Potsdam Institute for Climate Impact Research

Effectiveness of carbon pricing

What do we know from the existing literature and what can we learn for LMICs?

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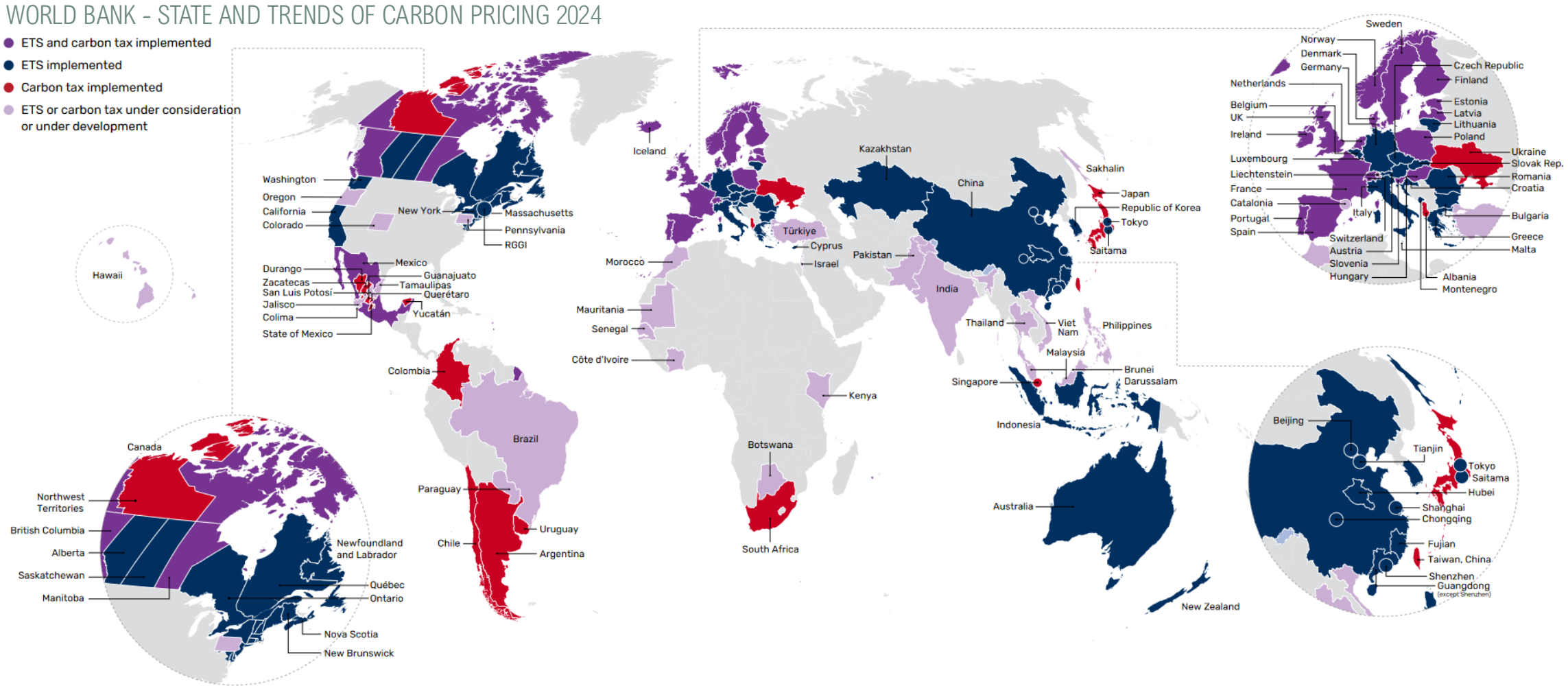
Leibniz Association

Carbon Pricing

- The idea of putting a price on emissions is older than 100 years
- Economists consider it the #1 instrument to curb climate change
- It gets increasing attention, including in low- and middle income countries

Increasing number of countries consider carbon pricing



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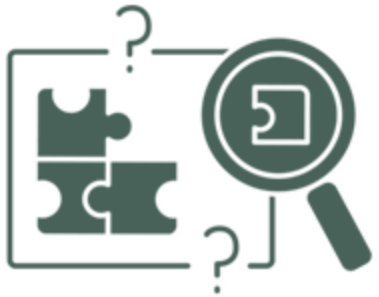
Why Carbon Pricing?



