MICROSIMULATION MODELLING OF CONSUMPTION, PRICES AND INDIRECT TAXATION

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**** OECD

MOTIVATION

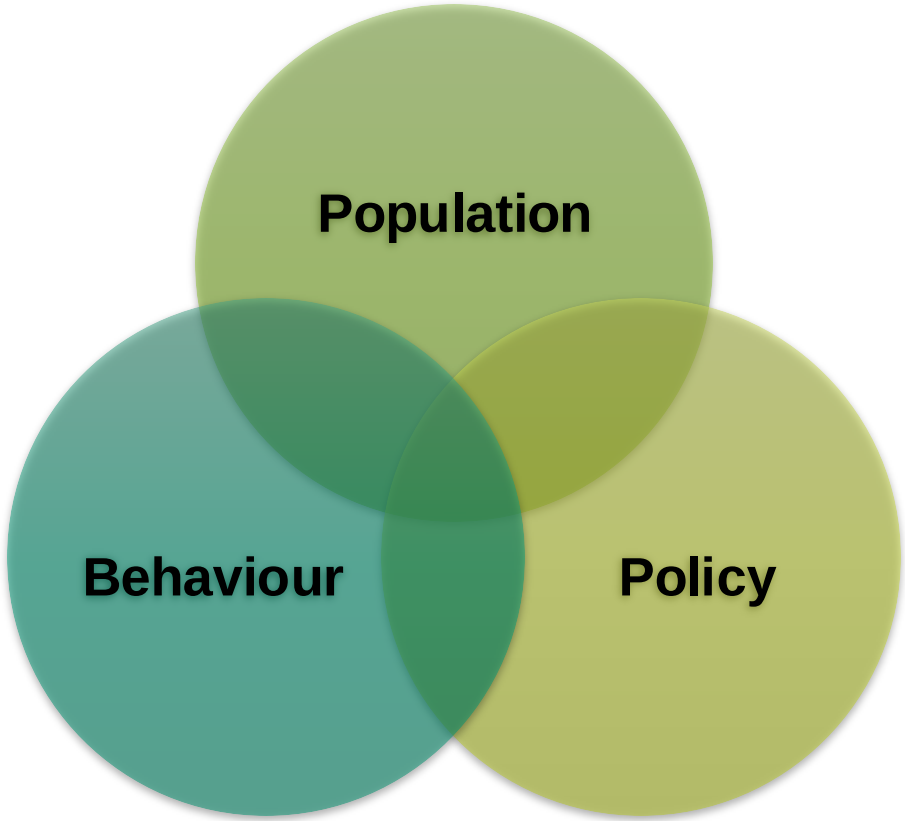
- The pattern of **consumption** influences many **public policy goals**
- **Indirect taxation** →important source of revenue – particularly in developing countries
  - **Exemptions** for necessities (low or zero rate VAT, no Excise Duties on Heating fuels)
- After a period of low inflation →**Cost of Living Crisis**
  - Disproportionally impacted **necessities food and energy**
  - **Housing cost** growth
- **Global sustainability goals** focus on reduced environmental footprint of consumption
  - **Carbon pricing**

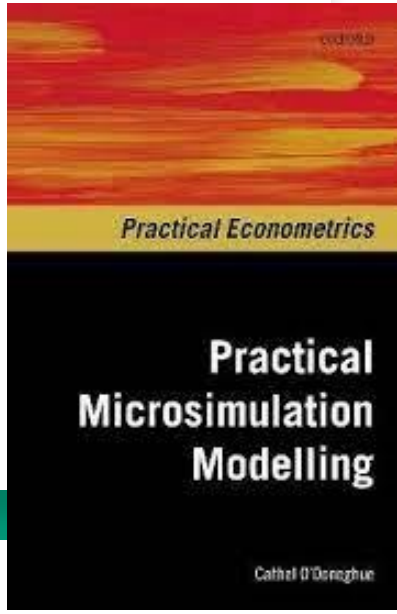
- While consumption is measured in household budget surveys, these **public policy dimensions**, typically are not
  - therefore to study – **we need to simulate** these instruments in micro surveys → microsimulation

Method - Microsimulation

- Study Impact of Public Policy
  - **Effectiveness** of Existing Policy
  - **Evaluate** potential reform
- **Micro-Simulation**
  - Analysis at **Micro** Level
  - Ex Ante **Simulate** Policy
- Helps in **Understanding Complexity**
  - Policy x Population x Behaviour
  - Micro → Complexity → Improve Design of Policy

Core Purpose of Microsimulation Models
Understand and Manage Complexity

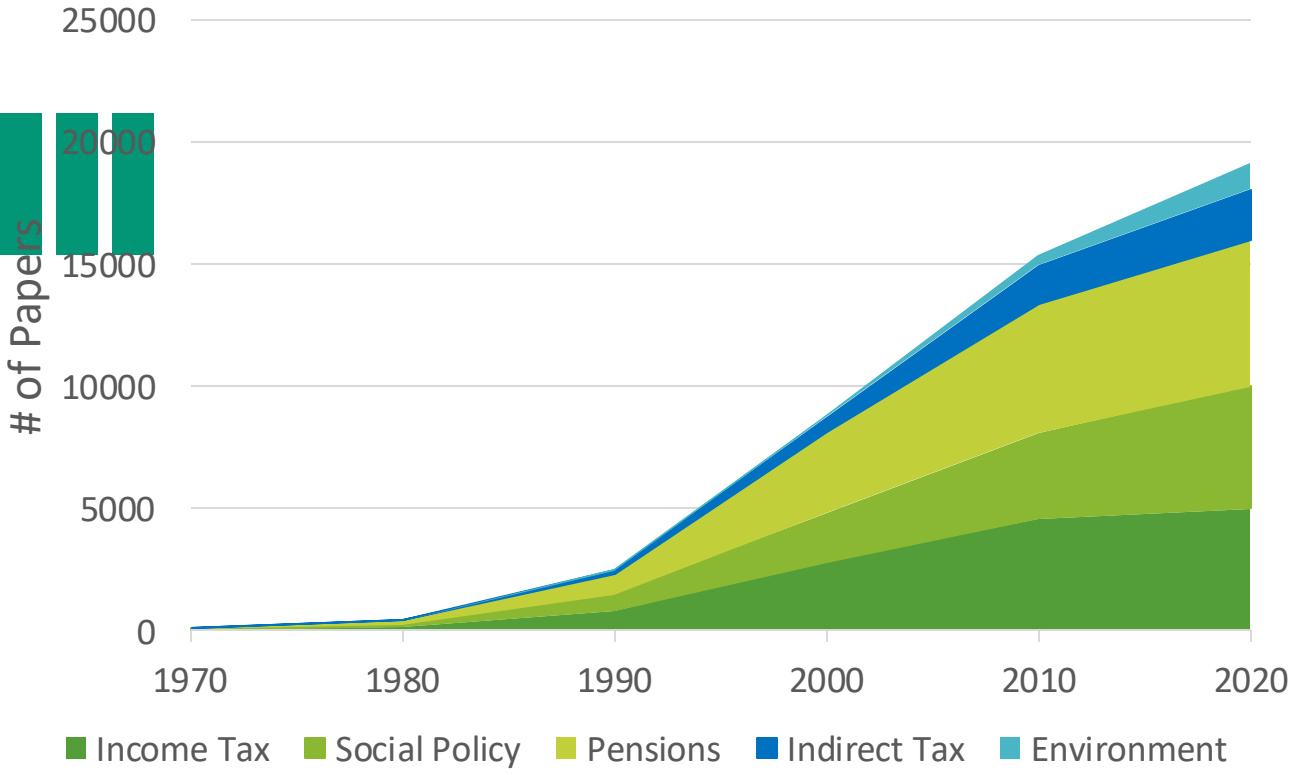


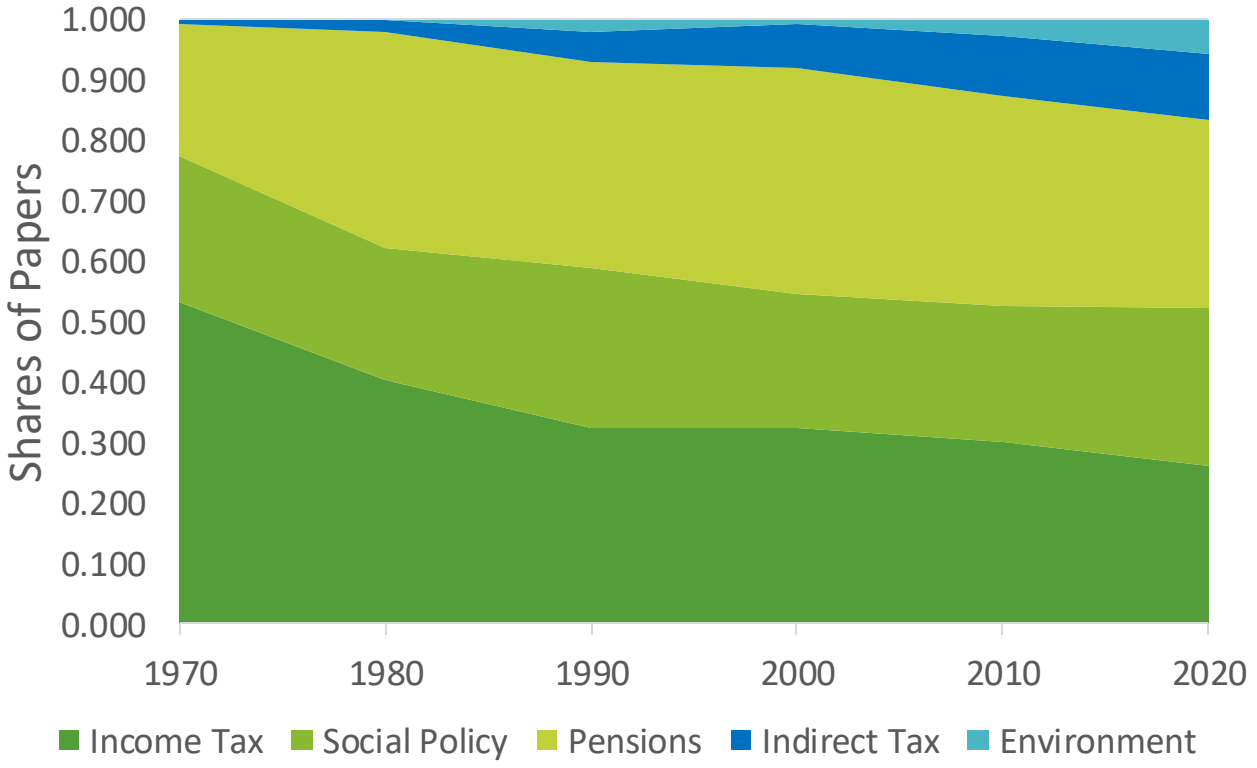


MICROSIMULATION MODELLING TRENDS

- Growth in consumption and environmental microsimulation modelling over time

Microsimulation publications

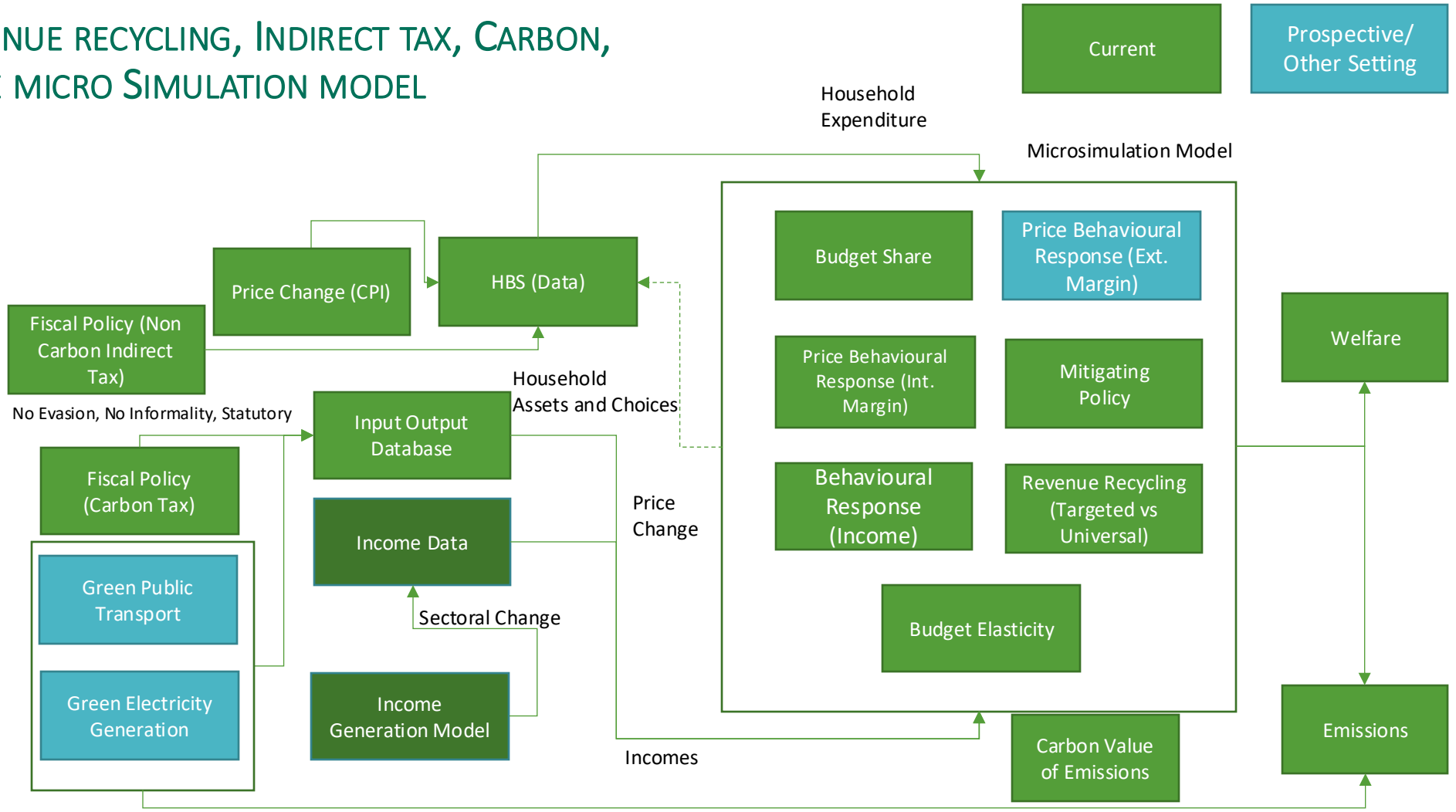




Source: Google Scholar

PRICES MODEL

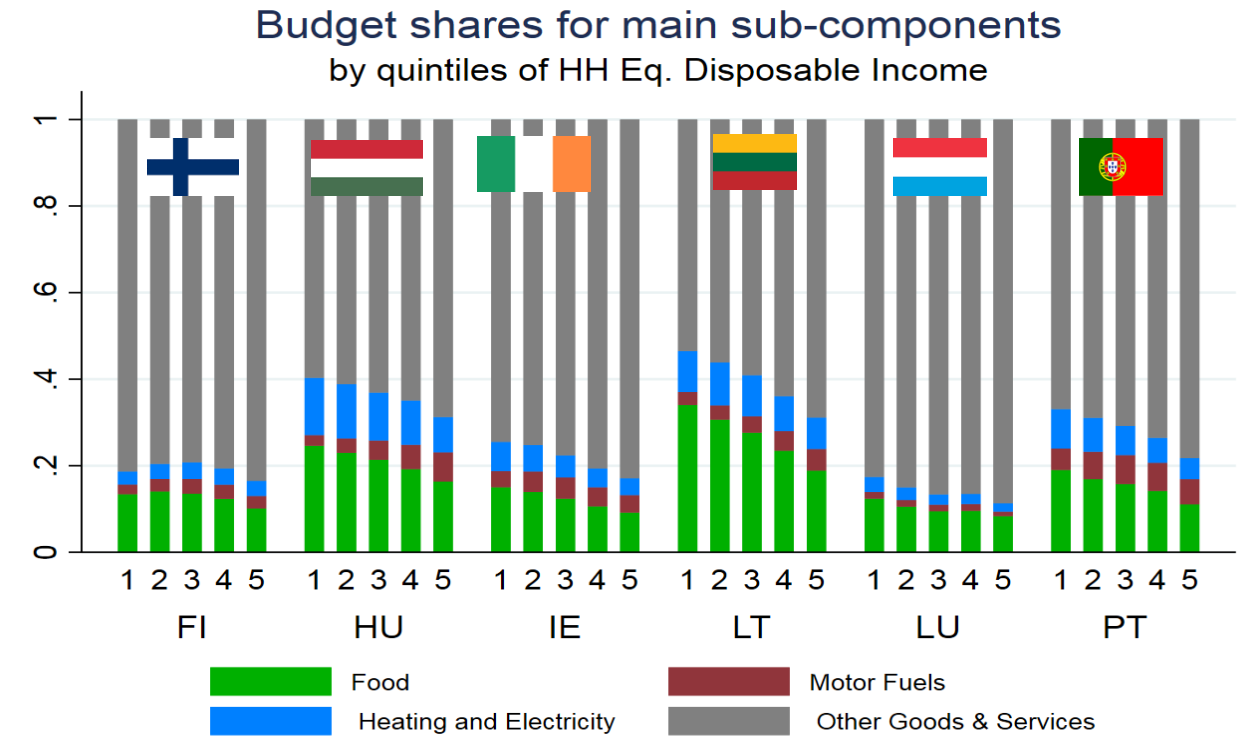
PRICES, REVENUE RECYCLING, INDIRECT TAX, CARBON, EXPENDITURE MICRO SIMULATION MODEL

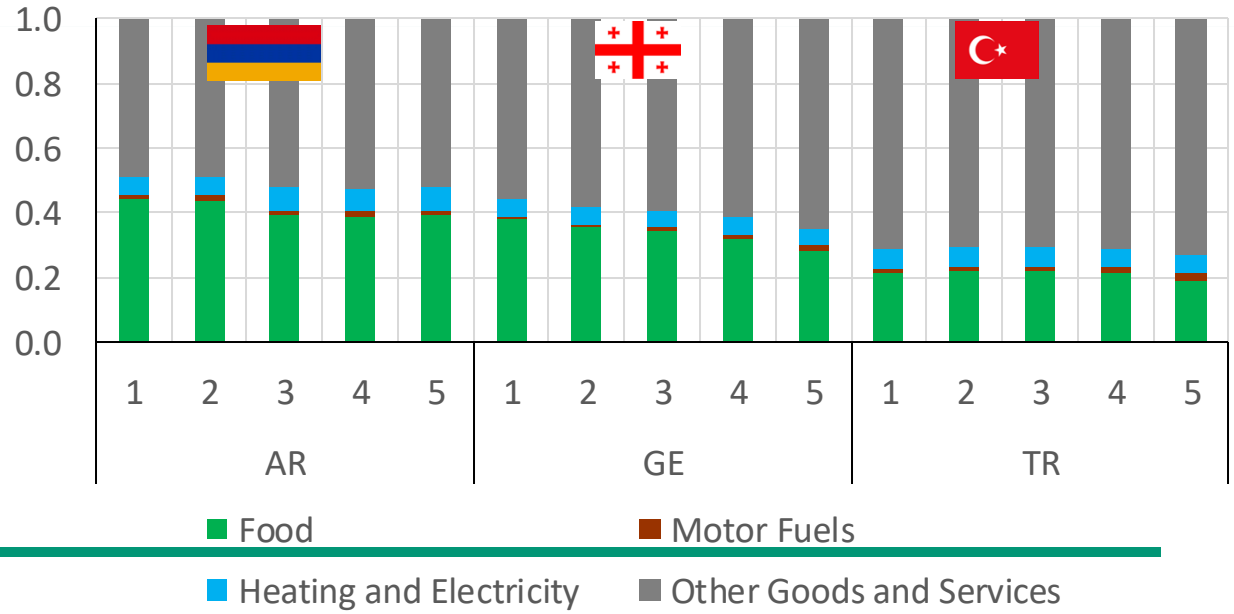


Distributional Composition of Expenditure

(as Share of Expenditure)

