Can omitted carbon abatement explain productivity stagnation?

Quantile shadow-price Fisher index applied to OECD countries

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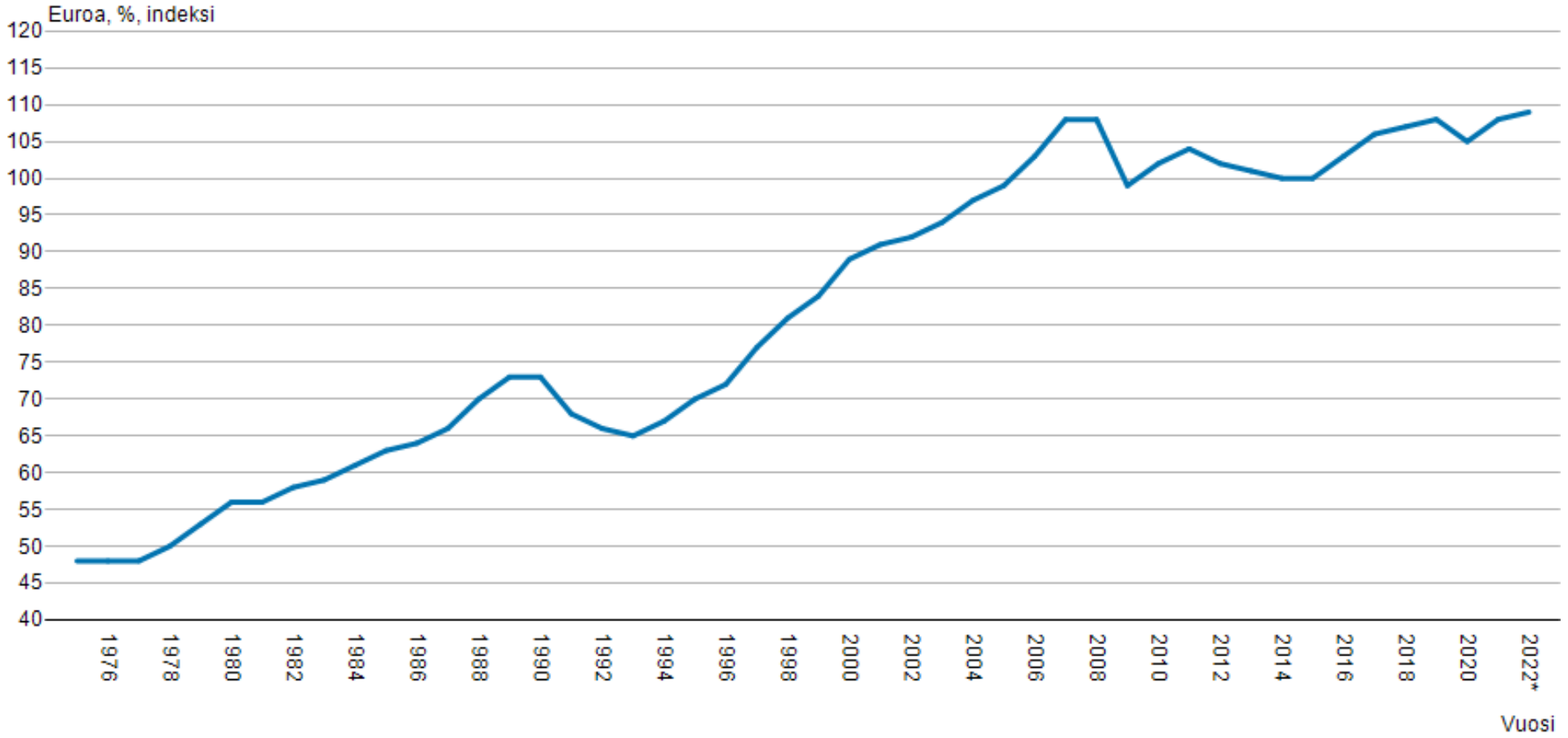
Stagnation in Finland

Real GDP per capita

Bruttokansantuote ja -tulo sekä tulot ja menot henkeä kohden, vuosittain muuttujina Vuosi.
B1GMH Bruttokansantuote markkinahintaan, Volyymi-indeksi, 2015 = 100.



Source: Statistics Finland https://statfin.stat.fi/PxWeb/pxweb/fi/StatFin/StatFin__vtp/

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Stagnation in Western countries:
Many explanations suggested in the literature

- Decline in business dynamism (new firms, job turnover, etc.)
  - Decker et al. (2016) *AER*, Grossman et al. (2017) NBER
- Growth of markups and market power
  - De Loecker et al. (2020) *QJE*
- Misallocation of resources
  - Hsieh & Klenow (2009) *QJE*; Restuccia & Rogerson (2017) *J. Econ. Persp.*
- New innovations getting harder to find
  - Gordon (2012) NBER; Bloom et al. (2020) *AER*
- Measurement problems (digital services, free goods)
  - Brynjolfsson et al. (2021)
- Other: ageing society, zero interest rates, China, etc.