- The idea of putting a price on emissions is older than 100 years
- Economists consider it the #1 instrument to curb climate change
- It gets increasing attention, including in low- and middle income countries

- But: Research- and implementation gaps! Many schemes with very low prices.
    - Is it effective, given particuar market environments?
    - Is it the optimal instrument, given other market failures?
    - Why is it politically difficult to implement?
    - Which are specific design features that can make it work?

This talk

› What do we know about effectiveness of carbon pricing?

› Can we be sure that this also applies for low- and middle income countries?

Effectiveness

Is carbon pricing effective?

Effectiveness – what do we know?

nature communications

Article

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Systematic review and meta-analysis of ex-post evaluations on the effectiveness of carbon pricing

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Check for updates

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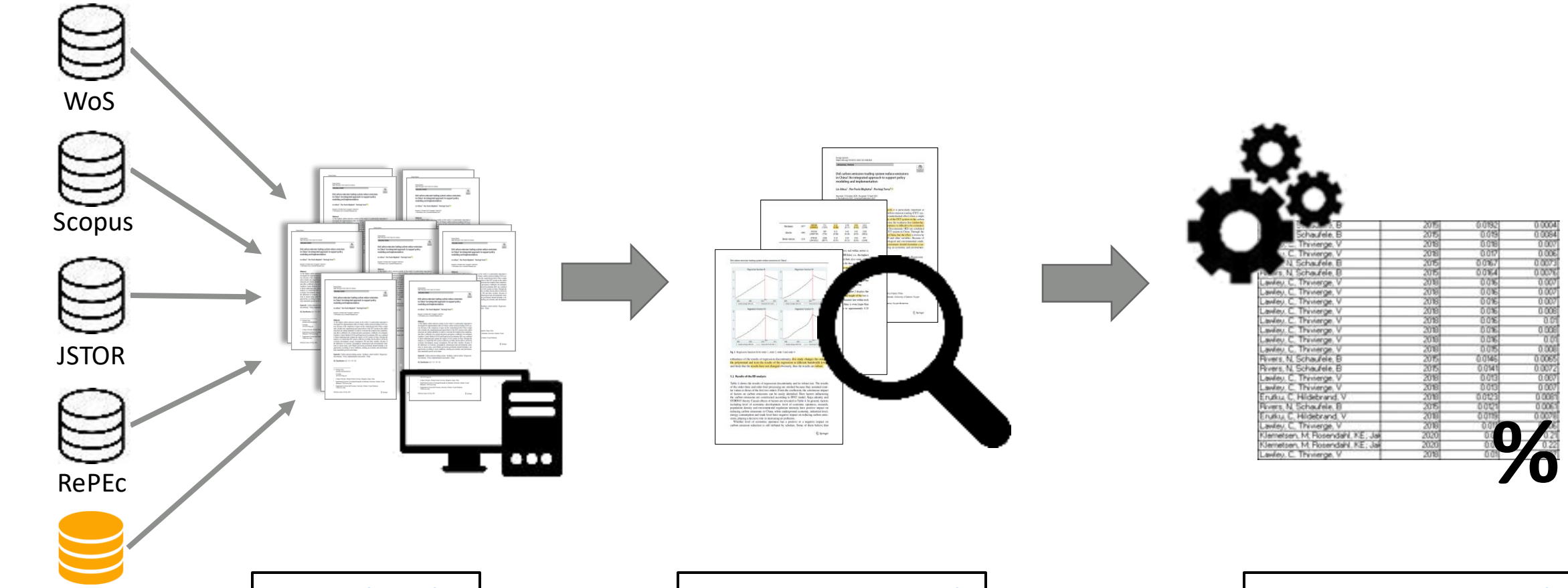
Systematic review method