- **Food and energy (necessities) shares are higher for low income households**
- Pattern consistent, but level different
- Food very important in poorest countries
- While energy is more of a luxury



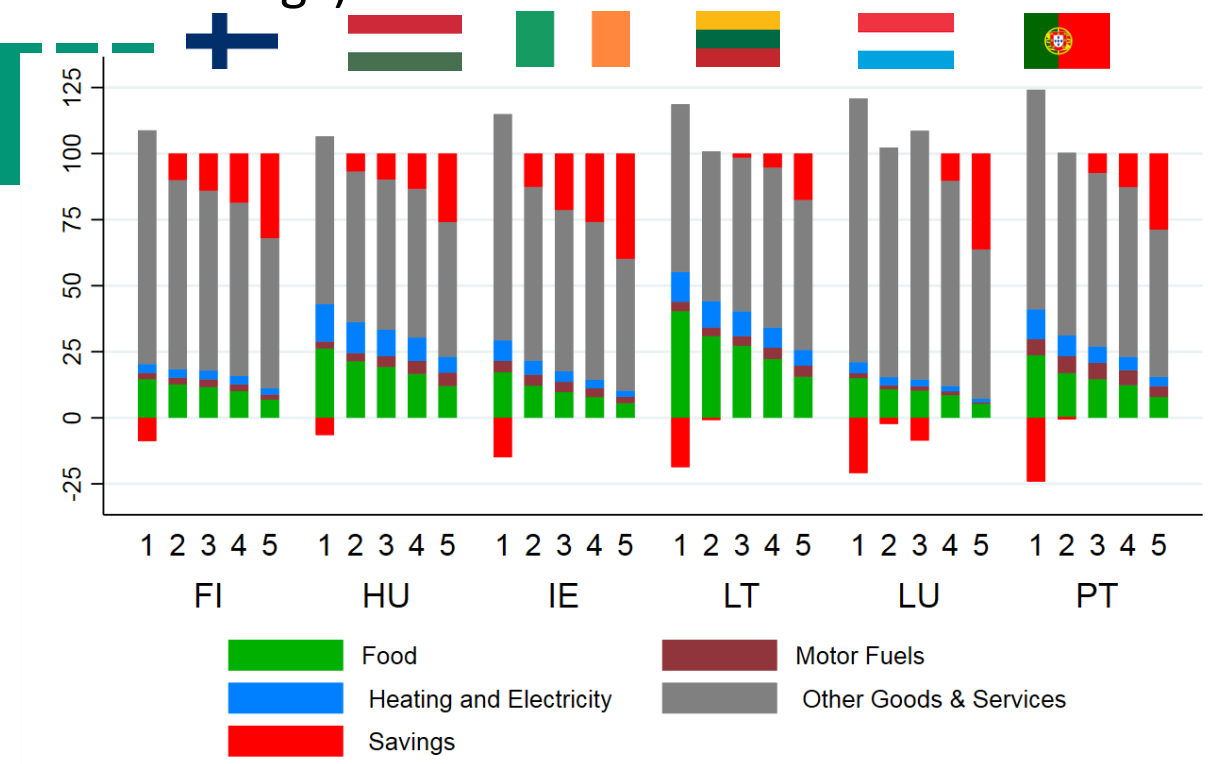


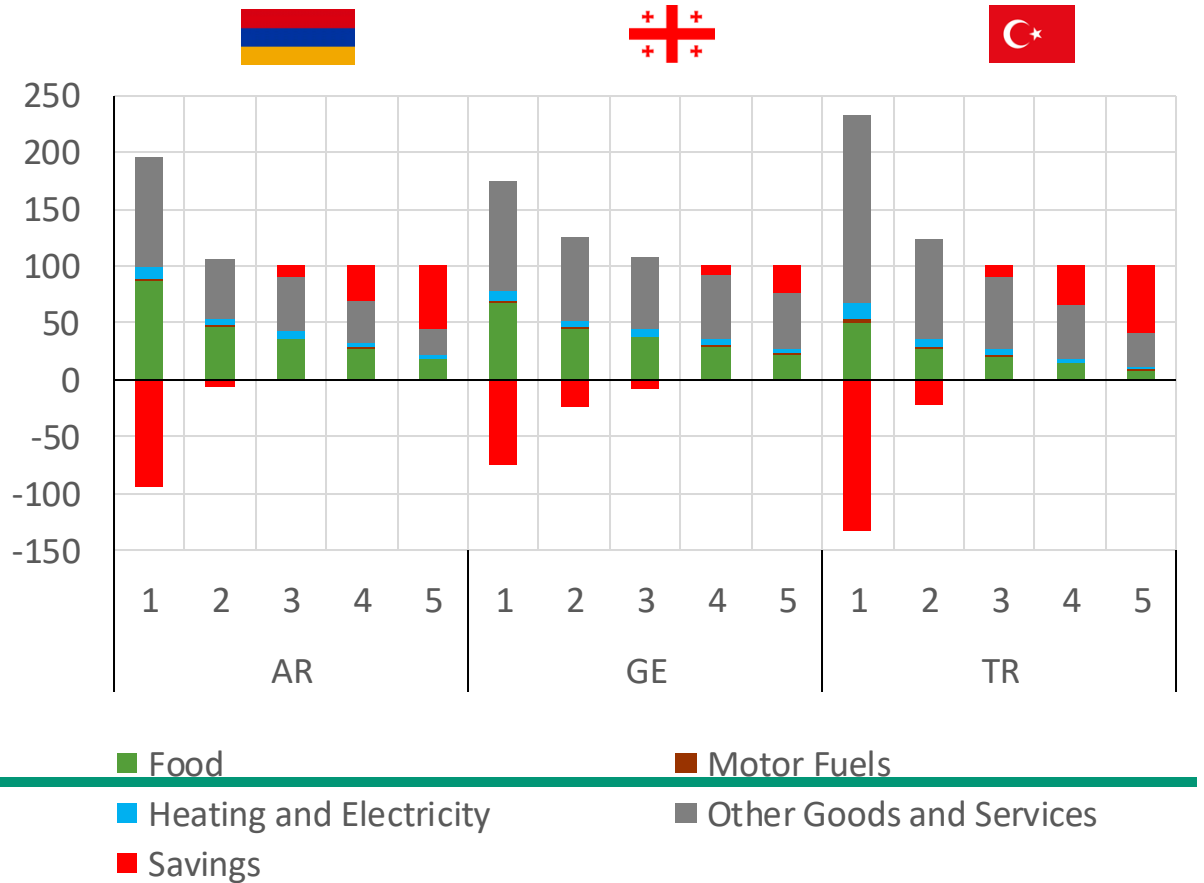
D. M. Sologon* C. O'Donoghue et al. Distributional Impact of Soaring Prices in Europe: A Cross-National Decomposition of Inflation's Regressivity and Progressivity **Forthcoming Review of Income and Wealth**

Z.G. Can, C. O'Donoghue D.M. Sologon et al., Modelling the Distributional Effects of the Cost-of-Living Crisis in Turkey and the South Caucasus: A Microsimulation Analysis ***Forthcoming International Journal of Microsimulation***

Composition of Expenditure across the DISTRIBUTION (As Share of Income) → Savings

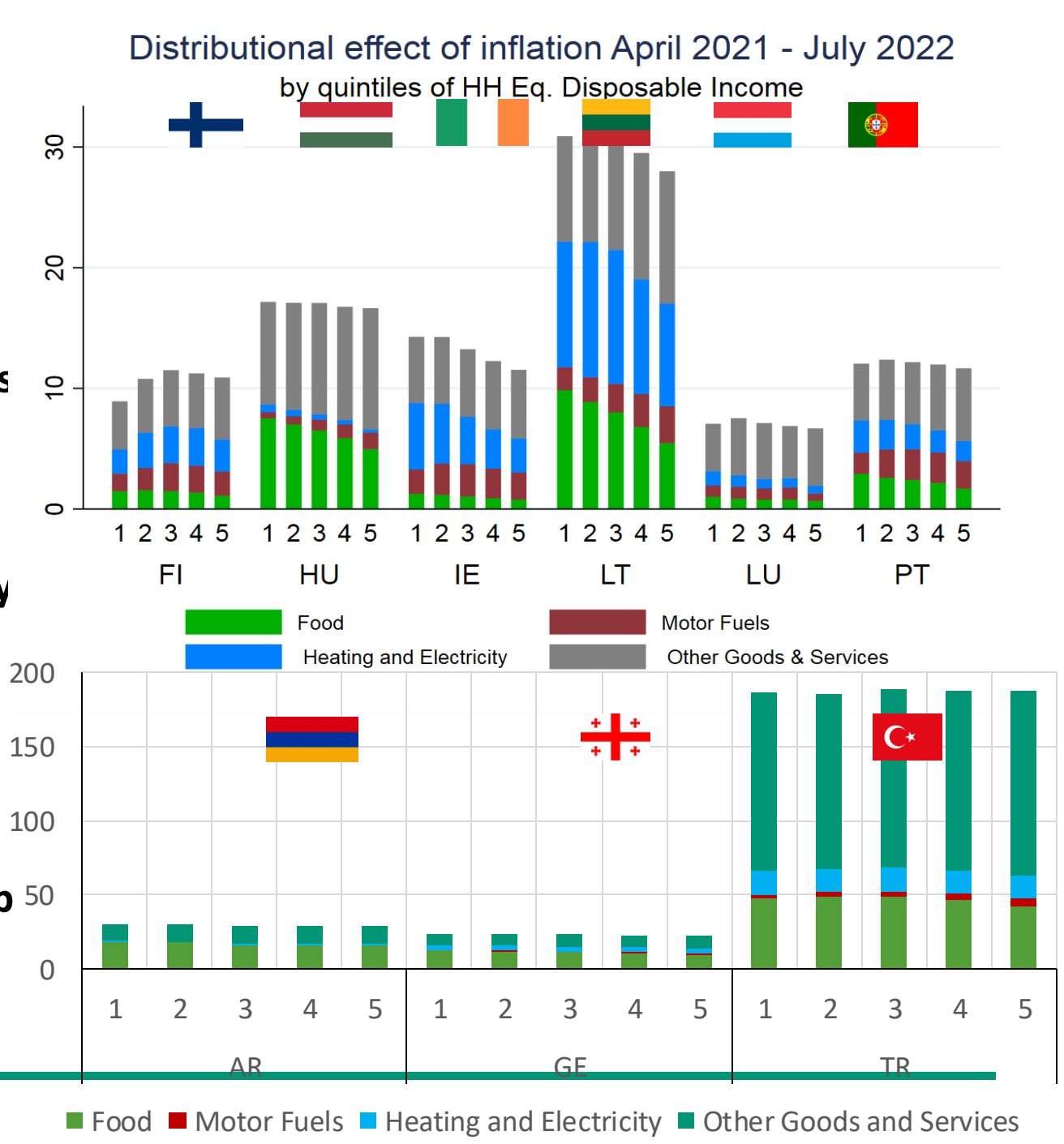
- **Savings shares** (red) in income are **important**; **consistent** story across countries
- However **income under-reporting** will overstate negative savings (Brewer et al., 2017)
- Poor → Reduced ability to tap into savings (Rich can maintain expenditure by reducing savings)





Distributional Impact of Inflation

- **Bars indicate the impact of specific groups on inflation 2021-2022**
- A complex story – influenced by
  - **compositions of expenditure**, and
  - **good specific price inflation (mainly fuel and food)**
- **Very different outcomes across countries**
  - **Levels**
  - **Distribution**
- **Results are flatter** than the public narrative
  - **Savings** and the **capacity to absorb** price changes?
- Turkish super inflation story



DRIVERS OF INFLATION REGRESSIVITY/PROGRESSIVITY

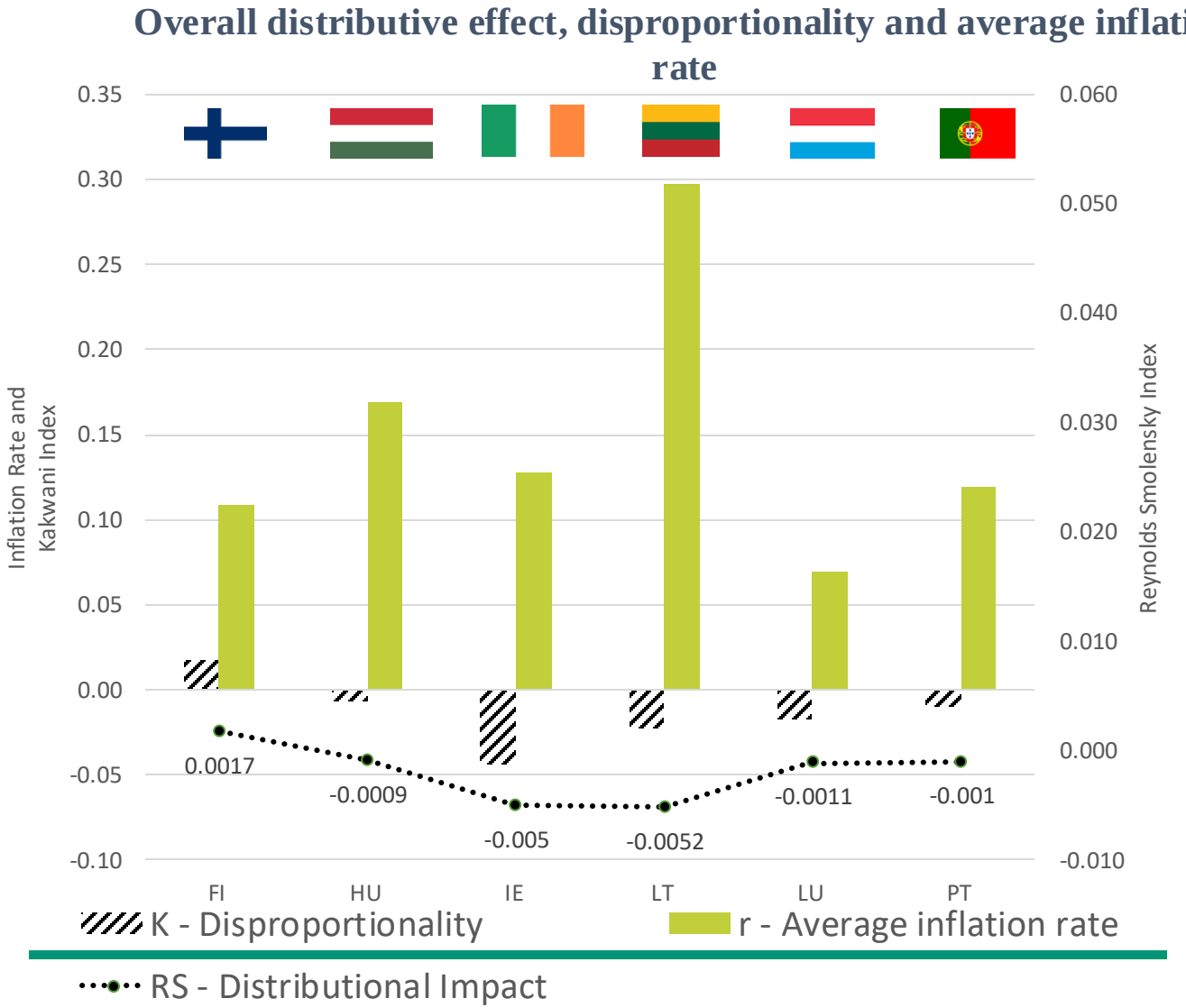
- In order to quantify inflation regressivity/progressivity
  - Reynolds-Smolensky index
    - RS>0 => progressive impact of inflation (higher at the top)
    - $RS = CI_{X+C} - CI_X$
      - CI_{X+C} = **concentration index of post-price change** expenditure when hh are ranked by income;
      - CI_X = **concentration index of initial expenditure** when hh are ranked by income
  - Kakwani index
    - the **disproportionality between**
      - the structure of **initial expenditure** and
      - the **increase in expenditure due to price changes**
    - K $= CI_C - CI_X$
    - CI_c = concentration index of the change in expenditure when hh are ranked by income
  - Pfhaler (1990)
    - to **decompose the distributional impact** of price changes into
      - **inflation rate** and
      - **disproportionality** components
    - $RS = \frac{r}{1+r} * K$

DRIVERS OF INFLATION REGRESSIVITY

No "one size fits all" :

- **Regressive – except Finland**
- **Similar levels of regressivity** of inflation (HU, LU, PT) and (IE, LT)
- Driven by **different levels** of **disproportionality** and **inflation** rate

- **IE more regressive but lower inflation rate than LT**



DRIVERS OF INFLATION REGRESSIVITY/PROGRESSIVITY

- K or the **progression of inflation along the income distribution** –
  - **Decomposed** into the **contribution of each commodity group**

- $K = \frac{r_1}{r} . K_{C_1} + \frac{r_2}{r} . K_2 + \ldots + \frac{r_i}{r} . K_{C_i}$

- K_{C_i} = **disproportionality** of the price changes in **each of the commodity item** group i
- r_i = **average inflation rate** for each commodity group

DRIVERS OF INFLATION REGRESSIVITY

- **Except Finland**:
- Regressivity of inflation is explained by
  - Food, Heating and Electricity **regressivity**
  - Other Goods **progressivity**
  - Motor Fuels Mixed