Forgotten explanation?
Cost-ineffective Kyoto Protocol

- Temporary association: First commitment period 2008 – 2012, Doha Amendment 2012 – 2020. (Note: EU implemented, USA never ratified)
- In the late 1990s, Kyoto Protocol was considered highly cost-ineffective
  - Nordhaus and Boyer (1999): the net present value of total cost is $716 billion US dollars (prices of 1990), which is 7 times higher than the benefit.
  - Murkowski (2000): average cost for a US household could be as high as $2728 per year, leading to eradication of 2.4 million jobs.
  - Stanford Energy Modeling Forum (EMF) (Campbell Watkins, 1999).

The range of EMF estimates for the predicted loss of GDP per capita in year 2010 in the "No trading" scenario ($€^{2010}$ per capita).

Region	min	max
USA	155	742
EU	130	708
Japan	99	811
Canada-Australia-New Zeeland	167	729

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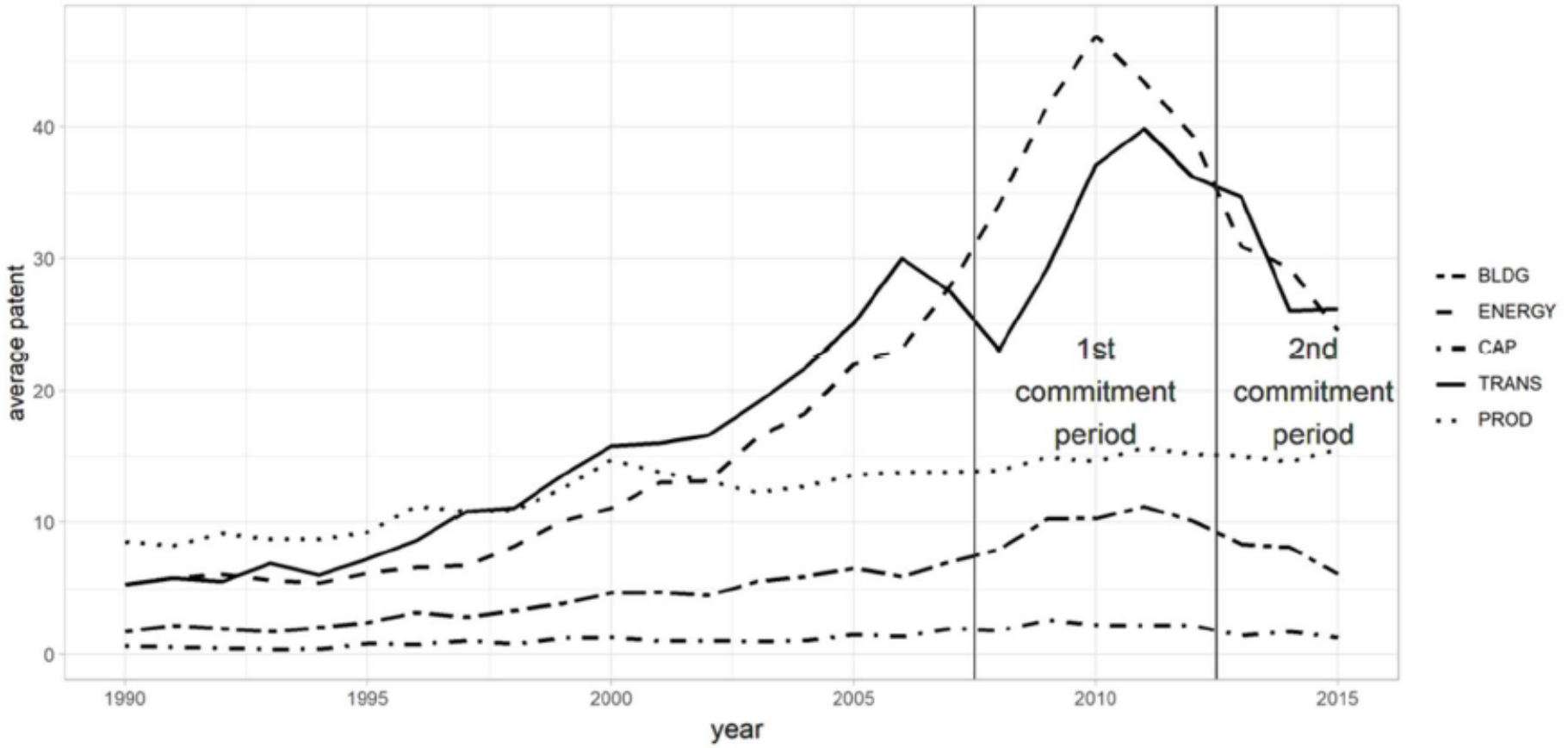
R&D efforts to mitigate climate change: Patents



Citation: Kim, Y. Technological Innovation, the Kyoto Protocol, and Open Innovation. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 198.

