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Estimating the Environmentally Sustainable Productivity Index (ESPI) for UK Agriculture

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Problem statement

Governments link agricultural research & Total Factor Productivity Index (TFPI) to measure the public funding effectiveness

TFPI relies entirely on monetary (market) input and output data

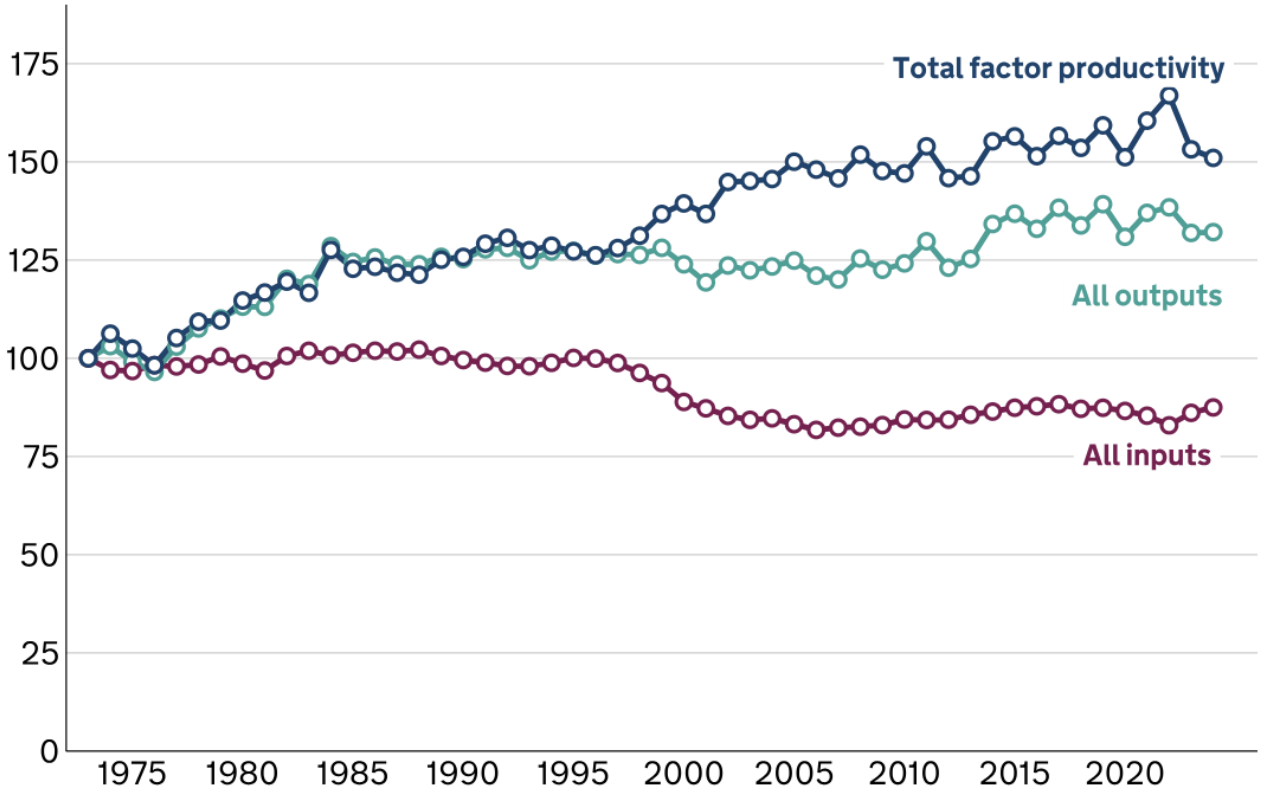
Yet, public funding often targets non-market goals

Environmental performance, Biodiversity, Animal welfare, Rural wellbeing.