- → **Progressive**

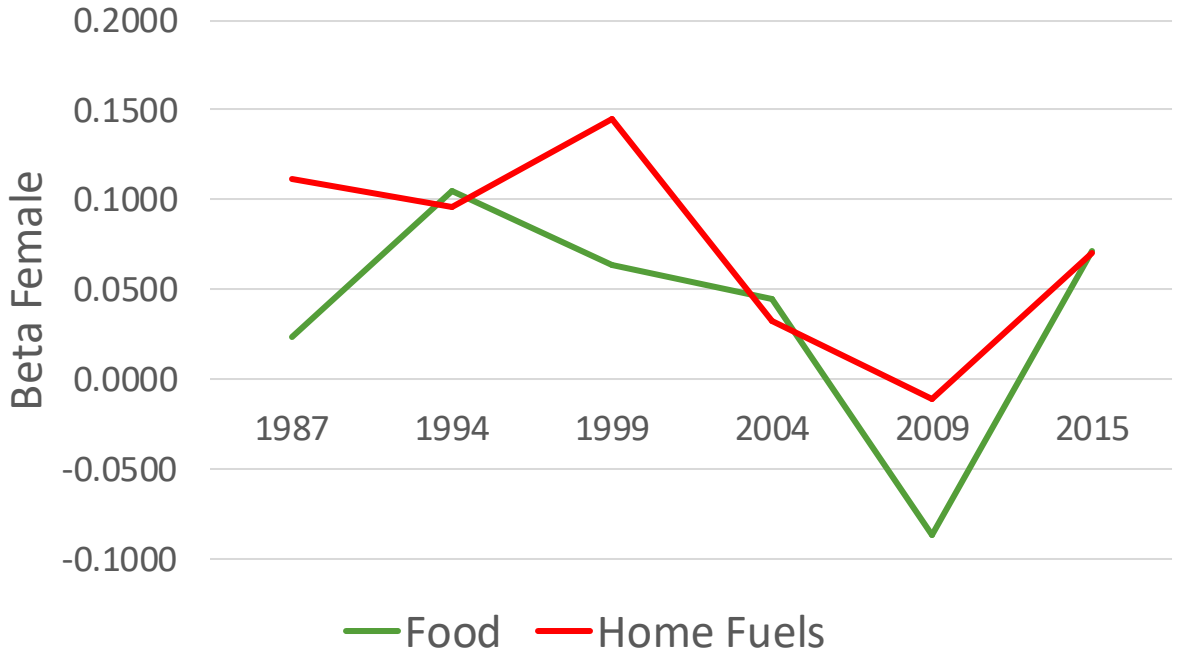
		FI	HU	IE	LT	LU	PT
Component	Formula						
Food	$\frac{r_1}{r} * K_{C_1}$	-42.0	440.6	16.6	122.6	43.0	192.0
Heating	$\frac{r_2}{r} * K_2$	24.5	61.4	68.5	45.5	70.2	39.3
Electricity	$\frac{r_3}{r} * K_{C_3}$	-4.2	0.0	20.4	28.4	2.6	125.5
Motor fuels	$\frac{r_4}{r} * K_{C_4}$	32.6	-153.8	1.4	-33.4	46.6	-42.2
Other goods and services	$\frac{r_5}{r} * K_{C_5}$	89.2	-250.4	-6.9	-62.8	-62.4	-215.4
Total	K	100.0	100.0	100.0	100.0	100.0	100.0

ation rate

FEMALE DIFFERENTIAL –NECESSITIES

- Female headed households have a **higher share of necessities**,
- The **differential has declined over time, although increasing in 2015**
- **Financial Crisis** →Female employment rate
- **Male headed households have a higher share** of motor fuels and tobacco
- Gender difference decline with income

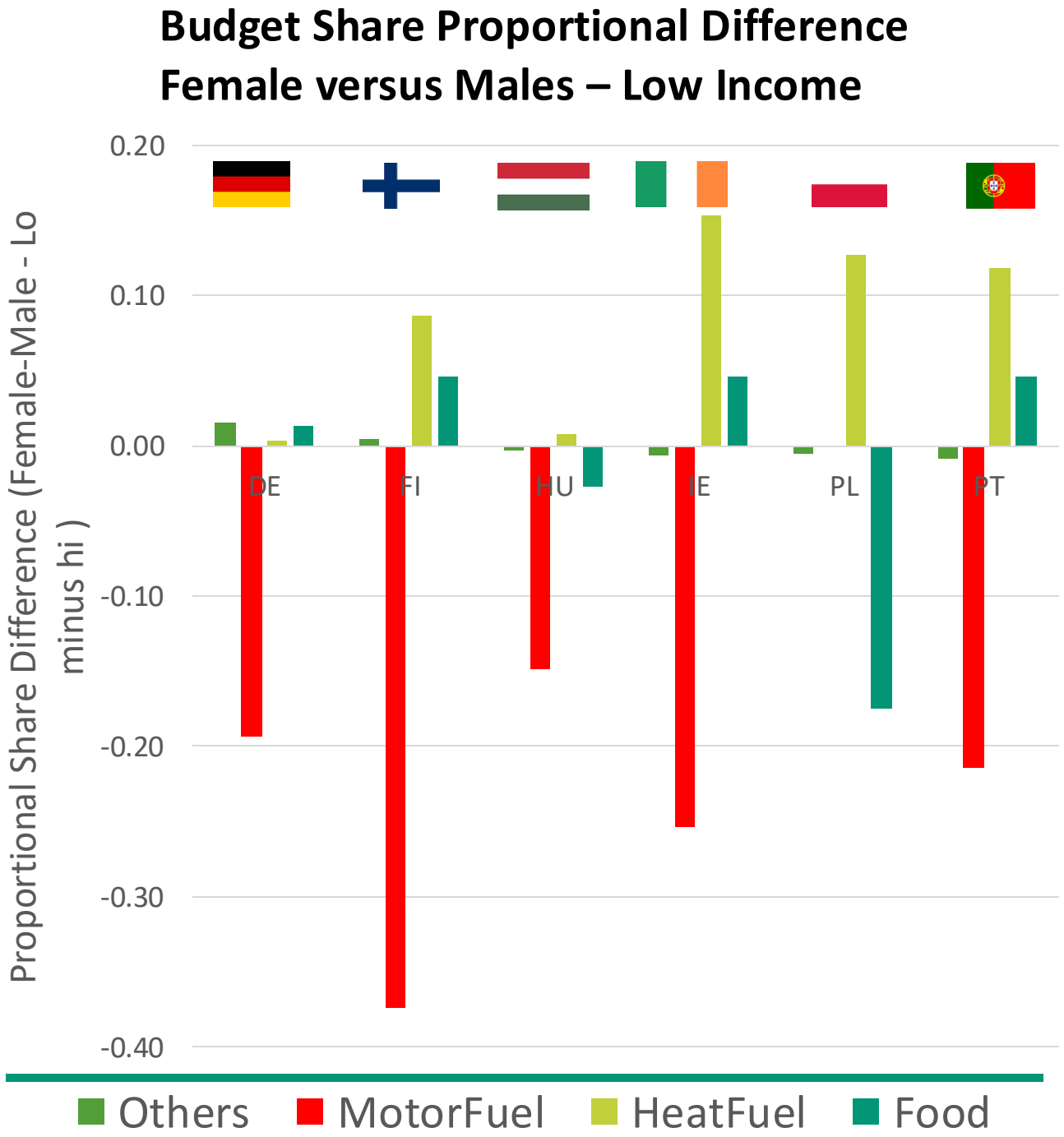
Female – dummy in budget share regression (Income interaction declines



O'Donoghue, C., K. Doorley, D.M. Sologon (2024), Gender Difference in Household Consumption: Some Convergence over Three Decades., *Economic and Social Review*

Female Differential Cross Country Comparison

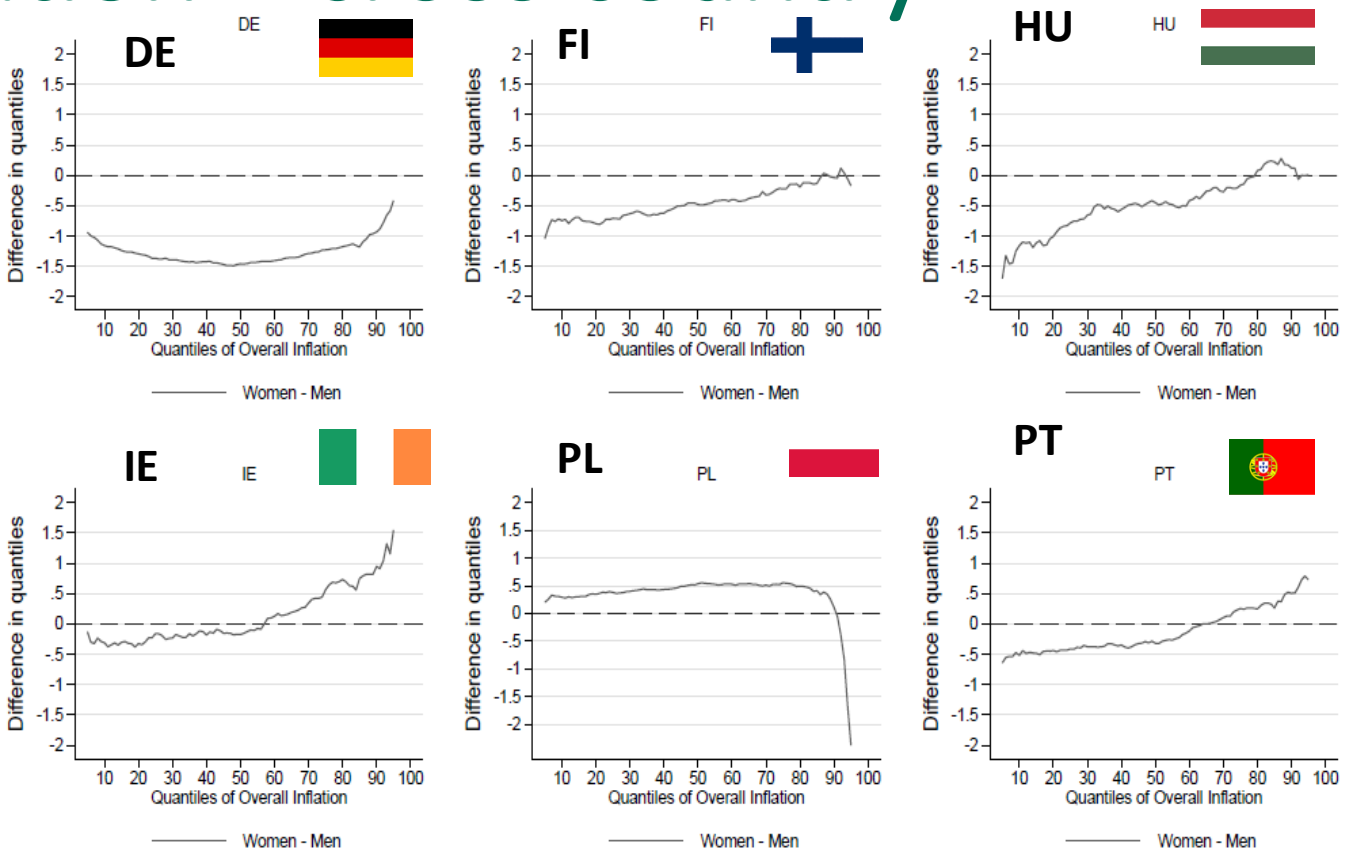
- Consistent Story Cross countries
- **Poor female headed households in general higher necessities**
- Opposite signs for heating fuels and motor fuels
- **Ambiguous impact of carbon pricing**
  - **Depends upon relative shares**



Sologon, D.M. , K. Doorley, C. O'Donoghue, E. Peluso, The Gendered Inequality Impact of the Cost-of-Living Crisis: A Comparative Analysis, *Under Review*

Gender Differential Inflation – cross country

- **Is there a gender inflation story?**
- **Quantiles of Inflation by gender – Difference of Women minus Men**
- **Almost always upward sloping** –
- **proportionally higher inflation** rate for the female hoh with highest inflation
- **IE and PT** female hoh with highest inflation have **higher inflation than men** – opposite at bottom – sign reversing
- **DE, FI generally lower inflation** – high income countries
- **PL generally higher for women** (except top,
- Difficult to draw cross-national conclusions

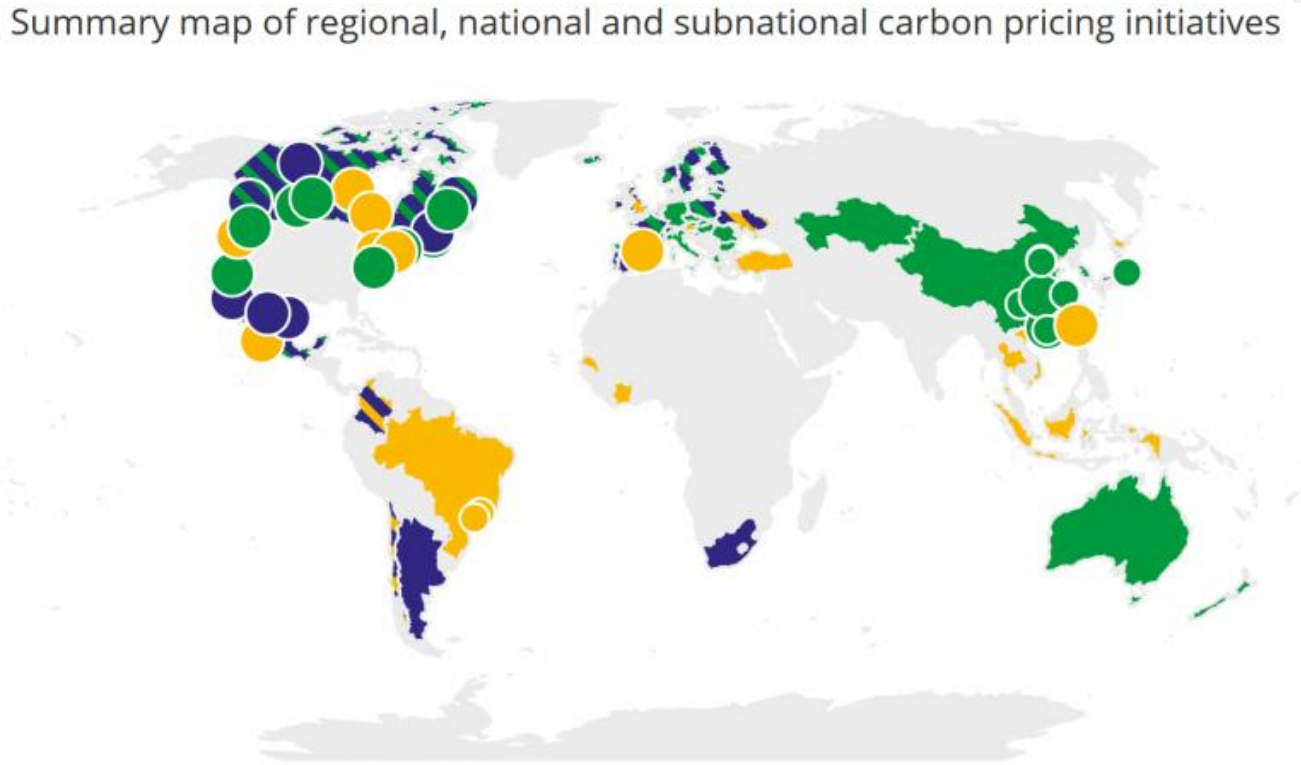


Sologon, D.M. , K. Doorley, C. O'Donoghue, E. Peluso, I Kyzyma, The Gendered Inequality Impact of the Cost-of-Living Crisis: A Comparative Analysis, *Under Review*

Carbon Pricing

- Many countries **have or are considering the use of Carbon tax/ pricing** to disincentivise **carbon emissions**

Carbon tax/pricing under development



***Green**: ETS implemented or scheduled*
***Yellow**: Considered an ETS or carbon tax*
***Blue**: Carbon tax implemented or scheduled*
***Green** / **Yellow** : ETS implemented, carbon tax under consideration*
***Blue**: **Yellow** : Carbon tax implemented or scheduled, ETS considered*

Linden, J., C. O'Donoghue, and D. Sologon, (2024) The many faces of carbon tax regressivity—Why carbon taxes are not always regressive for the same reason. Energy Policy

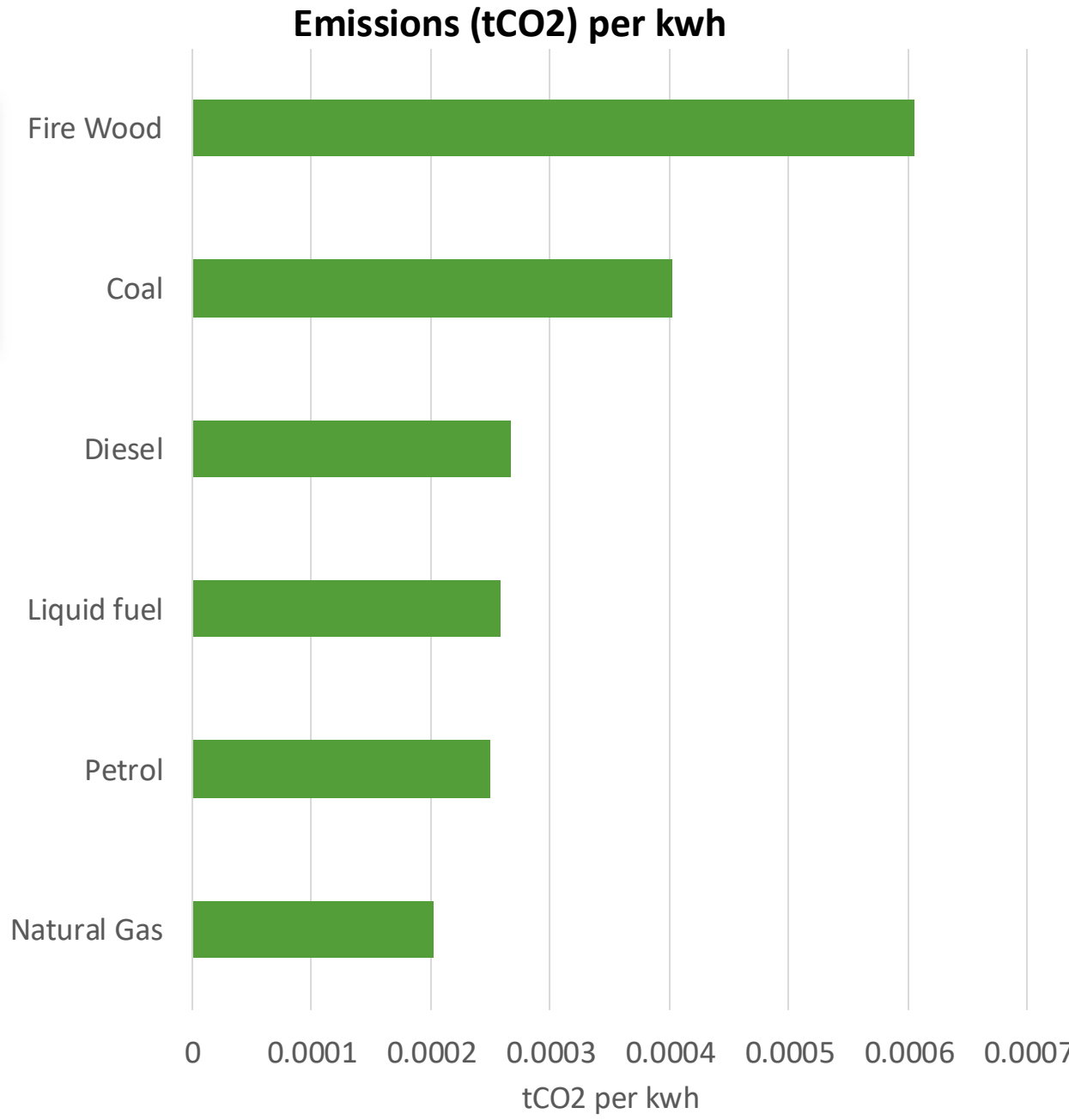
Source https://www.ciat.org/ciatblog-taller-de-la-onu-sobre-impuestos-al-carbono-parte-1-en-paises-en-desarrollo/?lang=en

DECOMPOSING THE DISTRIBUTIONAL IMPACT OF CARBON TAXATION (1)

- Disposable income ($\boldsymbol{Y_h}$) after a carbon tax ($\boldsymbol{Y_{hc}}$):
- $\boldsymbol{Y_{hc} = Y_h - \sum_i \left(Y_h * (1 - s_h) * w_{ih} * \frac{e_{ih}}{p_{ih}} * I_{ih} \right) * P_c}$
- s_h = savings rate
- w_{ih} = budget share of household expenditure allocated to expenditure group i
- e_{ih} = carbon intensity of expenditure category *i* expressed in t of CO2 per unit (kWh for energy goods2 and euro for non-energy goods)
- p_{ih} = price per unit of energy paid by household h
- I_{ih} = indicator variable → household owns a carbon-emitting asset
- P_c = carbon price per ton of CO2