Figure 2. Historical trend of specific fields of selected patents. Note: Climate change mitigation technologies related to buildings (BLDG), energy generation, transmission, or distribution (ENERGY), capture, storage, sequestration, or disposal of GHGs (CAP), transportation (TRANS), and the production or processing of goods (PROD).

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Mismeasurement of the productivity impacts of the green transition

- Mechanism:
  - Massive R&D and capital investments on the abatement of greenhouse gas (GHG) emissions
  - Conventional productivity measures (labor productivity, total factor productivity TFP) include labor and capital resources targeted to GHG abatement, but do not include reduction of GHG or the associated benefits
  - Measured productivity slowdown appears to explain stagnated economic growth

- Alternative *Green TFP* measures try to adjust the TFP for the changes in GHG emissions.

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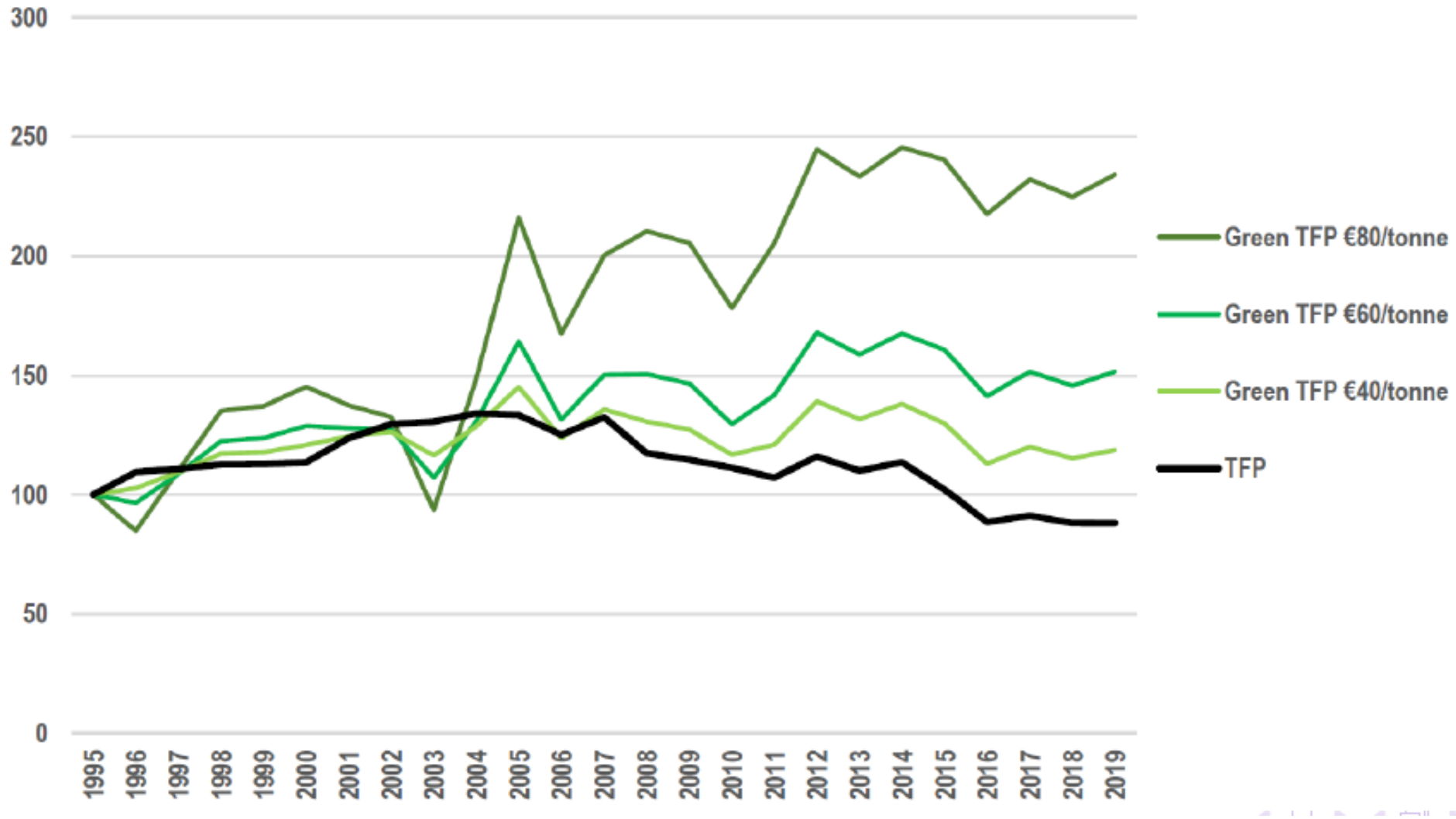
Green TFP in the Finnish energy industry (D) if the price of CO_2 is set at 0, 40, 60 or 80 €/tonne