Aim: *adapt ESPI, an OECD index-theory framework (Cobourn et al., 2024), to enable UK productivity tracking to internalise key environmental externalities.*

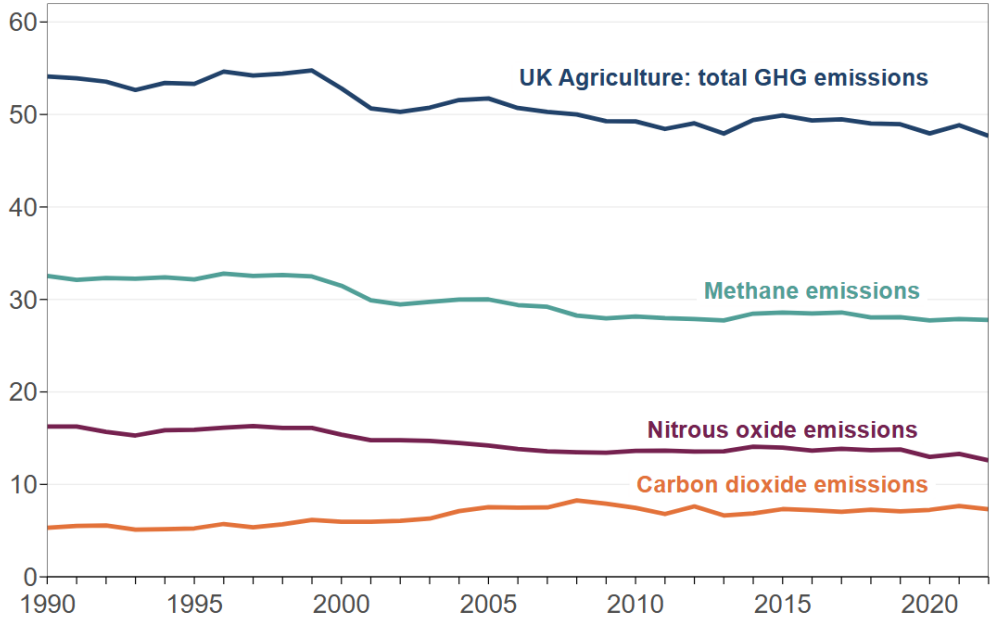
Background

TFPI trends UK agriculture (1973 = 100)



Source: Defra © Crown copyright

GHG emissions from UK agriculture ($MtCO_2e$)



Source: UK greenhouse gas emissions, Department for Energy, Security and Net Zero

TFPI to ESPI following OECD (Cobourn et al., 2024)

$$TFPI_t \equiv \frac{GI_t}{XI_t}$$

GI_t → **Market (Good) Outputs Index (crops, livestock, etc)**

XI_t → **Inputs Index (land, labour, machinery, etc)**

$$ESPI_t \equiv \frac{GI_t^{1-\alpha} BI_t^{-\alpha}}{XI_t}$$

$GI_t^{1-\alpha} BI_t^{-\alpha}$ → **Environmental (Bad) Outputs Index (GHG emissions, fertiliser surplus, etc)**

$\boldsymbol{\alpha} \in [\mathbf{0}, \mathbf{1}]$ is a parameter that measures the extent to which decision-makers account for bad outputs;

$\boldsymbol{\alpha} = \mathbf{0}$ means ignoring bad outputs (TFPI) → $higher\ \alpha$ = more weight on bad outputs

Approach: three phases using UK 1990-2023 data

I) Replicate baseline TFPI

Use DEFRA published value and volume indices (Fisher-chain) to aggregate them under the inputs and outputs indices

Department for Environment, Food & Rural Affairs

Accredited official statistics

Total Factor Productivity of the United Kingdom agricultural industry in 2024

Updated 5 June 2025

Use of Laspeyres, Paasche and Fisher chained growth

II) Build bad-outputs series

Collect time series for:

- GHG emissions (agriculture)
- Nitrogen surplus
- Phosphorus surplus

Estimate weights via Data Envelopment Analysis, DEA, (using weather controls).