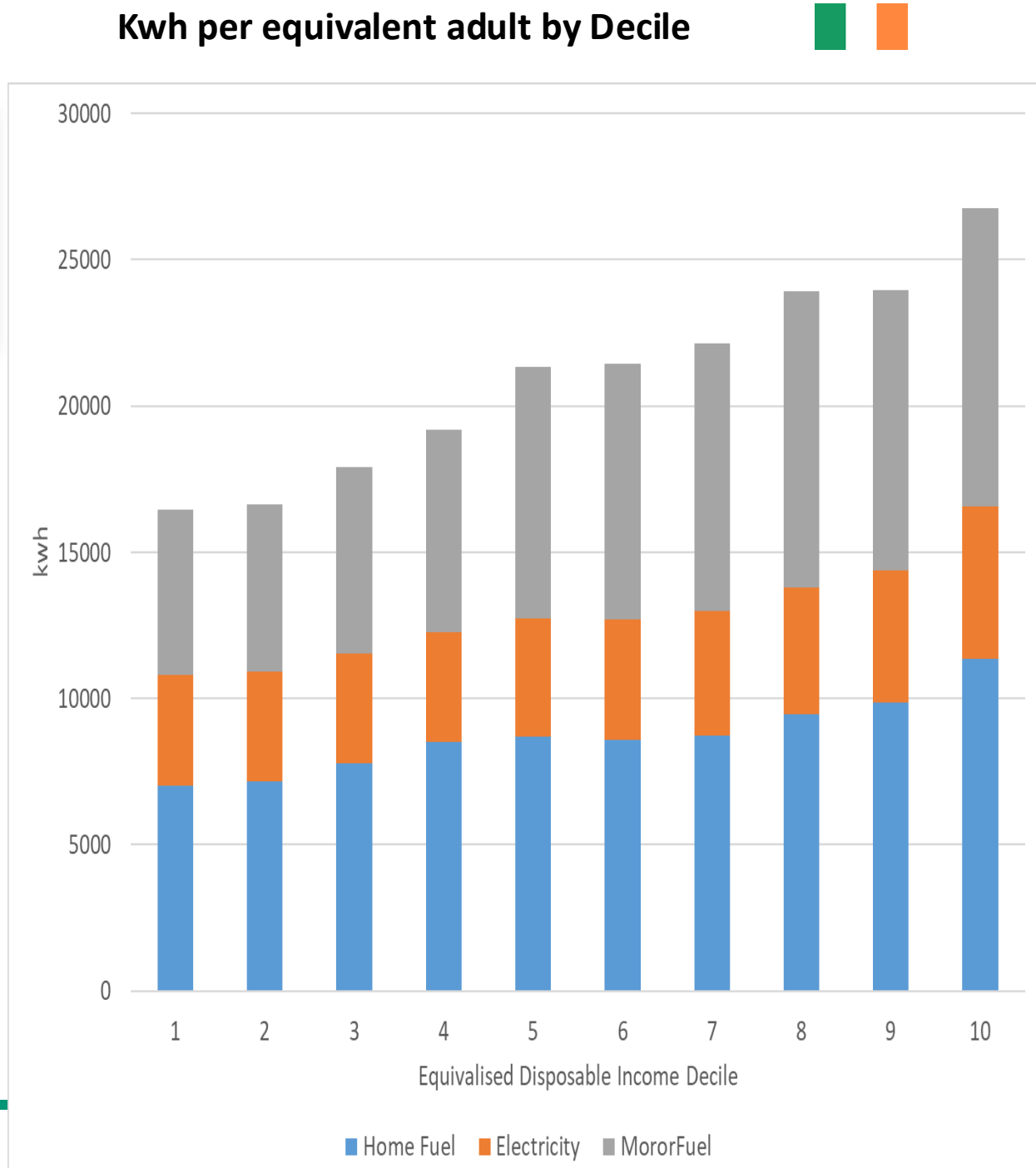
Carbon Emissions

- **Nature of emissions** consumed
  - Emission Factors per kwh vary by fuel type
  - Firewood high relative emissions →but renewable



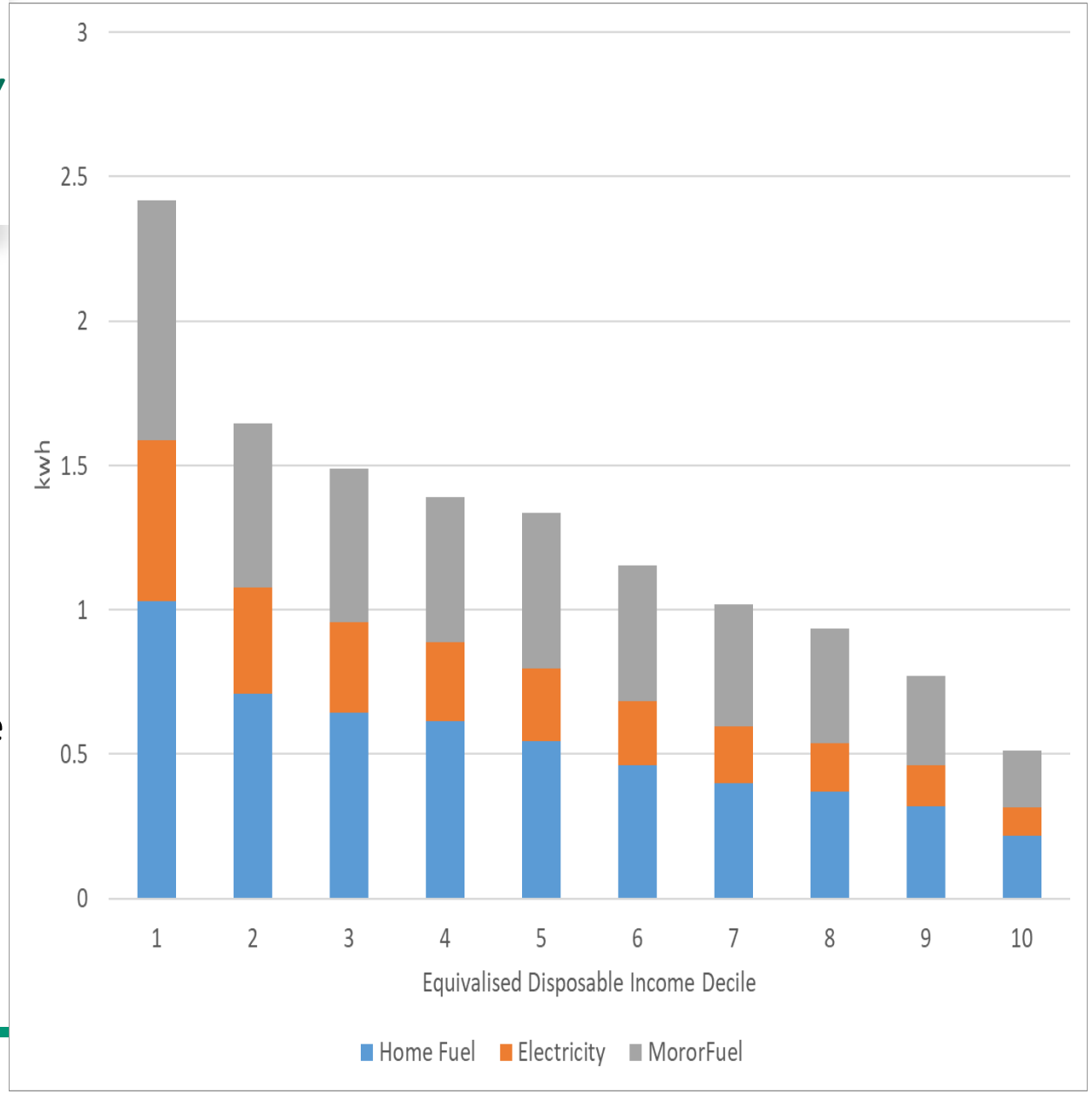
Energy Consumption

- **Distribution of Energy Consumption (**per equivalent adult)
  - **Energy Inequality**
  - Motor Fuels → **higher budget elasticity** than home fuels or electricity
  - **Big Inter-country differences too**



Energy Consumption Intensity

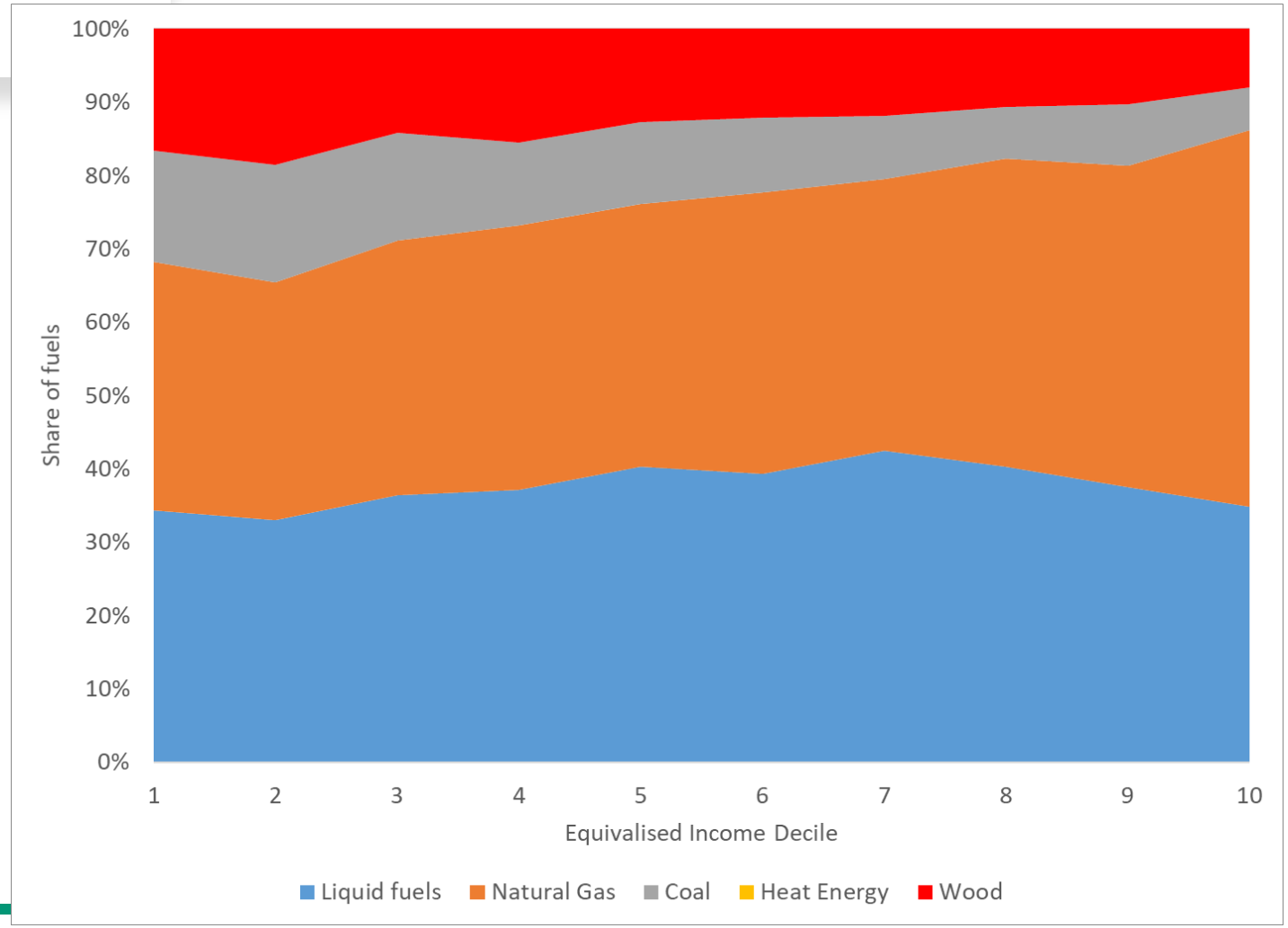
- **Energy Intensity** → Ratio of kwh to Income
- **Falling share of income**
  - **Savings Rate Important**
- **Non-equal incidence**
  - Influence distributional incidence of carbon price



Heating Fuel Mix

- **Heating Fuel Mix**
- Non-equal **distributional incidence** by type
  - **Solid fuels higher incidence at bottom**
  - **Natural Gas at top**
  - Urban and Central Heating Systems
- **Intensive Margin** – change in energy use
- **Extensive Margin** – investment in alternative technology

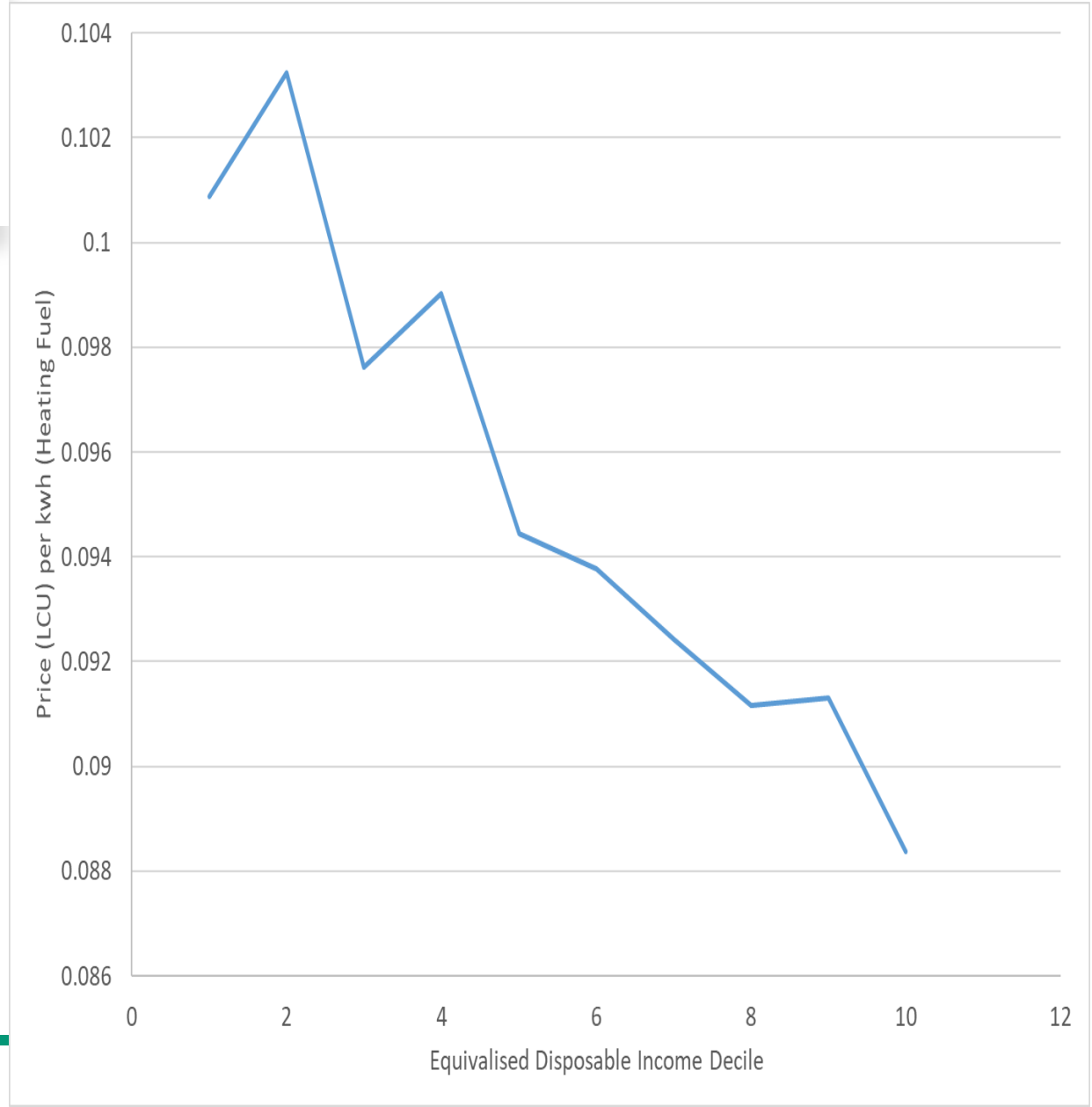
Budget Share of Fuel Type by decile



Price of Energy

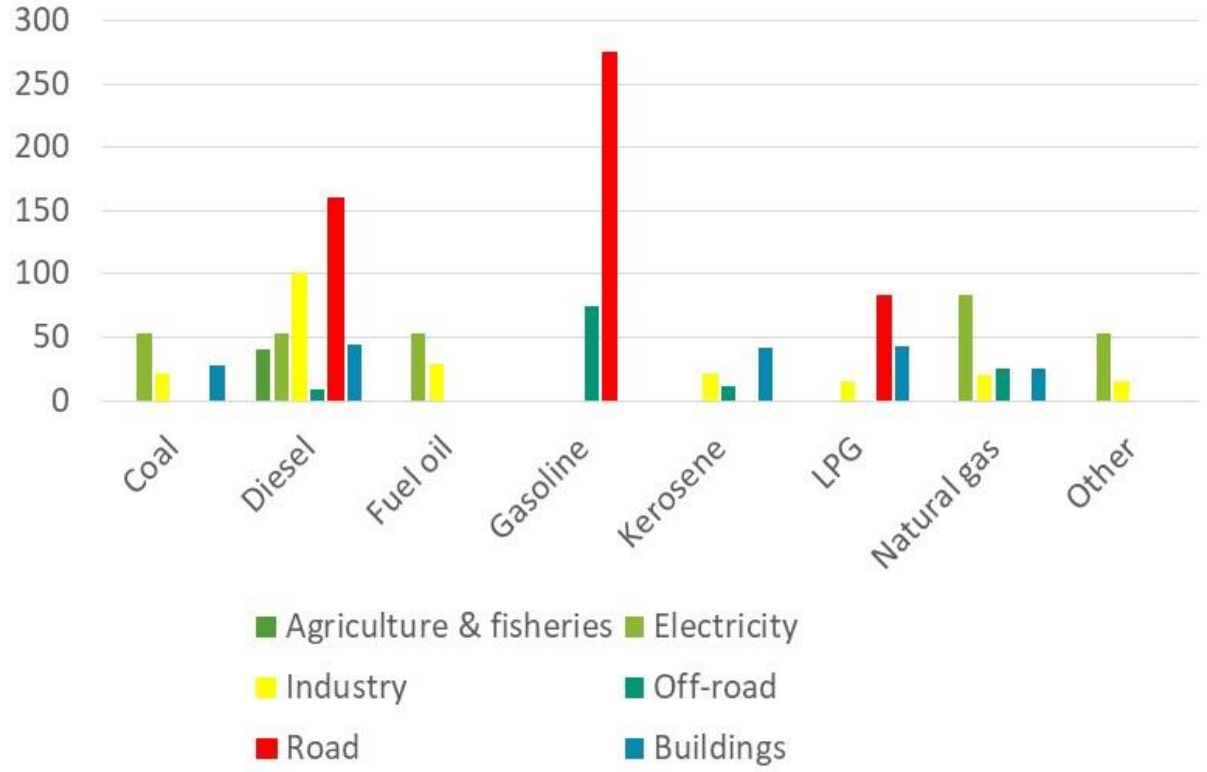
- Fuels **vary in Price**
- **Poor** consume **more expensive** energy