(index 1995 = 100)



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This paper: shadow-price Fisher index

- In the index theory, Irving Fisher's "ideal" index has many desirable properties
- Fisher TFP index is a quantity index that uses prices as index weights
- If price information is incomplete (e.g., CO_2 emissions), Kuosmanen et al. (2004) propose to use shadow-prices

$$F_s(\boldsymbol{\rho}^{0,1}, \boldsymbol{\omega}^{0,1}, \boldsymbol{y}^{0,1}, \boldsymbol{x}^{0,1}) \equiv \left[\frac{\boldsymbol{\rho}^0\boldsymbol{y}^1}{\boldsymbol{\rho}^0\boldsymbol{y}^0} \times \frac{\boldsymbol{\rho}^1\boldsymbol{y}^1}{\boldsymbol{\rho}^1\boldsymbol{y}^0}\right]^{1/2} \Big/ \left[\frac{\boldsymbol{\omega}^0\boldsymbol{x}^1}{\boldsymbol{\omega}^0\boldsymbol{x}^0} \times \frac{\boldsymbol{\omega}^1\boldsymbol{x}^1}{\boldsymbol{\omega}^1\boldsymbol{x}^0}\right]^{1/2}$$

- The shadow-price Fisher index is closely related to the Malmquist productivity indicator that similarly uses shadow prices, but retains the properties of the Fisher "ideal" index

Shadow-price Fisher index of GTFP

- Including bad outputs b (such as GHG), we have the shadow price Fisher index of GTFP

$$F_s^b(\tilde{\rho}^{0,1}, \tilde{\delta}^{0,1}, \tilde{\omega}^{0,1}, y^{0,1}, x^{0,1}, b^{0,1}) \equiv \left[\frac{\tilde{\rho}^0 y^1 - \tilde{\delta}^0 b^1}{\tilde{\rho}^0 y^0 - \tilde{\delta}^0 b^0} \times \frac{\tilde{\rho}^1 y^1 - \tilde{\delta}^1 b^1}{\tilde{\rho}^1 y^0 - \tilde{\delta}^1 b^0}\right]^{1/2} \Big/ \left[\frac{\tilde{\omega}^0 x^1}{\tilde{\omega}^0 x^0} \times \frac{\tilde{\omega}^1 x^1}{\tilde{\omega}^1 x^0}\right]^{1/2}$$

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How do we estimate the shadow-prices?

- Kuosmanen and Zhou (2021) propose a convex quantile regression (CQR) approach for the estimation of shadow prices

$$\min_{\alpha,\beta,\gamma,\delta,\varepsilon^-,\varepsilon^+} (1-\tau)\sum_{i=1}^{n}\varepsilon_i^- + \tau\sum_{i=1}^{n}\varepsilon_i^+$$

$$s.t.$$

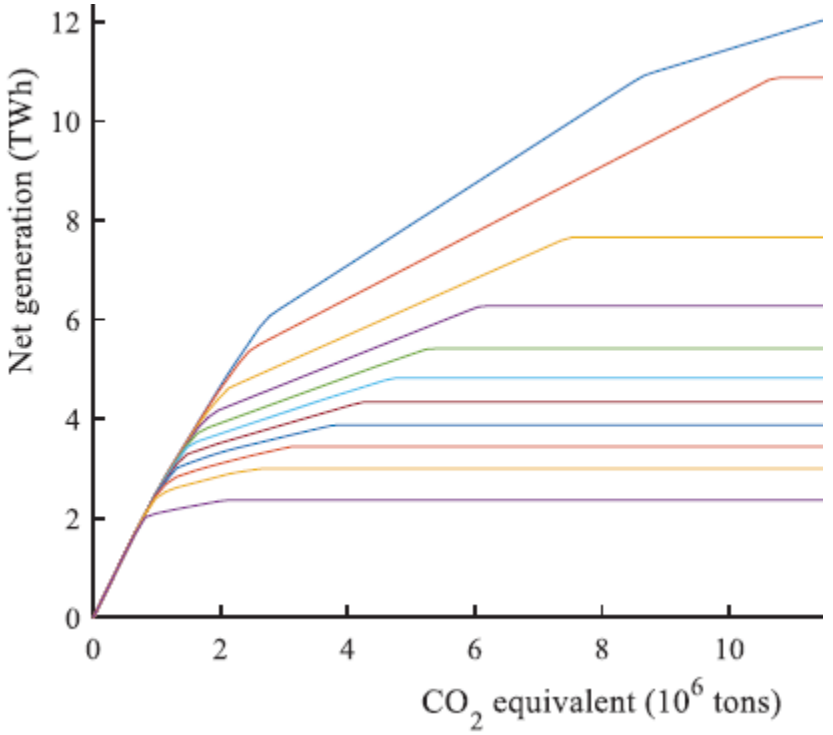
$$\gamma'_i\mathbf{y}_i = \alpha_i + \beta'_i\mathbf{x}_i + \delta'_i\mathbf{b}_i - \varepsilon_i^- + \varepsilon_i^+ \forall i$$