Department for Environment, Food & Rural Affairs

Official Statistics

Soil nutrient balances UK, 2024 - statistics notice

Published 30 October 2025

Official Statistics

Agri-climate report 2024

Updated 28 November 2025

III) Compute ESPI

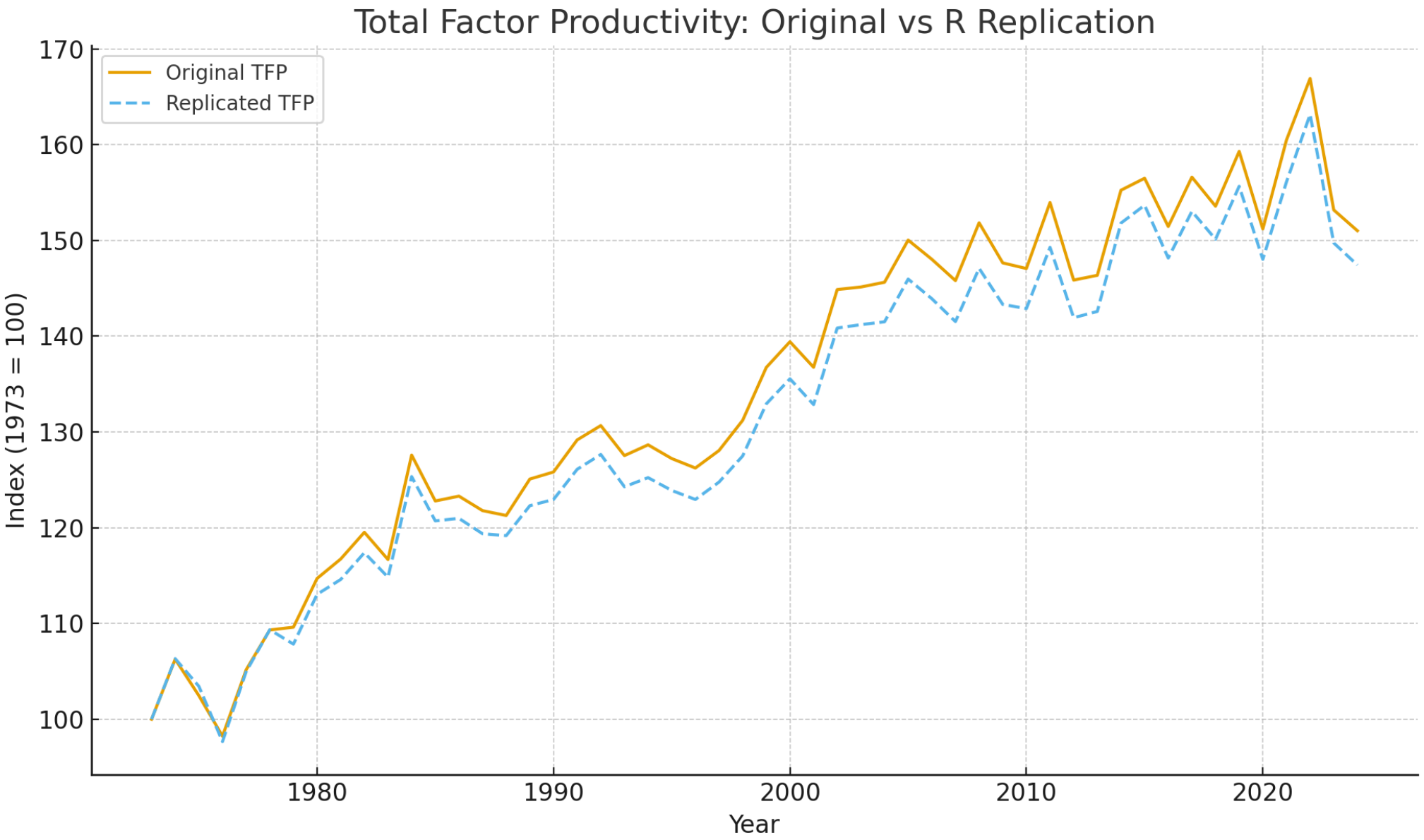
Construct multiplicative ESPI and run sensitivity over α.