Price of Domestic Energy per kwh by decile



Tax Rate of Energy

- **Energy Taxes**
  - Excise Duties
  - Emissions Trading Scheme
  - Carbon Prices
- **Non-equal energy tax rate**
  - **By Fuel Type and by Sector**
  - **Households → Road and Buildings**
- **Heating fuels** typically have lower taxation and/or higher subsidies
- If you add a carbon tax, proportional price change may be lower

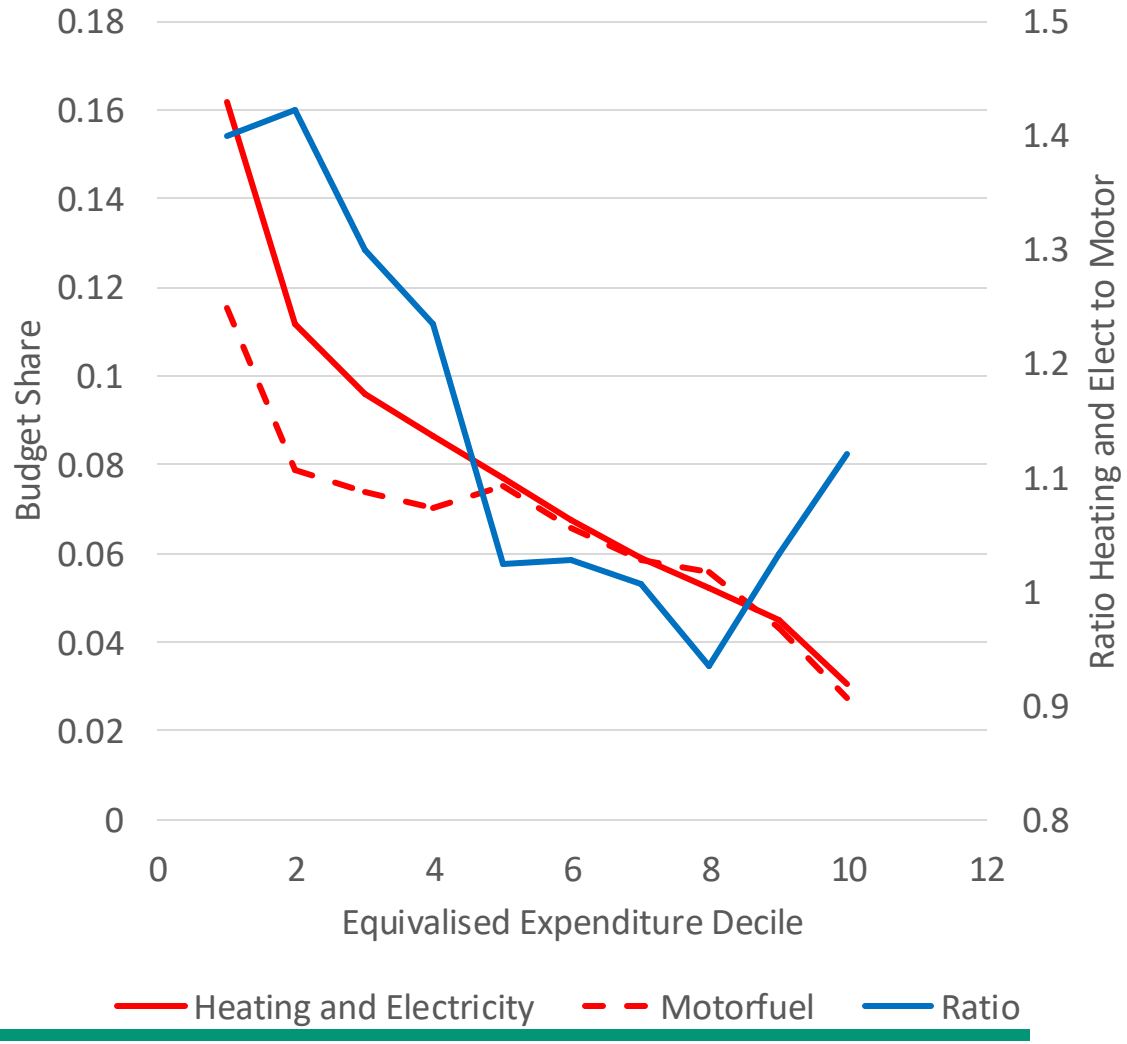


Source OECD Effective Carbon Rate

Fuel Budget Share

- **Location of greenhouse gas emissions** across the **income distribution**
  - Blue – **Ratio** Home Energy to Motor Fuels
  - Typically **Domestic Fuels** are more concentrated at the bottom
  - The profile for **Motor Fuels** is flatter

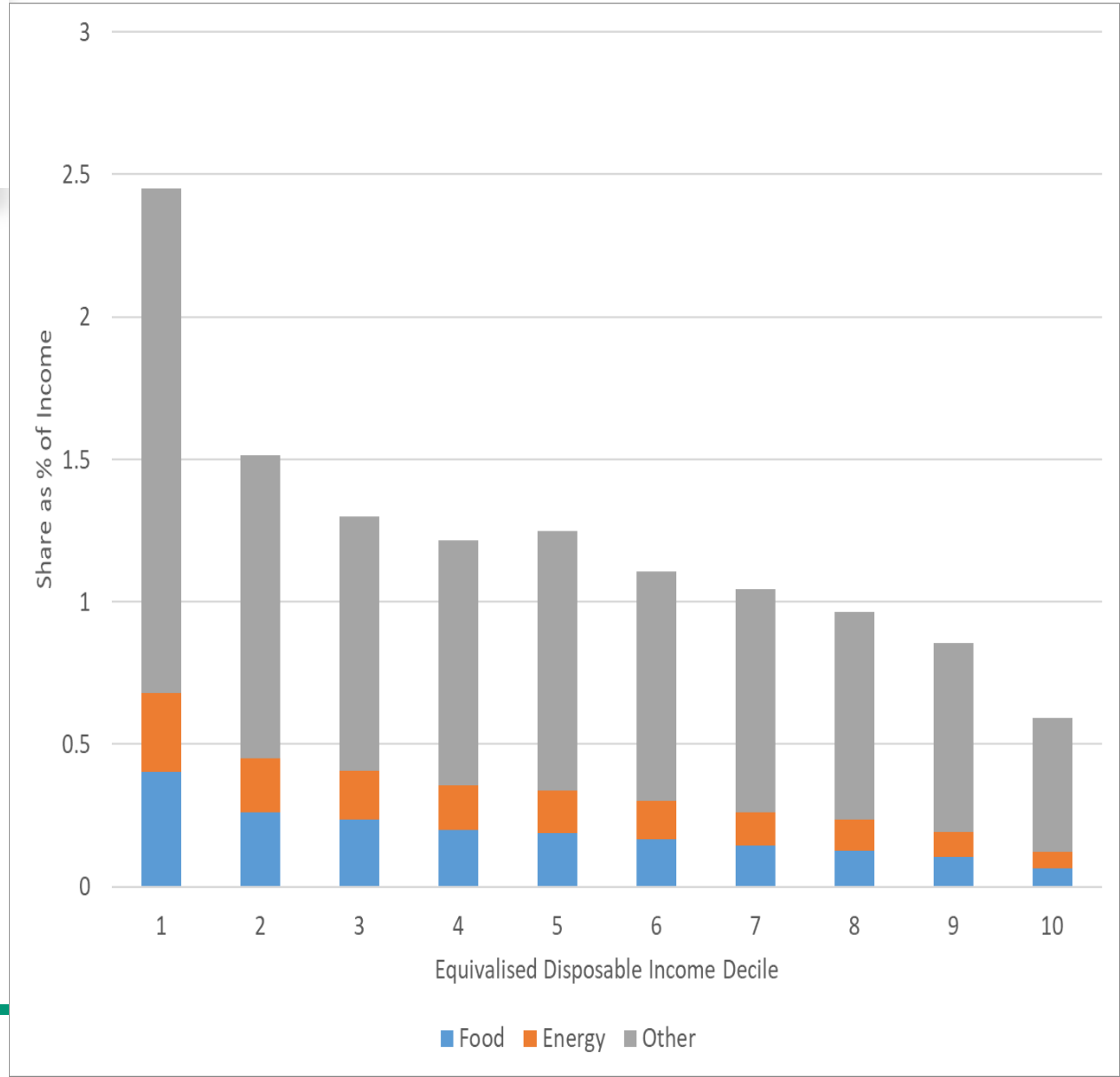
Budget Share in Income for Energy by decile



Direct and Indirect Emissions

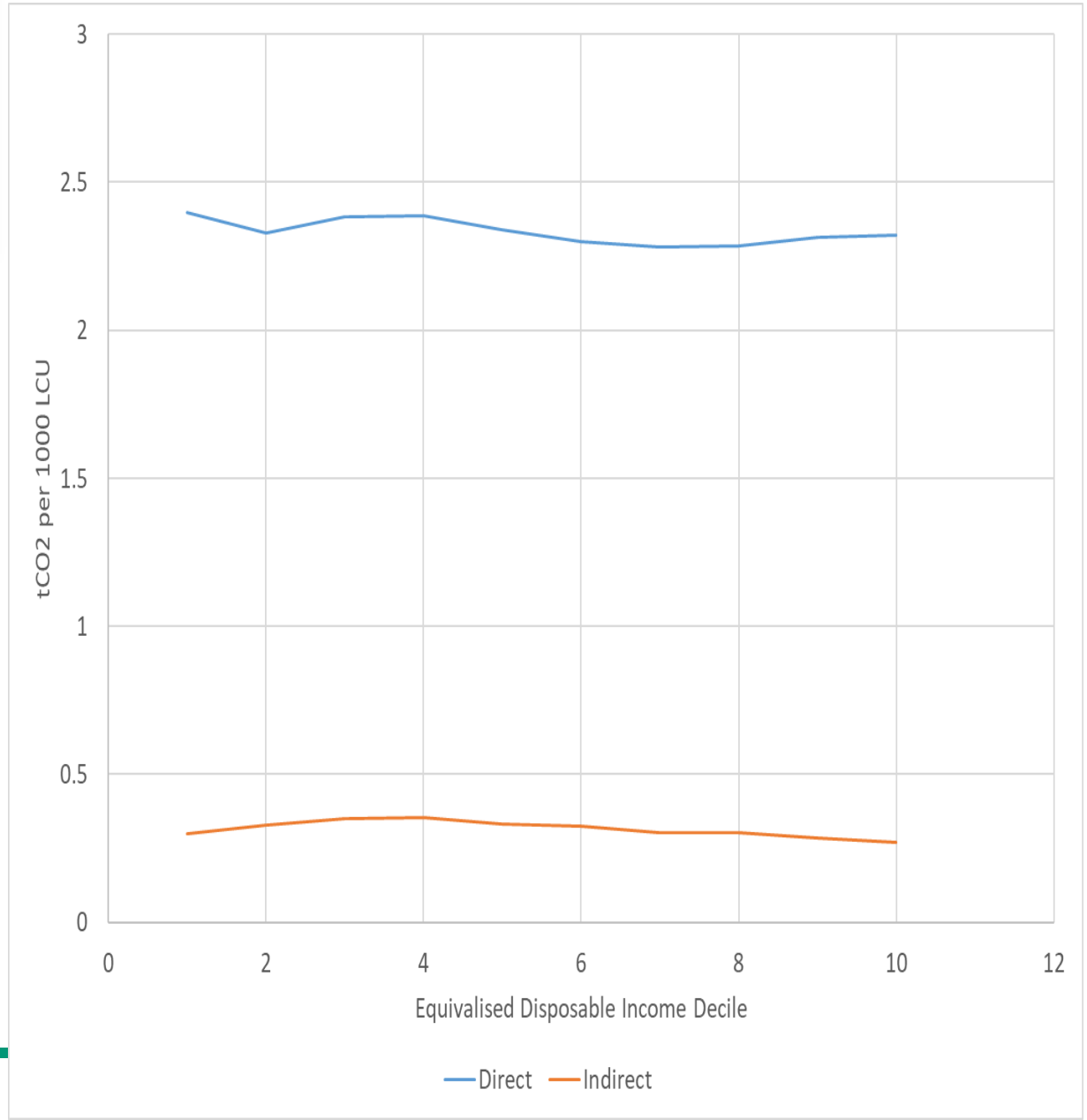
- **Direct –** Fuels Consumed by Household
- **Indirect –** Energy Used in the production of the Good or Service → Use Input-Output Table
- **Food and Other** goods and services have **higher budget shares**
- **Non Energy consumption** has energy use associated with production
- **NB → Food** has significant non-energy emissions

Budget Share in Income for Energy by decile



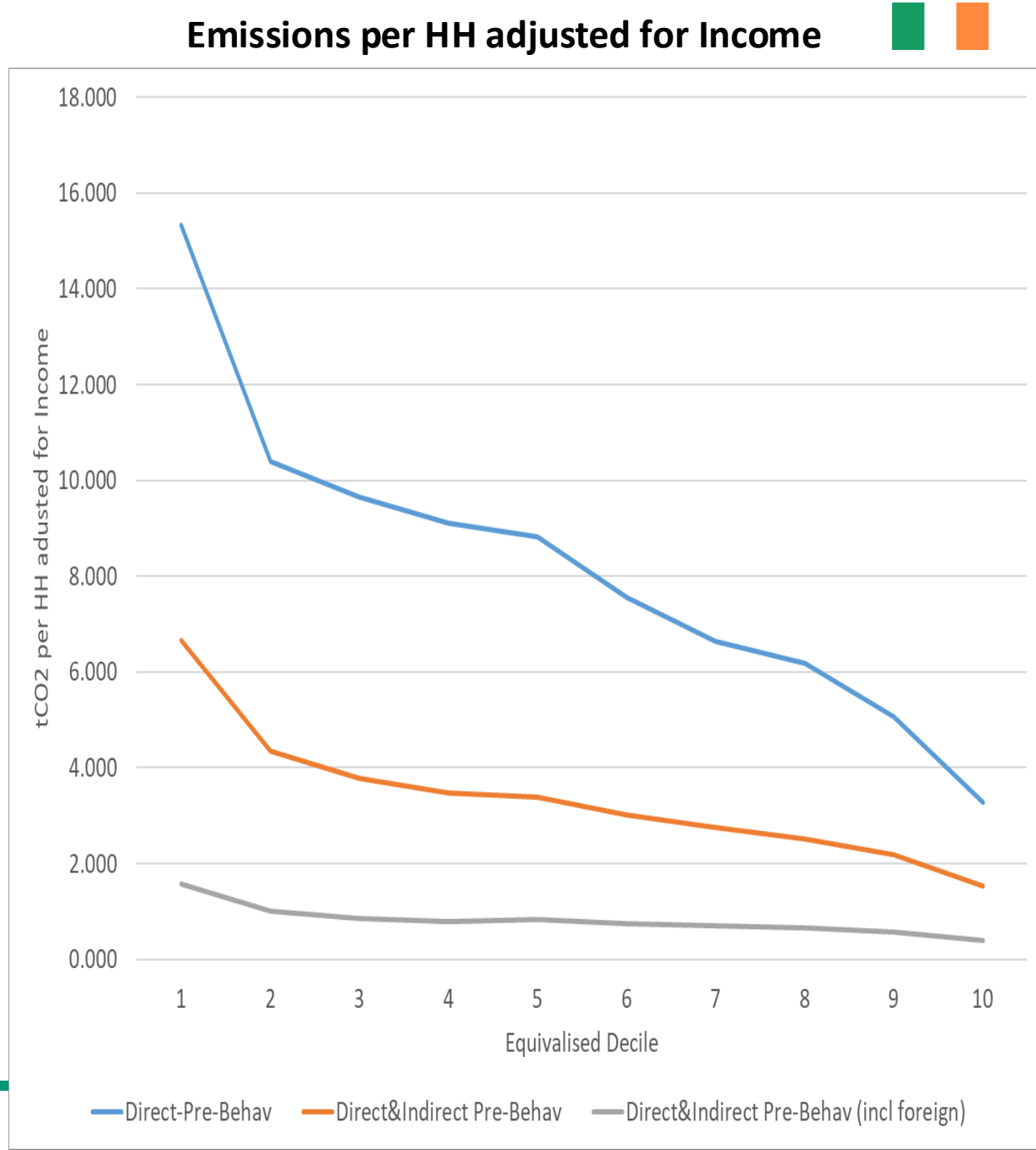
Carbon Intensity - Direct and Indirect Emissions

- **Emissions to Euro ratio** → much higher for direct energy consumption than for non energy goods and services
- Direct Energy Consumption → likely to dominate distributional incidence



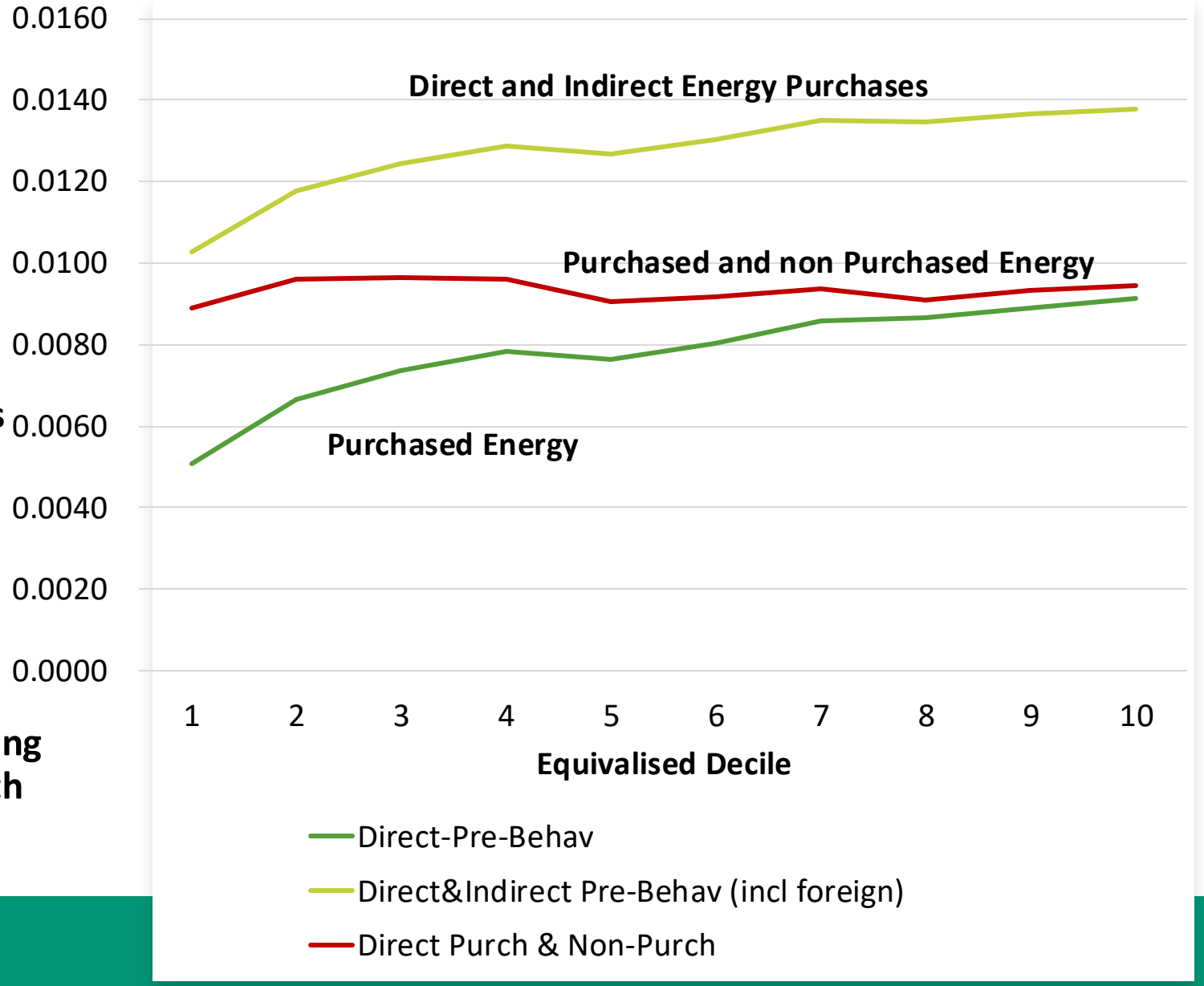
Direct and Indirect Emissions

- Direct more important than domestic indirect and much more important than imported emissions