$$\alpha_i + \beta'_i\mathbf{x}_i + \delta'_i\mathbf{b}_i - \gamma'_i\mathbf{y}_i \le \alpha_h + \beta'_h\mathbf{x}_i + \delta'_h\mathbf{b}_i - \gamma'_h\mathbf{y}_i \forall i,h$$

$$\beta'_i\mathbf{g}^x + \delta'_i\mathbf{g}^b + \gamma'_i\mathbf{g}^y = 1 \forall i$$

$$\beta_i \ge \mathbf{0}, \gamma_i \ge \mathbf{0}, \delta_i \ge \mathbf{0} \forall i$$

$$\varepsilon_i^- \ge 0, \varepsilon_i^+ \ge 0 \forall i$$



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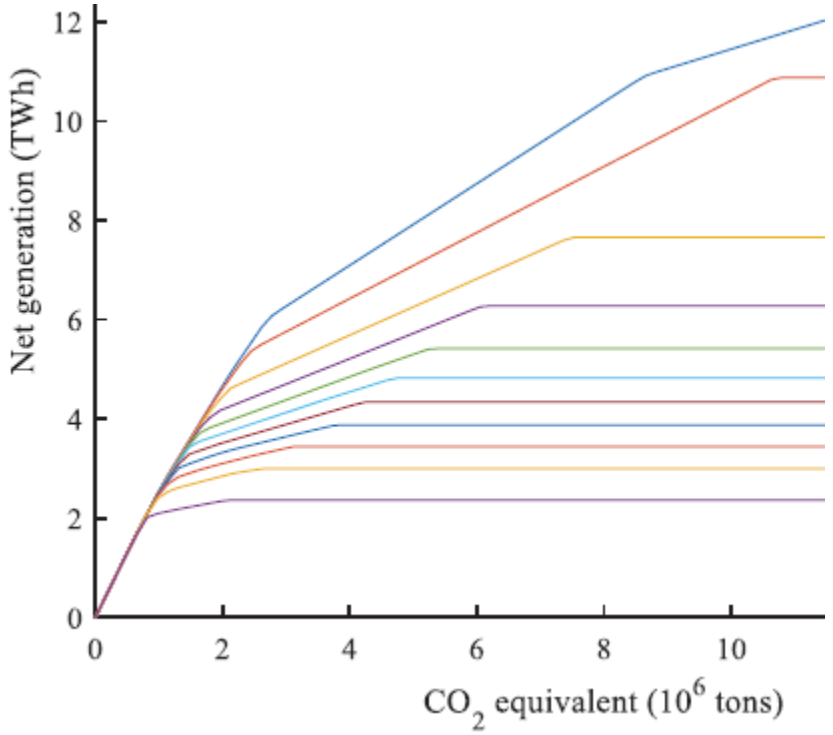
How do we estimate the shadow-prices?

- Kuosmanen and Zhou (2021) propose a convex quantile regression (CQR) approach for the estimation of shadow prices
- Key advantages:
  - Data-driven, fully nonparametric approach
  - Imposes axioms such as monotonicity, convexity
  - Adjusts for technical inefficiency
  - Robust to noise and heteroskedasticity
  - Can avoid quantile crossing problem
- Python package *pystoned*:
  - Dai et al. (2024), *J. Stat. Software*



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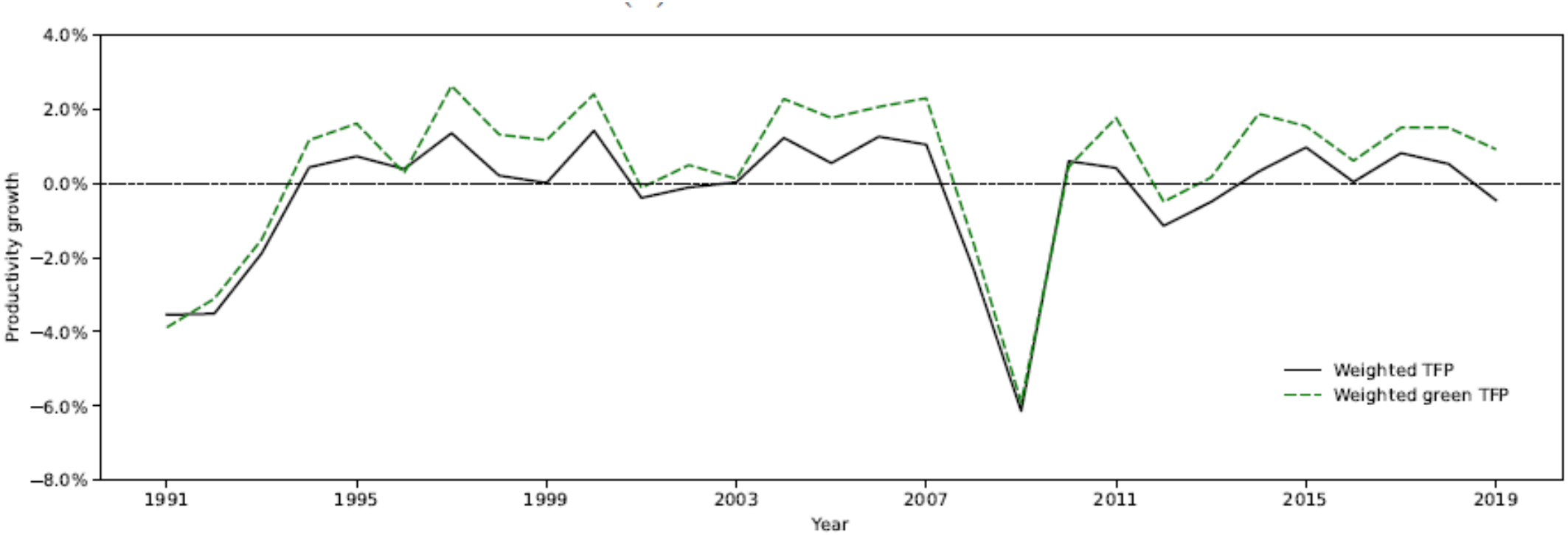
Application to OECD countries