RStudio®

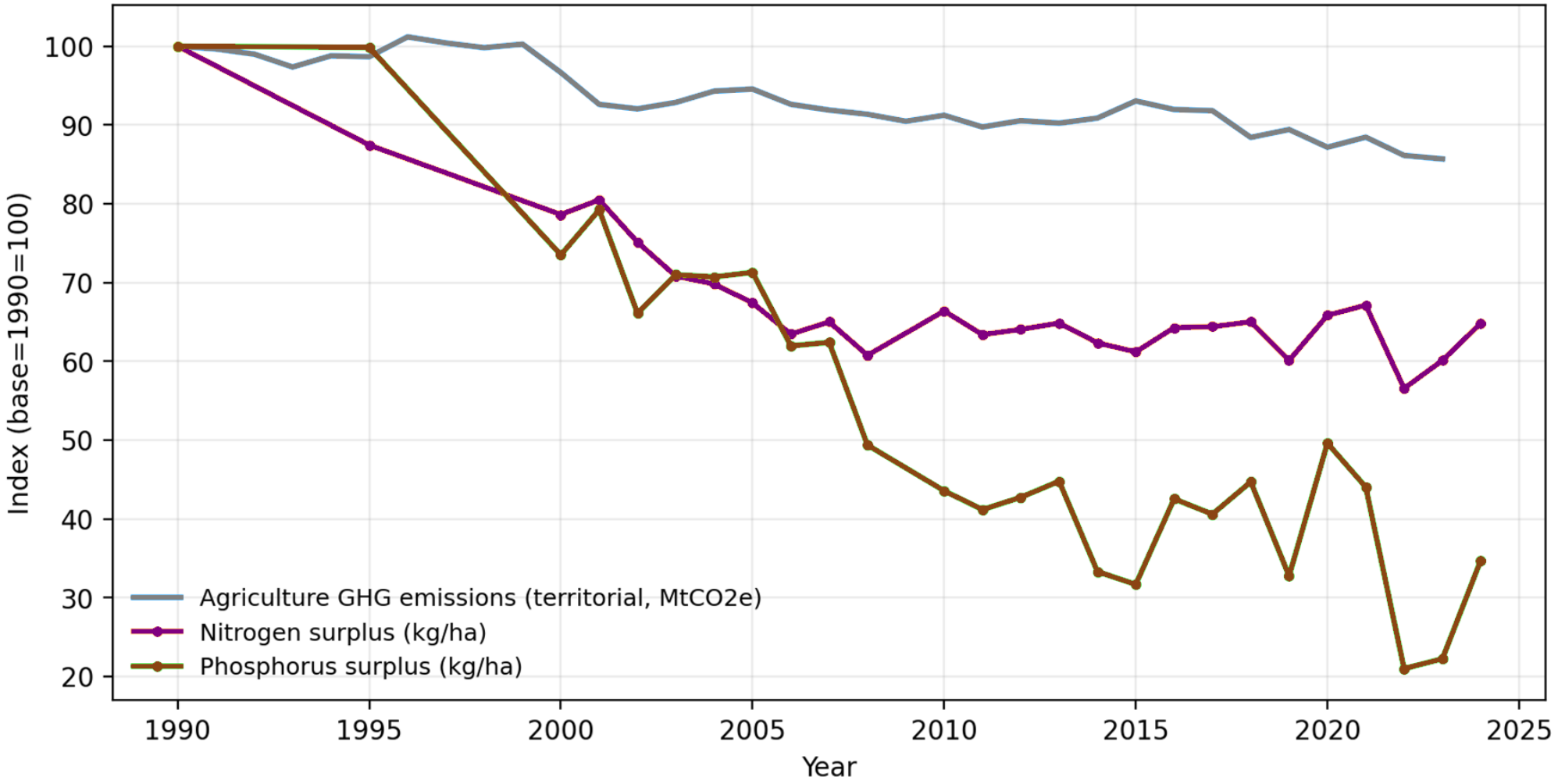
rDEA

Results

Phase I. Replicating baseline TFPI

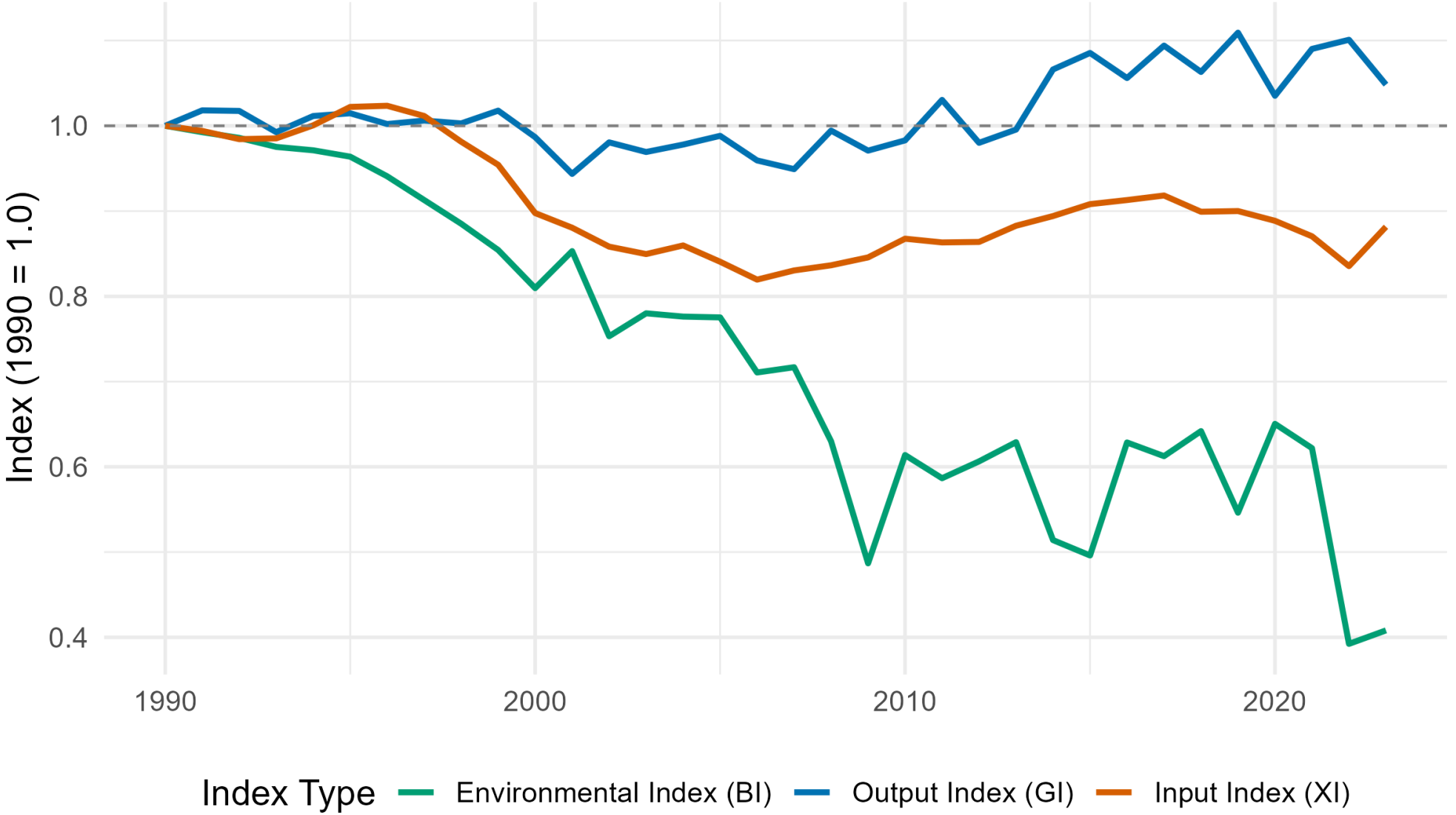


Phase II. Environmental ‘bad outputs’ we can observe in UK statistics: GHG emissions, N & P surplus