Impact of non-Purchased fuels (Pakistan)

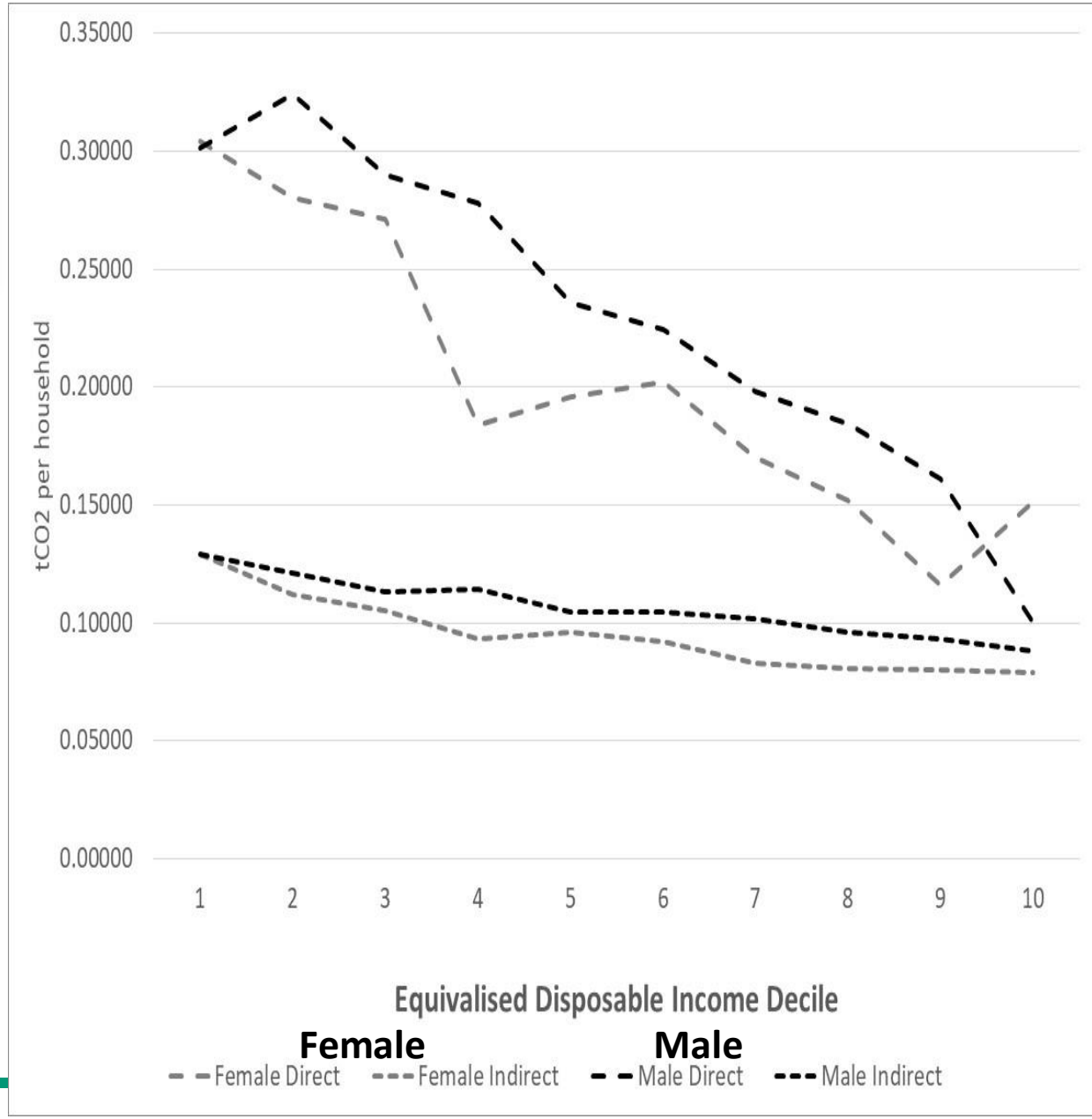
- Different in lower income countries
  - Food dominates distribution
  - Energy is a luxury →**purchased fuels increase with incomes**
  - **Indirect** component relatively **more important** than **OECD** countries
- Impact of the **non-purchased fuels**
  - **Flattens the distribution**
- **Own produced consumption in developing countries – firewood – hard to reach with policy**



HORIZONTAL – GENDER (LUX)

- Mirroring gender difference in consumption
- In general **higher carbon intensity for male headed households** → driven by direct emissions, particularly motor fuels
- Consistent in most countries considered (not Ireland though)

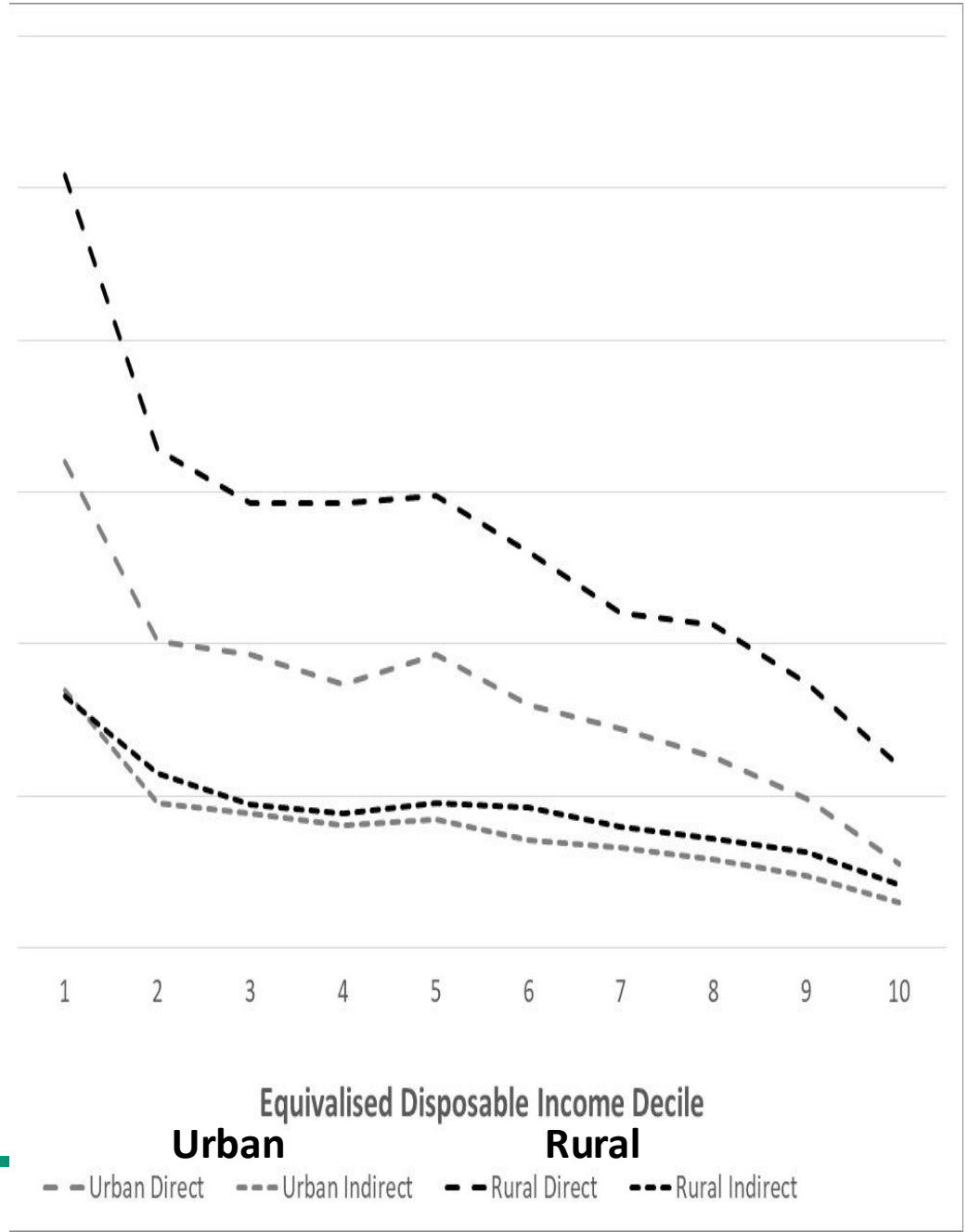
Carbon Intensity (tCO2 /Income) by Gender of Head



HORIZONTAL – RURAL

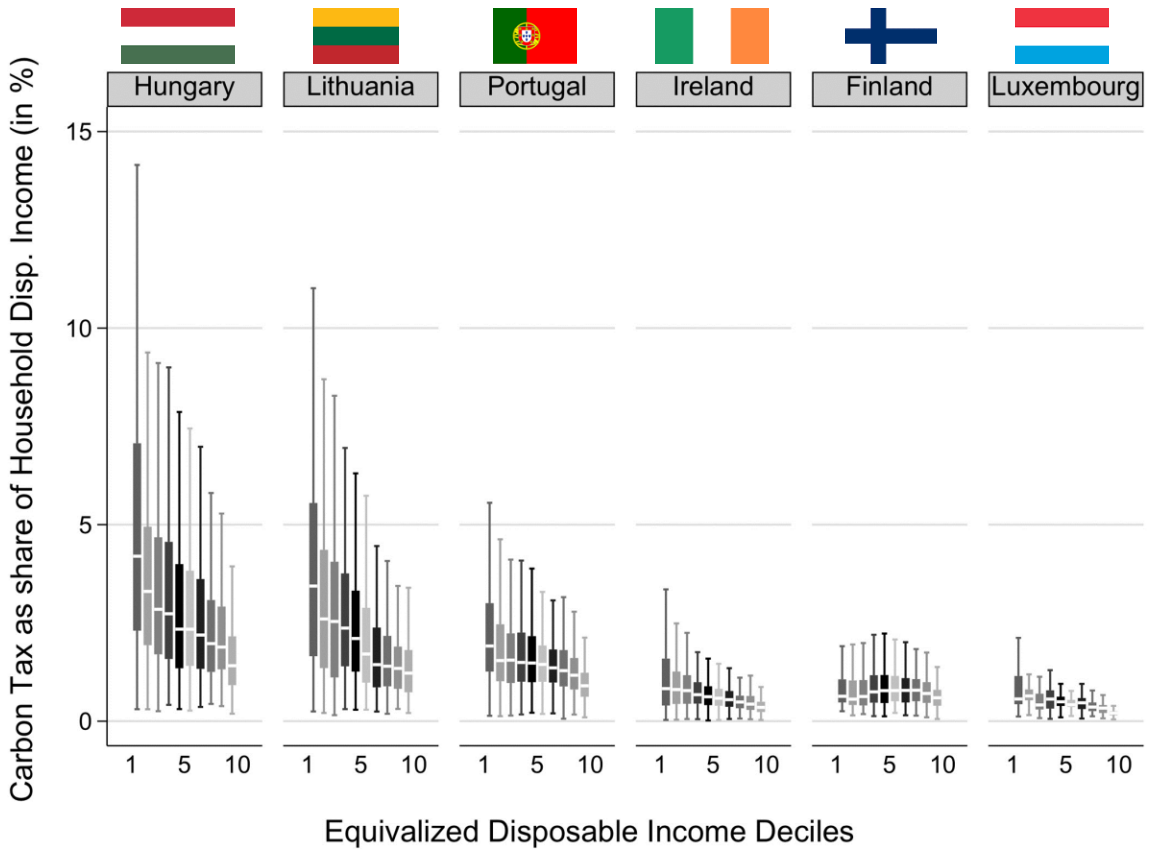
- **In general higher carbon intensity for Rural households** → driven by direct emissions, particularly motor fuels

Carbon Intensity (tCO2 /Income) by Residence



Carbon Tax payments as a share of household disposable income.

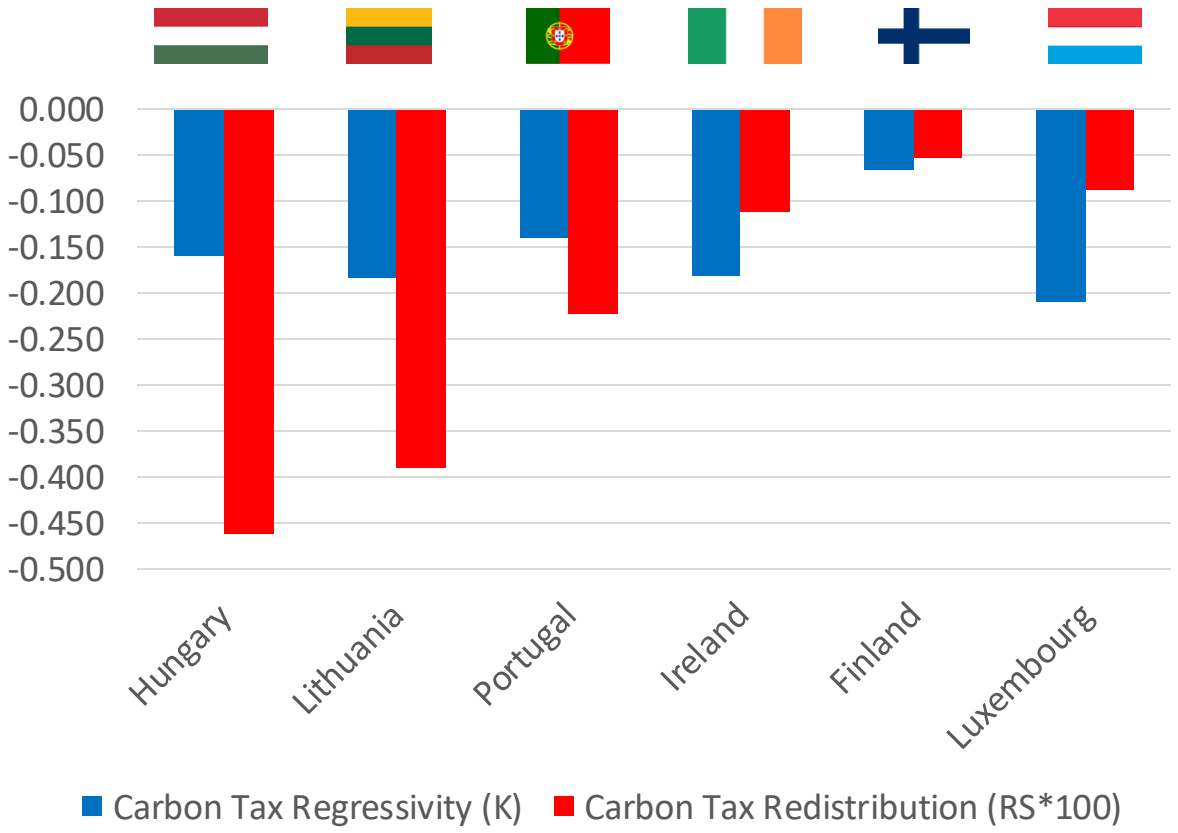
- Comparative analysis - €30 per tCO2
- **Carbon taxes are regressive**, but the scale depends upon the nature of the budget shares
  - **Finland less regressive**
- Poorer countries in EU have higher shares of fuels



Linden, J., O'Donoghue, C., & Sologon, D. M. (2024). The many faces of carbon tax regressivity—Why carbon taxes are not always regressive for the same reason. *Energy Policy*, *192*, 114210.

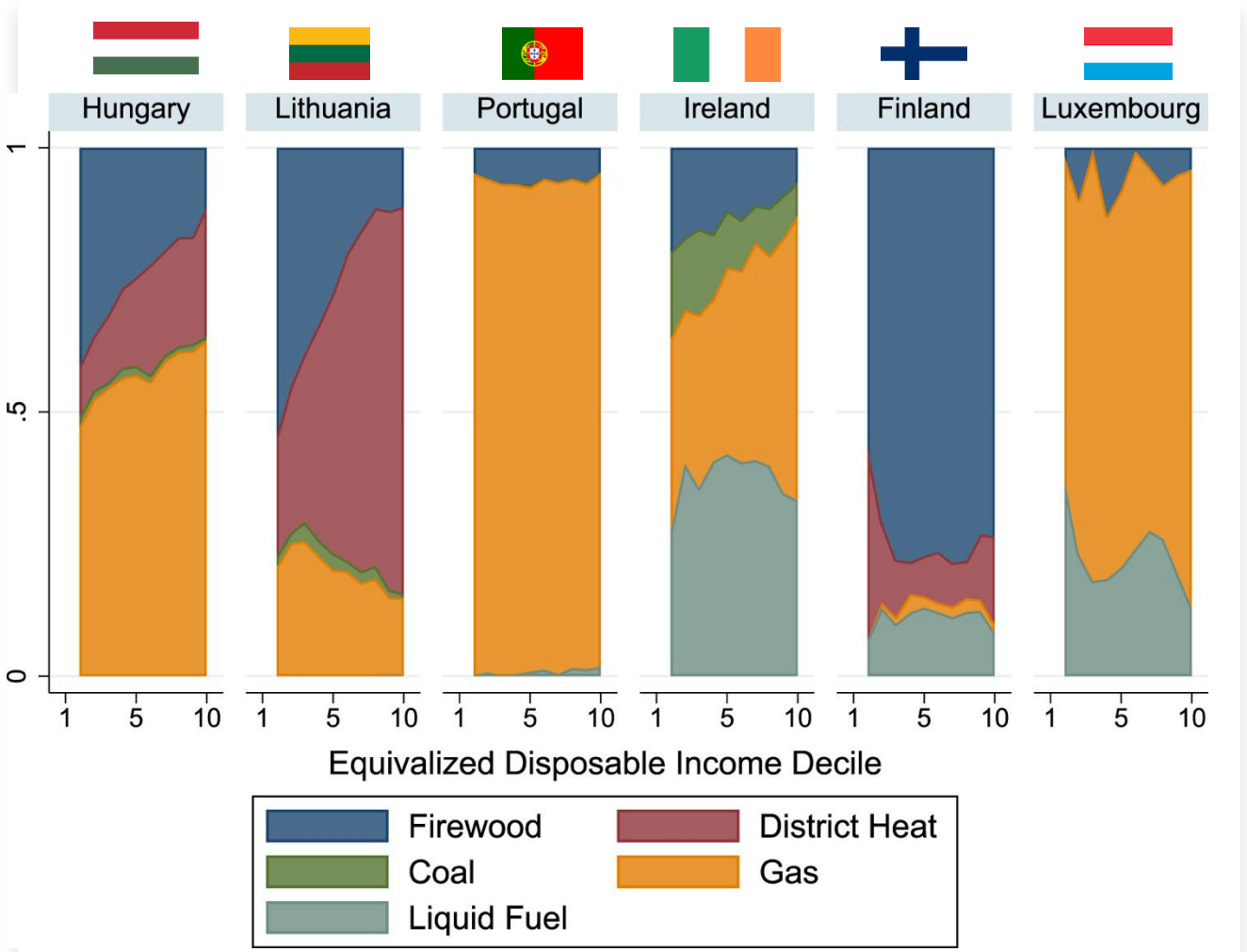
PROGRESSIVITY AND REDISTRIBUTION OF THE CARBON TAX

- **Regressivity of carbon tax similar**
- However **redistributive nature** depends upon the differential rates and budget shares



AVERAGE BUDGET SHARES OF CARBON-INTENSIVE GOODS ACROSS EQUIVALIZED DISPOSABLE INCOME DECILES.