- 38 OECD countries in 1990-2019 (Penn World Tables)
- Outputs: GDP and GHG
- Inputs: labor and capital stock
  - Alternative input measures: capital services and human capital

Variable	Unit	Mean	Std. Dev.
Labor	million	15	25
Capital stocks	million 2017US$	5174738	9683973
GDP	million 2017US$	1193039	2581171
GHG	million tonnes	399	1016
Capital services	million 2017US$	479156	1017760
Human capital	years	11	2

Yearly growth of TFP and GTFP in the OECD countries



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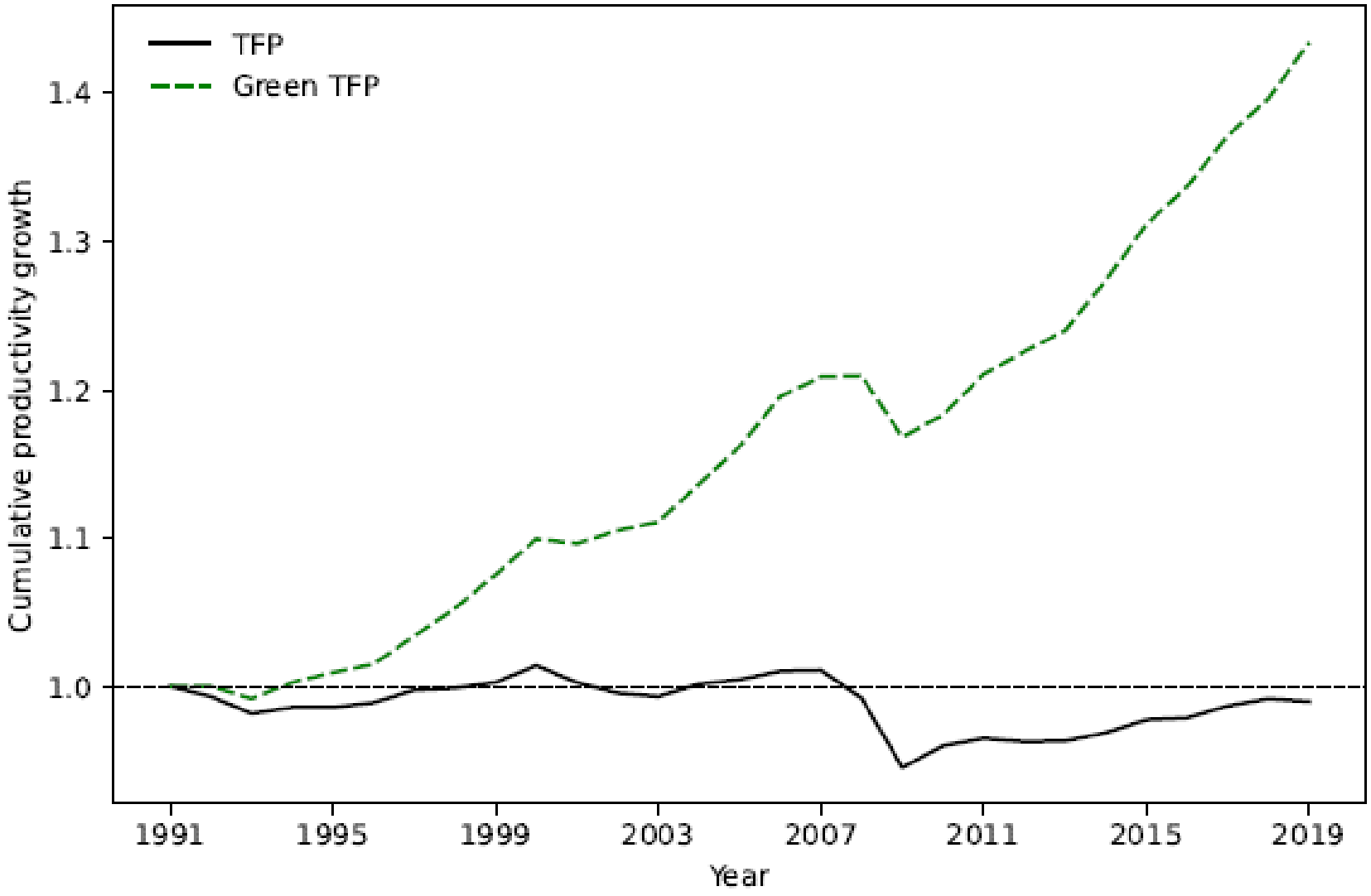
Cumulative TFP and GTFP of the OECD countries



