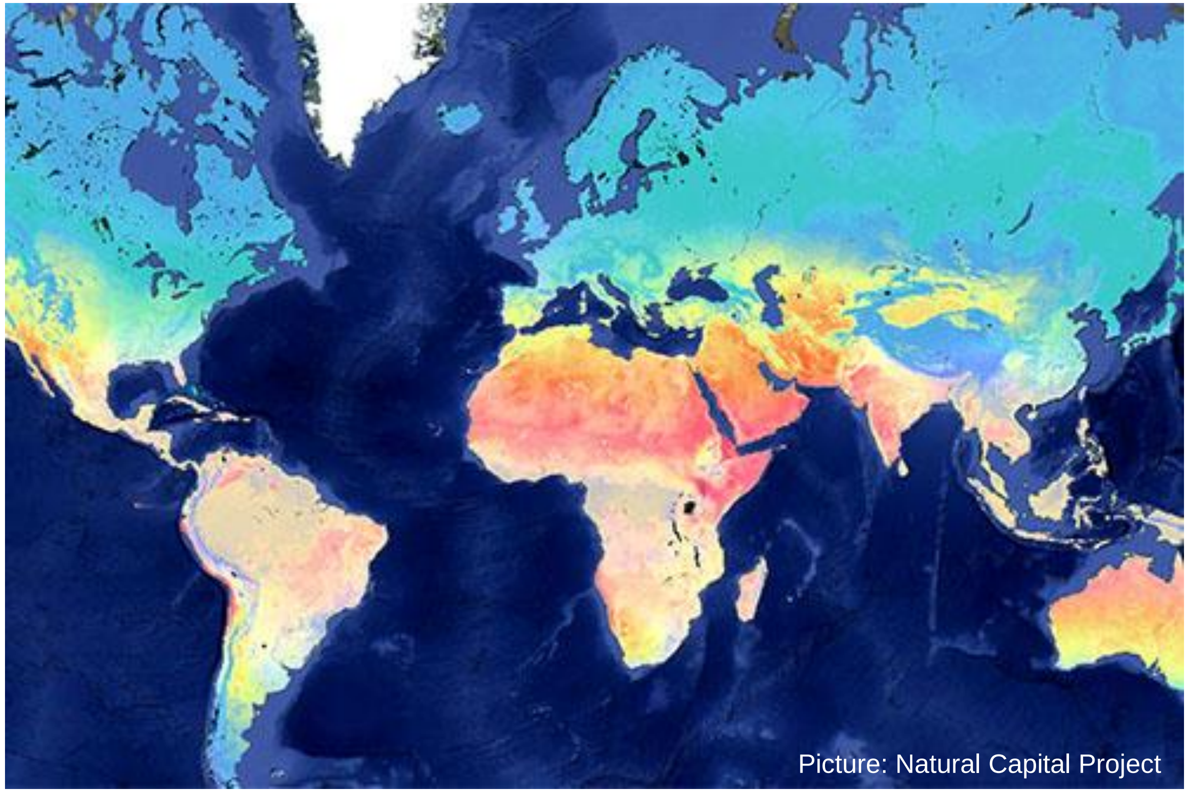
European Commission

Communication and data use

- Raise awareness of already existing data among mainstream macroeconomists
- Green NDP (e.g. **Barbier 2019**)
- Consider what is useful for evidence-based policy-making
  - this presentation focuses on the sustainability of potential economic output
  - there are other dimensions of sustainability and wellbeing

Extensions

- Beyond production: Natural capital and utility / wellbeing
- Inputs into production vs. consumption footprints
- Accounting frameworks for sustainability and well-being (e.g. New Zealand Living Standards Framework, OECD Better Life Initiative, Stanford Natural Capital Project).



Tentative conclusions

Our objectives:

- Unbiased estimates of long-run potential output for surveillance & policy analysis
- Cover feedback loop economic activity → natural capital → potential output
- Understand nonlinear features (tipping points)

Knowledge gaps:

- Understanding of the bio-physical processes through which NK enters production is advancing but still incomplete.
- Measurement and valuation are still partial.

Way(s) forward:

a) Highly aggregated production functions (DSGE, EUCAM) for simulations and basic understanding.

b) Structure of SEEA is compatible with I/O tables. Suitable for use in CGE-type models.

c) Focus on (small number of) critical systems to assess tipping points.

d) Damage functions as key ingredient for integrated assessment modelling.

Thank you

Selected reading

Barbier, E. (2019). The concept of natural capital. *Oxford Review of Economic Policy* 35 (1),14–36.

Bastien-Olvera, B. and F. Moore (2021). Use and non-use value of nature and the social cost of carbon. *Nature Sustainability* 4, 101-108. https://doi.org/10.1038/s41893-020-00615-0.

Cárdenas Rodríguez, Haščlč and Souchier (2018). Environmentally Adjusted Multifactor Productivity: Methodology and Empirical Results for OECD and G20 Countries. *Ecological Economics* 153: 147-160.

COACCH (2023). New damage curves and multimodel analysis suggest lower optimal temperature. Nature Climate Change https://doi.org/10.1038/s41558-023-01636-1

Dasgupta, P. (2021). *The Economics of Biodiversity: The Dasgupta Review*. London: HM Treasury.

Döhring, B., A. Hristov, A. Thum Thysen, C. Carvello (2023). Reflections on the role of natural capital for economic activity. European Economy Discussion Paper 180.

Hassler, J., P. Krusell and C. Olovsson (2021). Directed Technical Change as a Response to Natural Resource Scarcity. *Journal of Political Economy* 129(11), 3039-3072.

La Notte, A., I. Grammatikopoulou, M. Zurbaran Nucci, S. Ferrini, A. Marques, S. Cerilli, and M. Tamborra (2022). *LInking accounts for ecosystem Services and Benefits to the Economy THrough bridging (LISBETH) Part II*. Publications Office of the European Union, Luxembourg. doi:10.2760/010621, JRC130438.

United Nations (2020). Natural Capital Accounting For Sustainable Macroeconomic Strategies. Department of Economic and Social Affairs, New York.

United Nations (2021). System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA). New York.

Varga, J., W. Roeger and J. in 't Veld (2022) E-QUEST: A multisector dynamic general equilibrium model with energy and a model-based assessment to reach the EU climate targets. Economic Modelling 114: 105911. https://doi.org/10.1016/j.econmod.2022.105911.

Weitzel, M., B. Saveyn and T. Vandyck (2019). Including bottom-up emission abatement technologies in a large-scale global economic model for policy assessments. Energy Economics 83: 254-263. https://doi.org/10.1016/j.eneco.2019.07.004.

World Bank (2021). *The Changing Wealth of Nations 2021 : Managing Assets for the Future.* Washington, DC.