- Within **fuels the mix is very different in different countries** → Difficult to draw common conclusions
- **Big differences in HU and LT** between top and bottom – **District Heat**
- **Finland** – renewable energy
- **Solutions** quite different in different countries



DECOMPOSING THE DISTRIBUTIONAL IMPACT OF CARBON TAXATION (2)

- **To decompose the distributional impact of the carbon tax**,
  - construct **counterfactual** disposable income **distributions**
  - **- replacing one factor of** with **population average,** holding all **other factors constant**
- **Counterfactual distributions:**
  - Y_{hc}^{s} counterfactual distribution with equalized savings
  - Y_{hc}^{e} counterfactual distribution with equalized carbon intensity
  - Y_{hc}^{w} counterfactual distribution with equalized budget shares
  - Y_{hc}^{I} counterfactual distribution with equalized assets

DECOMPOSING THE DISTRIBUTIONAL IMPACT OF CARBON TAXATION (3)

- **Biewen (2014) Decomposition**
- Calculate the change in the Gini index due to the carbon tax,

$$D^0 = G_{hc} - G_h$$

- Compute the change in Gini index under **each counterfactual scenario**, using the post-carbon tax income distribution as a baseline.

$$D^k = G_{hc} - G_{hc}^c, \; k = s, e, w, V, H$$

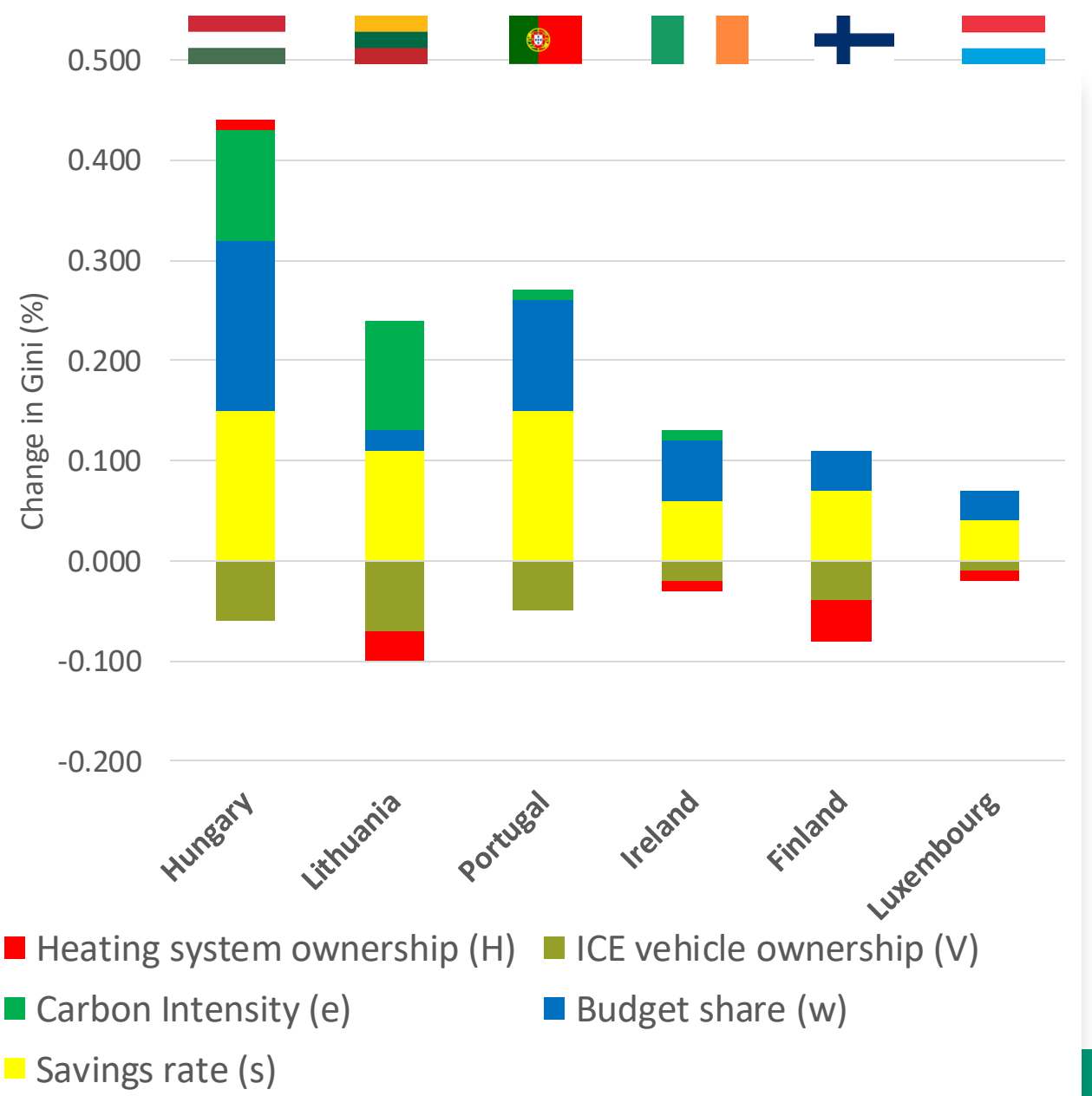
- The change in Gini, D^0, can be decomposed following Biewen (2014)

$$D^0 = (D^s + D^e + D^w + D^V + D^H) + \quad \textit{\{Direct effects, ceteris paribus\}}$$

$$D^0 - (D^s + D^e + D^w + D^V + D^H) \quad \textit{\{Interactions\}}$$

Decomposition of Carbon Price

- **Decomposition**
- **Consumption profile (Budget Share and Savings) are most important drivers of regressivity**
- Carbon intensity which relates to **fuel mix less important** outside of Hungary and Lithuania
- **Asset Ownership**, which increases with income – **mainly progressive**
- Interaction terms omitted → but small



Revenue Recycling (Türkiye)

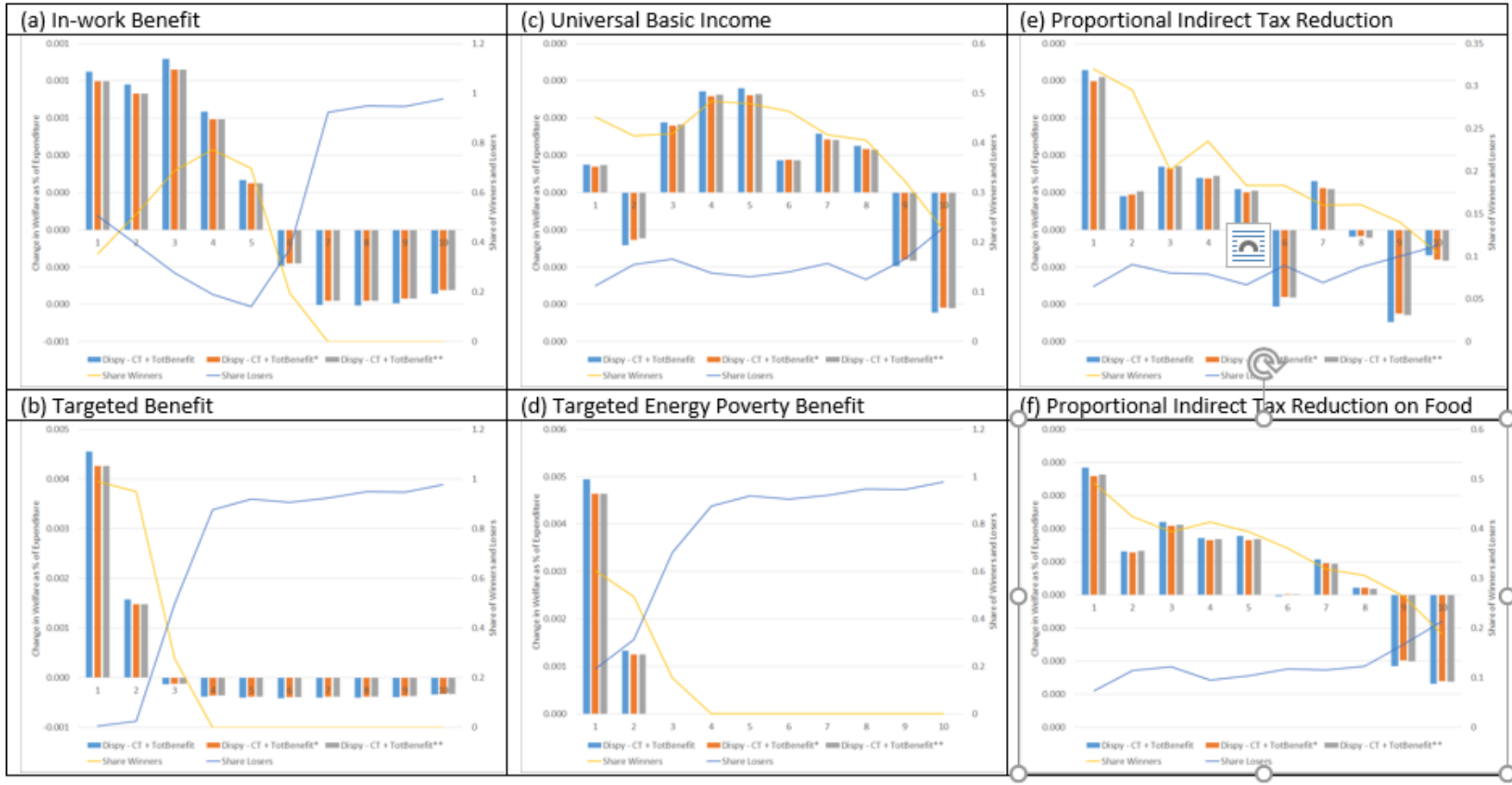
Can, O'Donoghue and Sologon Forthcoming

- What **revenue** is spent on is very important
- **Distributional impact** depends upon **nature of revenue recycling**

Bars – Net Carbon Tax and Revenue Recycling

- Static
- Price Behaviour
- Price Behaviour + Income Effect

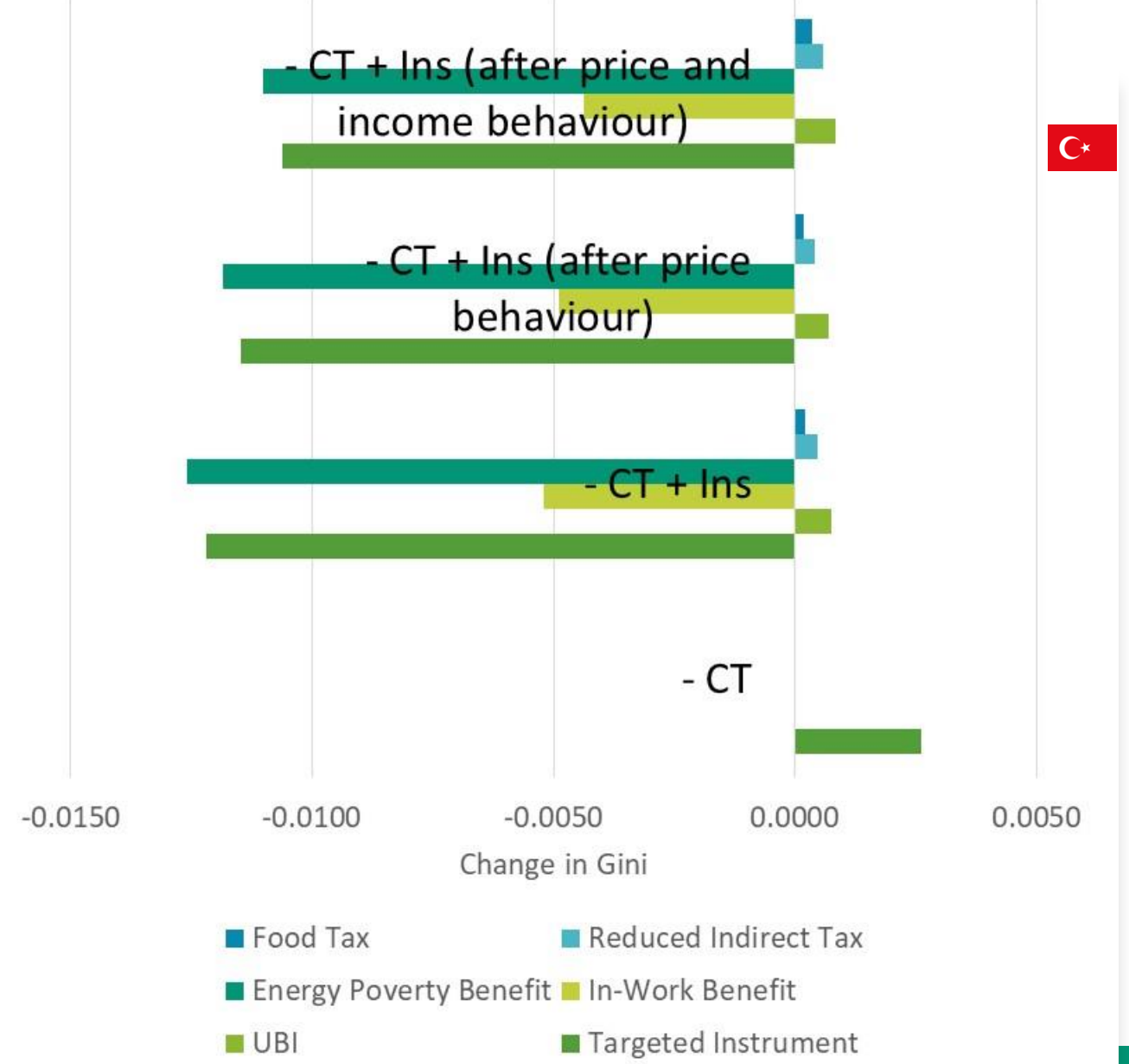
Lines – Winners and Losers



Redistributive Impact (Türkiye)

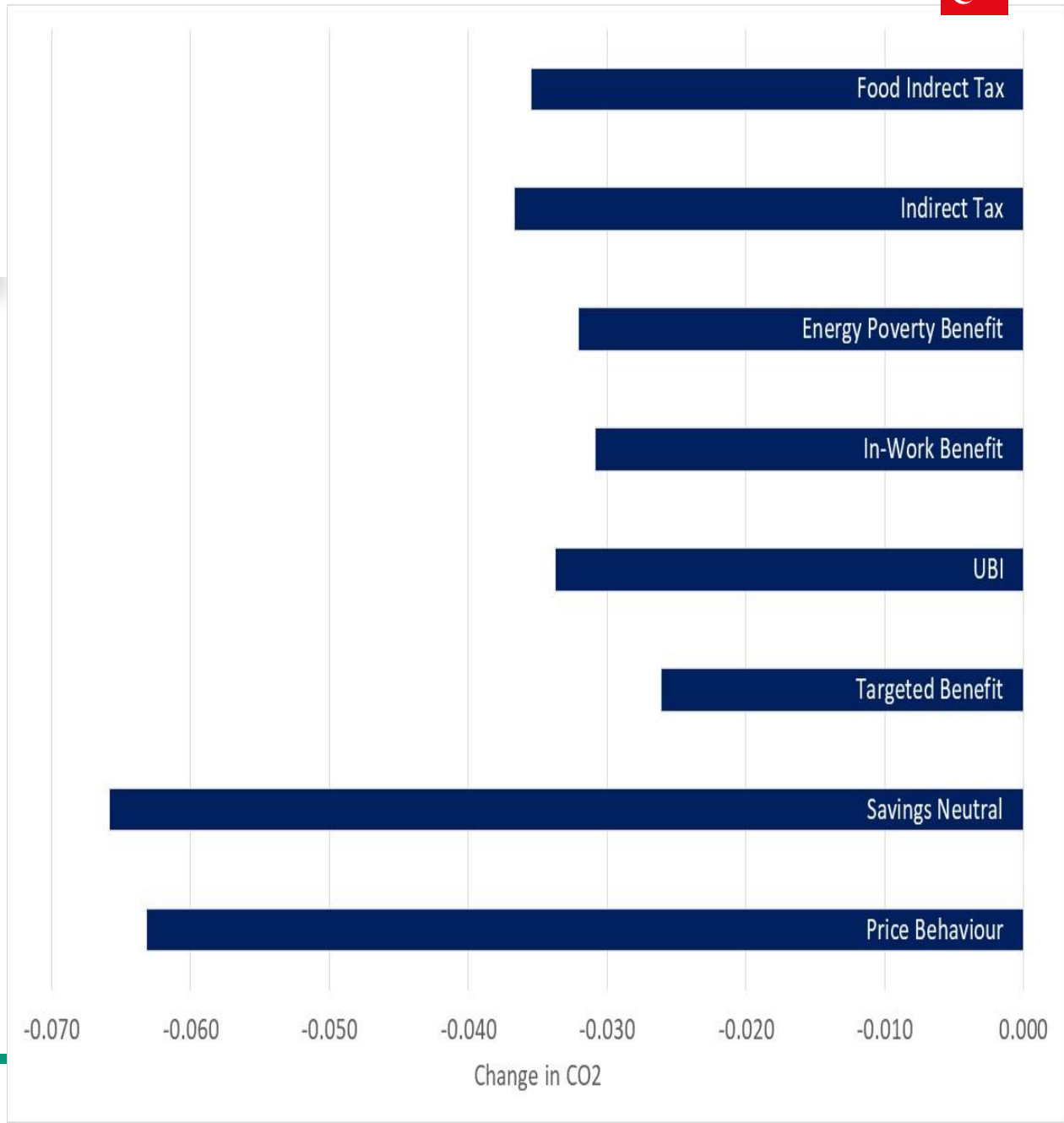
- Carbon Tax (CT) + Mitigation Instrument (Ins)
- (1) Static, (2) Price Response (3) + Income Response
- In fact **redistributive of revenue recycling** impact **more important** than the **carbon tax**
- Price and income response **reduce redistributive impact**