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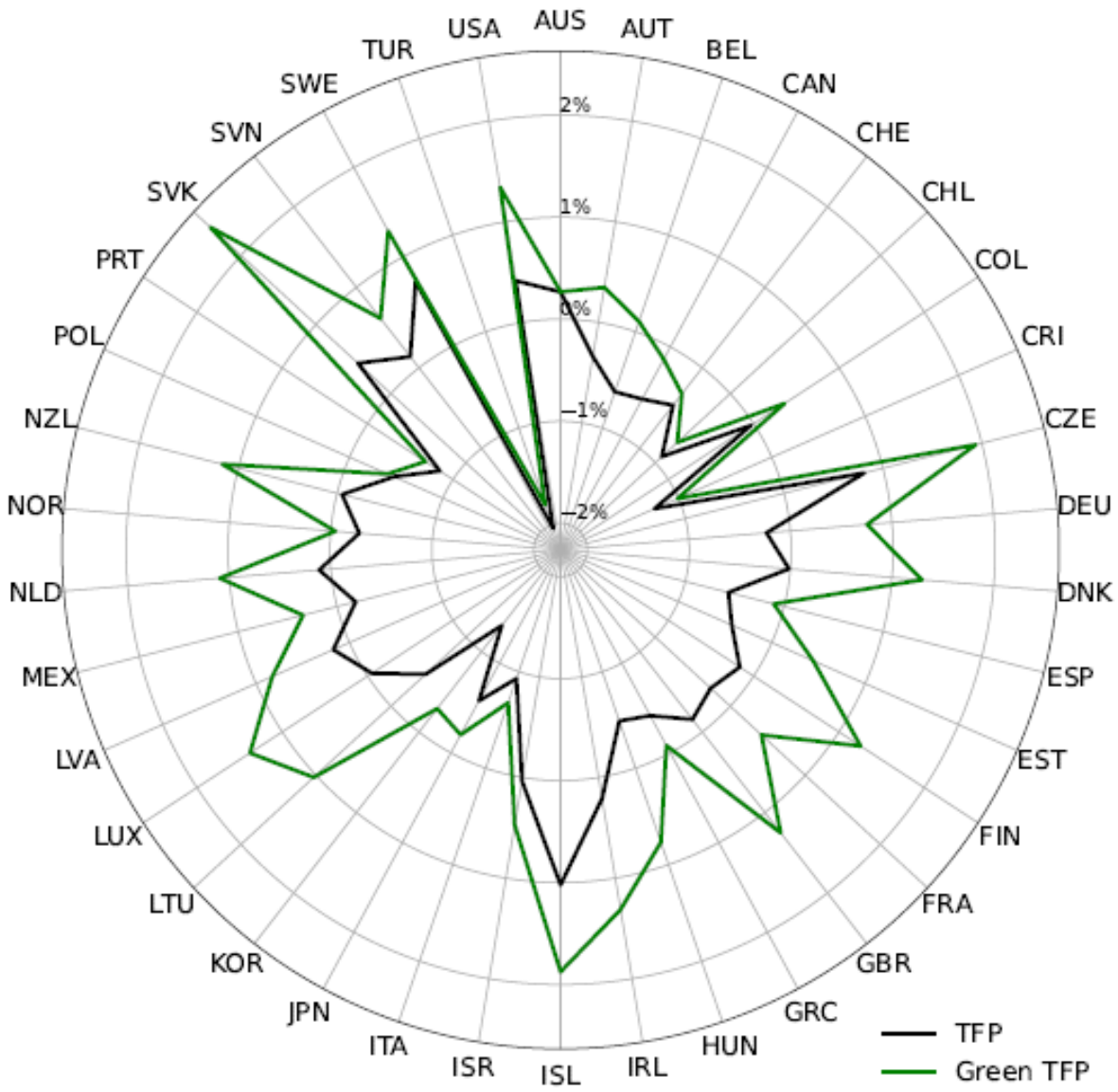
Average TFP and GTFP growth (%) by country