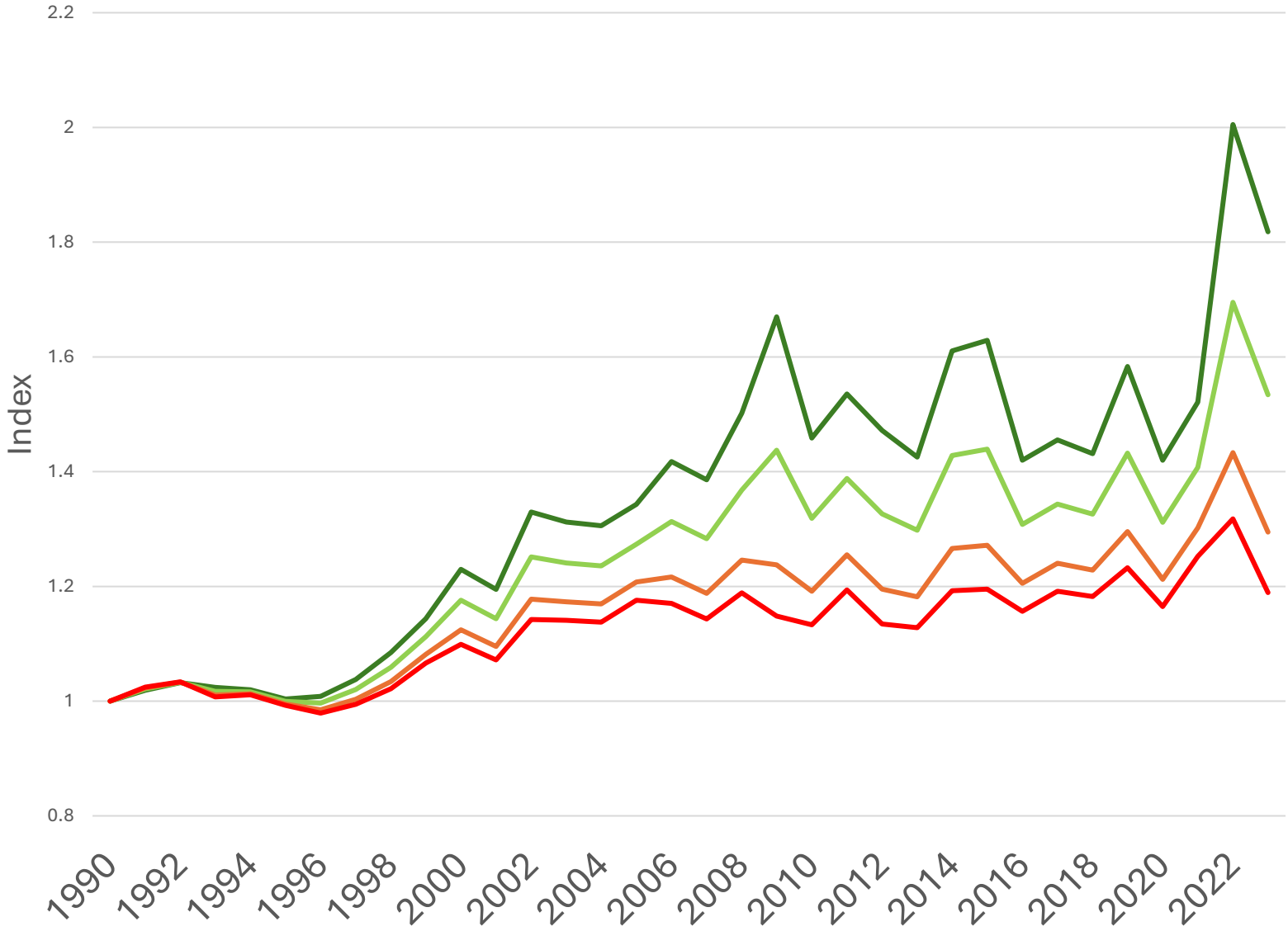


Sources: DESNZ territorial GHG emissions tables (agriculture sector); DEFRA soil nutrient balance statistics (UK). Nutrient series are annual from 2000 with benchmark years before.

Phase III: Estimating ESPI
Underlying indices computation



Phase III: ESPI and α sensitivity (1990-2023; 1990=1.0)



α ↑ = stronger penalty on ***bad outputs*** *(greater credit for reduction)*

- ESPI α=0.5
- ESPI α=0.3
- ESPI α=0.1
- ESPI α=0 (TFPI)

Robustness / limitations

- Collinearity & numerical conditioning: Certain items with similar trends (N and P surplus) can lead to correlation and scaling issues.

- α values suggested from the literature and Cobourn et al.'s work. Empirical estimation via variance minimisation and other econometric approaches, such as Bayesian methods, is under evaluation.

- Comparability: The results are UK-specific but consistent ESPI-OECD's Sustainable Productivity Growth (SPG) narrative.

Why is this useful for policy and evaluation

- Provides a single, index-number-compatible metric that can be reported alongside TFPI (not a replacement).
- Makes trade-offs transparent: productivity gains can be decomposed into changes in output, inputs, and environmental pressures.
- Modular: can incorporate additional externalities (e.g., biodiversity proxies, water quality risk) as data improve.
- Pragmatic for agencies: builds on existing DEFRA/OECD TFP toolkits and avoids full parametric structural estimation.
- But the usefulness of ESPI for estimating agricultural research impact is limited by the short time series

Next steps and discussion points

- Finalise alignment with DEFRA TFPI implementation.
- Compare alternative α choices: policy-set values vs empirical estimation (Bayesian using priors); report uncertainty/sensitivity.
- Extend the framework with additional non-market outputs/inputs as defensible time series become available.
- Discussion: *which externalities matter most for UK productivity evaluation, and what weights are acceptable for official statistics?*

Thank you!