NB CT +Ins Carbon Tax + RR Instrument



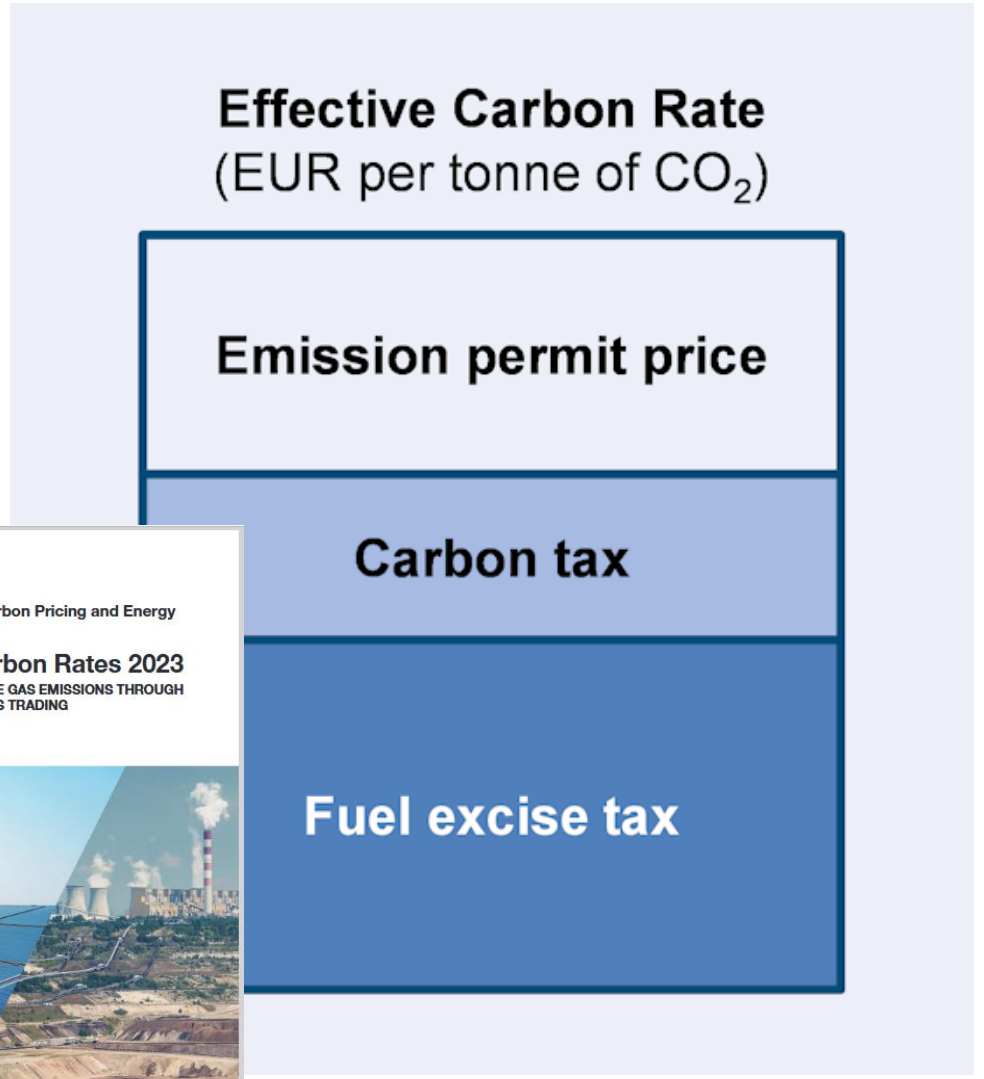
Environmental Impact (Türkiye)

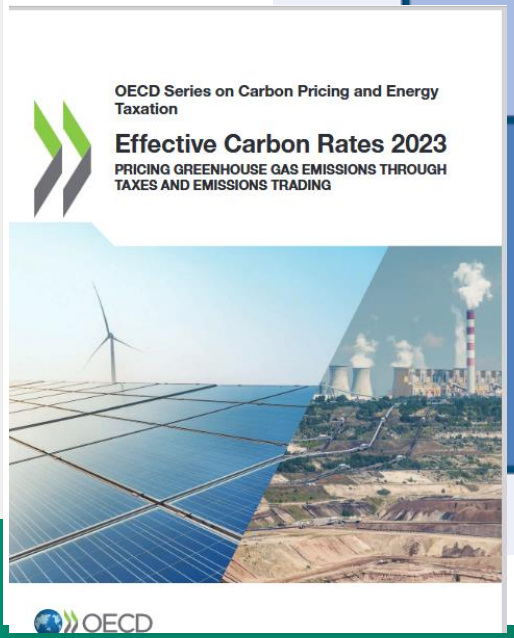
- **CO2 reductions** also depend also upon **nature of revenue recycling**
- **Targeted benefit** although reducing poverty, sees lowest fall in emissions as
  - **poor have a higher carbon intensity**



OECD Effective Carbon Rates

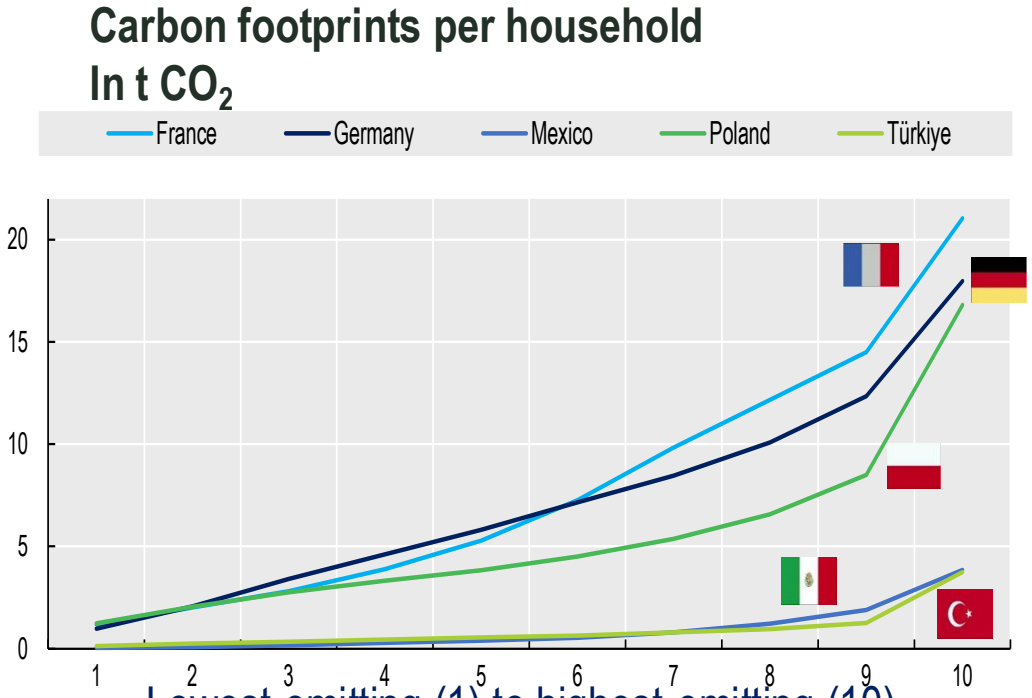
- Move from **theoretical carbon price** to **actual policy choices**
- OECD → Effective Carbon Rates every three years – with a focus primarily on **carbon generated from Energy**
- Different Sources of Carbon Prices
  - **Emissions Trading**
  - **Carbon Taxes**
  - **Fuel Excise Tax** – although not based upon carbon, they are proportional to the volume of fuel used





VERY UNEQUAL CARBON FOOTPRINTS BOTH ACROSS AND WITHIN COUNTRIES

- **Many factors drive country differences:**
  - level of development,
  - population density,
  - consumption patterns,
  - production technology
- **Average household emissions** range from
  - 1 tonne (MEX, TUR) to
  - 8-9 (DEU, FRA)
- **Consumption of top 10% emitting households** in MEX & TUR produced the
  - Same emissions as **3rd decile in DEU**



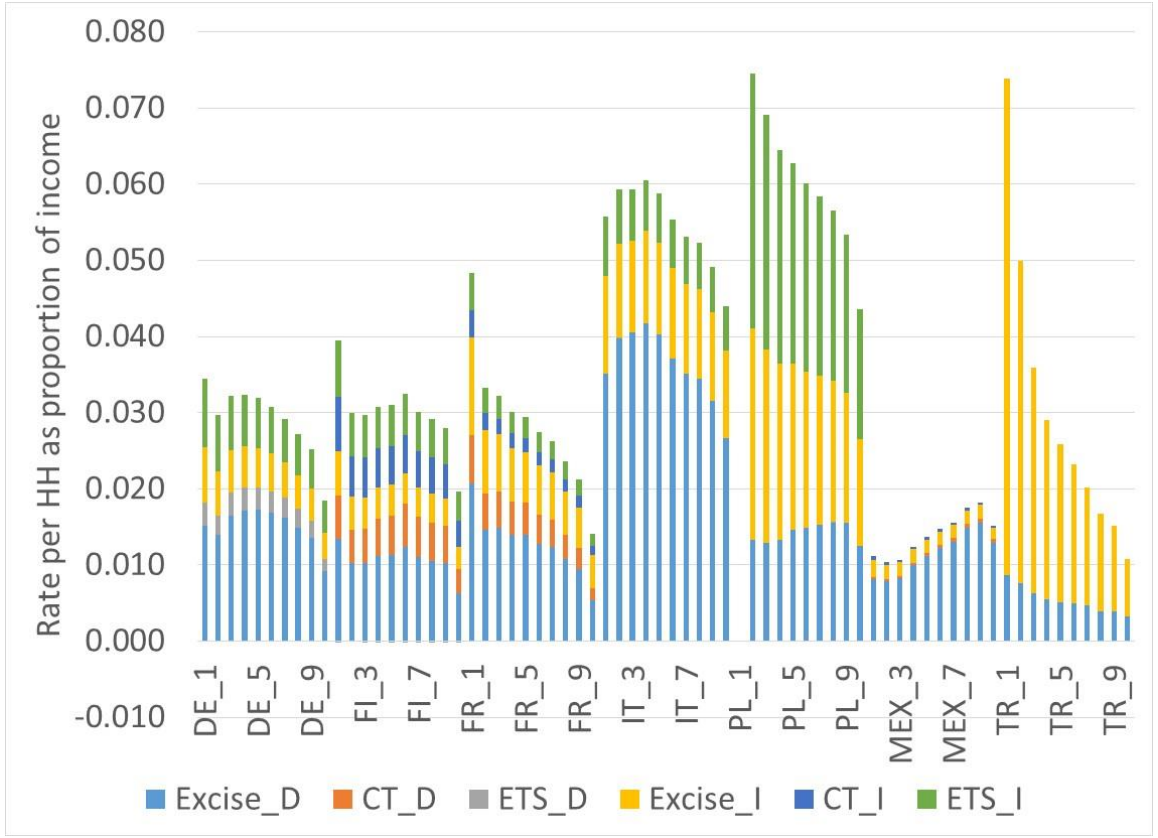
Lowest-emitting (1) to highest-emitting (10) households in each country (emissions decile groups)

Source: https://doi.org/10.1787/9138d7e3-en

Distribution of Carbon Price Instruments 2021

- Carbon Price Instruments divided into
  - **3 Instruments** Excise Duties, Carbon Taxes, ETS
  - **2 Dimensions** – Direct Energy Use; Energy used in other goods and services – **No Revenue Recycling**
- 2021
  - **Generally declining** as share of income (**except Mexico**),
  - Particularly **Direct Excise** Duties
  - **Others similar importance across distribution**
  - However this will change as CT and ETS grow relative to Excise Duties

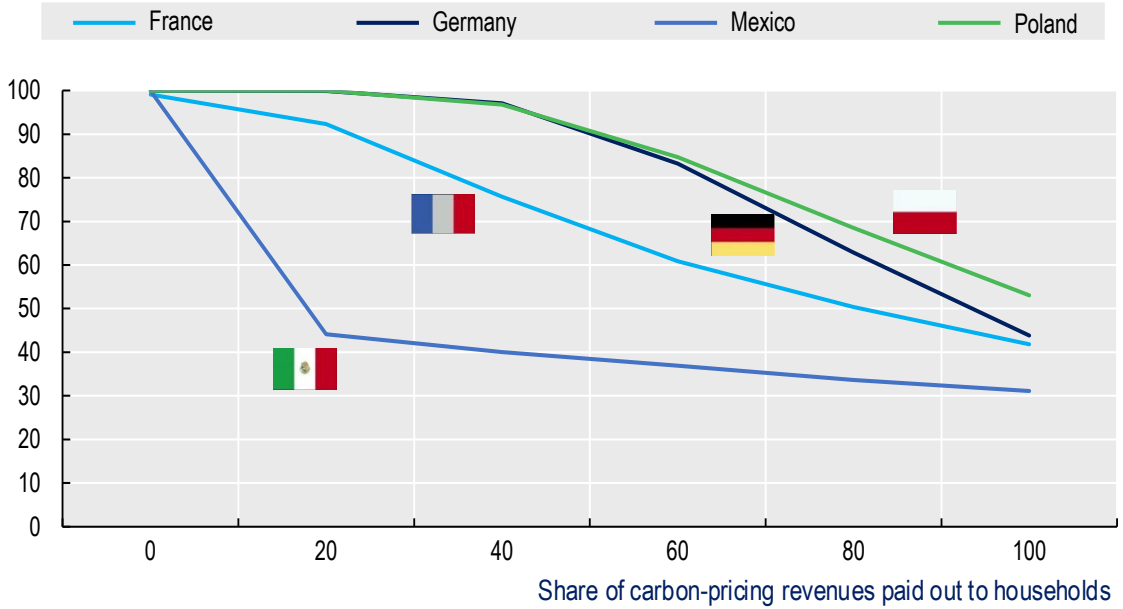
Carbon Price Instruments in 2021 as % of income **(ranked by income decile)**



Carbon pricing with revenue recycling
‘Gainers and losers’, fiscal cost

- Governments can **use carbon-pricing revenues to finance cash transfers that soften detrimental distributional** effects
  - Only **some countries directly "recycle" revenues** back to households in this way (eg. Austria).
- In the near future, deteriorating fiscal outlooks are likely to translate into **competing demands on carbon-pricing revenues**
  - This may **reduce the scope for compensating households**
- Need **cost-effective compensation**, in coordination with existing support and social protection programmes that may be available to affected groups

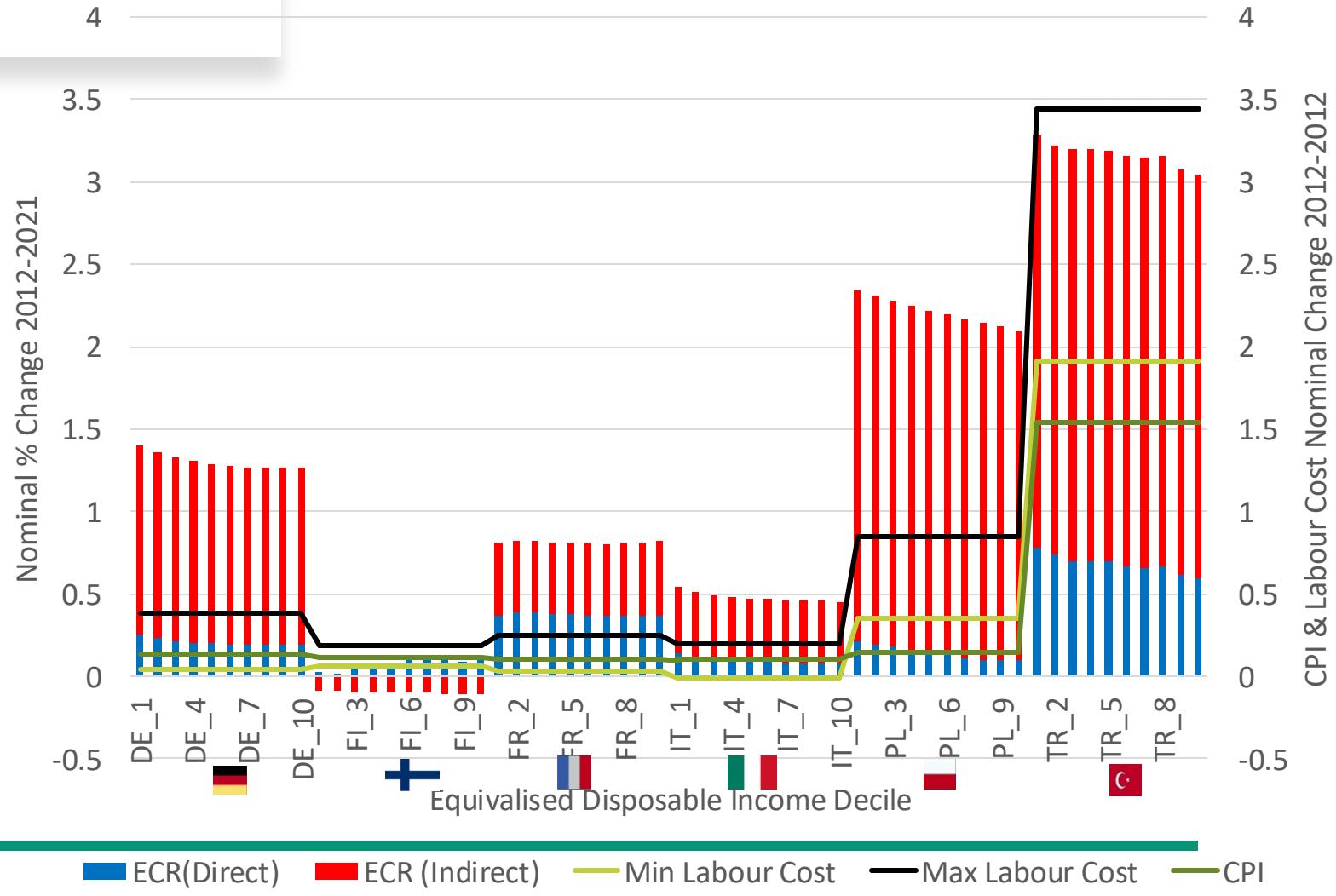
Partial revenue recycling: Lump-sum transfers
Share of individuals with net losses, by share of revenues p



Source: https://doi.org/10.1787/9138d7e3-en

Growth in Carbon Pricing relative to growth in Wages or other Prices

- **Carbon pricing has grown faster than CPI and the labour cost** growth in all sectors between 2012 and 2021.
- **Post 2021** – likely to be different story with COLC
- However to have an impact on behaviour **carbon pricing should have to grow faster than income growth**
- NB Finland – **Revenue Recycling decision** to replace Excise Duties and low indexation – real decline



CONCLUSIONS

- **Difficult to draw common conclusions** about either price or carbon pricing given **different budget shares** across countries → need for country specific research
- In rich countries – similar redistributive effect of inflation, but regressivity and rate effects vary
- **Importance of savings** in the capacity to absorb price changes → potential driver of trust in institutions →**Trust – 24 of 28 countries across world at all time lows** during the cost of living crisis, even if regressivity low.
- **Important gender differences over time** – poor female headed household more likely to spend more on necessities, but richer look more like male headed household. **Carbon intensity higher for men**

CONCLUSIONS

- When done well, **carbon pricing reduces emissions in "invisible hand" type fashion**. But at levels needed for meeting climate commitments, **impact on households anything but invisible**
- **Without carefully tailored compensation for households**, reforms **unlikely to be seen as inclusive**. May meet **stiff resistance**, especially when prices increase quickly / unpredictably
  - **Integration of tax and expenditure important ~ Integration of Tax and Social Welfare in 1990's**
- Distributional Impact: Differences across countries
  - Mainly regressive carbon prices →Quite different strategies in terms of instruments
  - **Substitution of existing revenue** – reduces capacity for mitigation
- Mitigation
  - **Hard to achieve both reductions in distortions and to protect losers**
  - **Revenue recycling differs across countries**, → population structure along income distribution
- Session – International Microsimulation Association June 2025

Thank you

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