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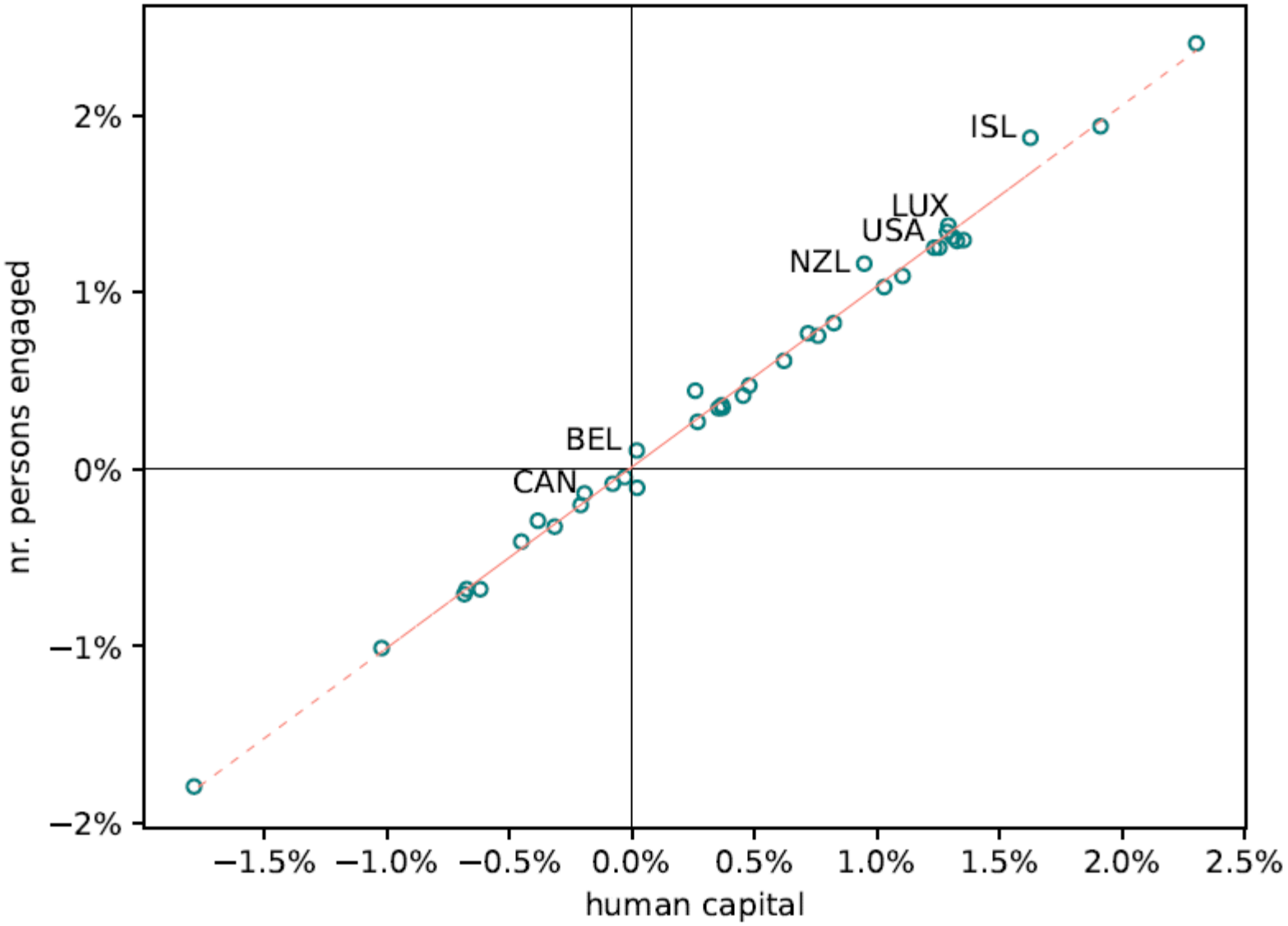
A robustness check: GTFP estimated using the number of persons vs human capital as the labor input



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Conclusions

- We empirically show that the OECD countries exhibit major growth of GTFP, while the conventional TFP has stagnated
- To put the present stagnation into a perspective, it is important to recognize that there can be economic progress, which GDP does not capture
  - Instead of falling in pessimism, perhaps we should appreciate that our living standards did not collapse despite the cost-ineffective implementation of the Kyoto Protocol
- Achieving the net zero targets will require further investment and innovation over the next decades
  - Long-term perspective: like any transition, the low-carbon energy transition is temporary and will come to an end one day

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Two advertisements

- The 45th Annual Meeting of the Finnish Economic Association in Tallinn, February 6-7, 2025, Tallinn University of Technology (TalTech)

https://www.taloustieteellinenyhdistys.fi/2025-annual-meeting-of-the-finnish-economic-association-call-for-papers/

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