Search and Screening

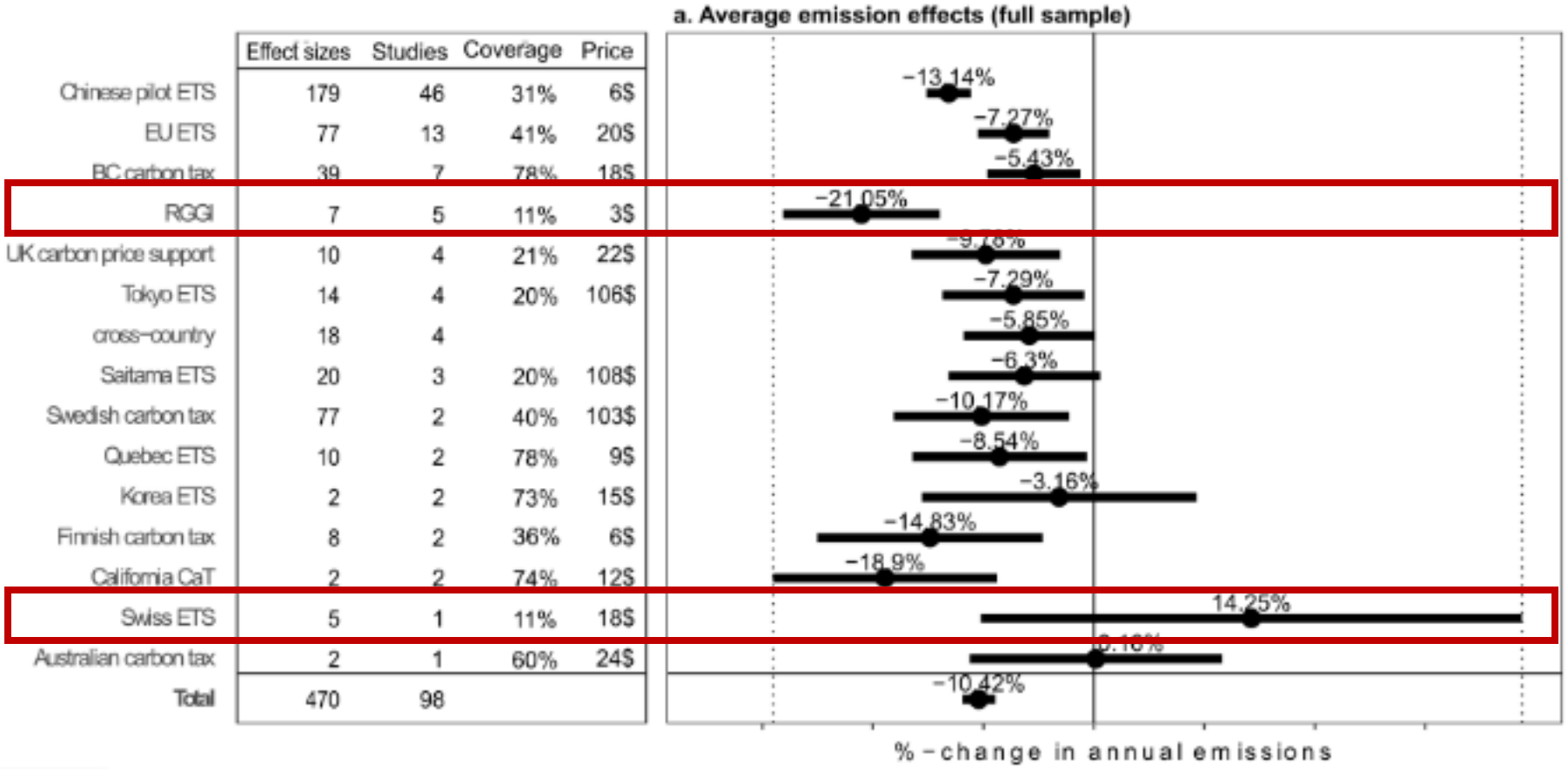
Data extraction und Critical appraisal

Harmonisation and Meta-Analysis

Findings

	Effect sizes	Studies	Coverage	Price
Chinese pilot ETS	179	46	31%	6$
EU ETS	77	13	41%	20$
BC carbon tax	39	7	78%	18$
RGGI	7	5	11%	3$
UK carbon price support	10	4	21%	22$
Tokyo ETS	14	4	20%	106$
cross-country	18	4		
Saitama ETS	20	3	20%	108$
Swedish carbon tax	77	2	40%	103$
Quebec ETS	10	2	78%	9$
Korea ETS	2	2	73%	15$
Finnish carbon tax	8	2	36%	6$
California CaT	2	2	74%	12$
Swiss ETS	5	1	11%	18$
Australian carbon tax	2	1	60%	24$
Total	470	98		

Findings



Findings

Not a lot of evidence for LMICs

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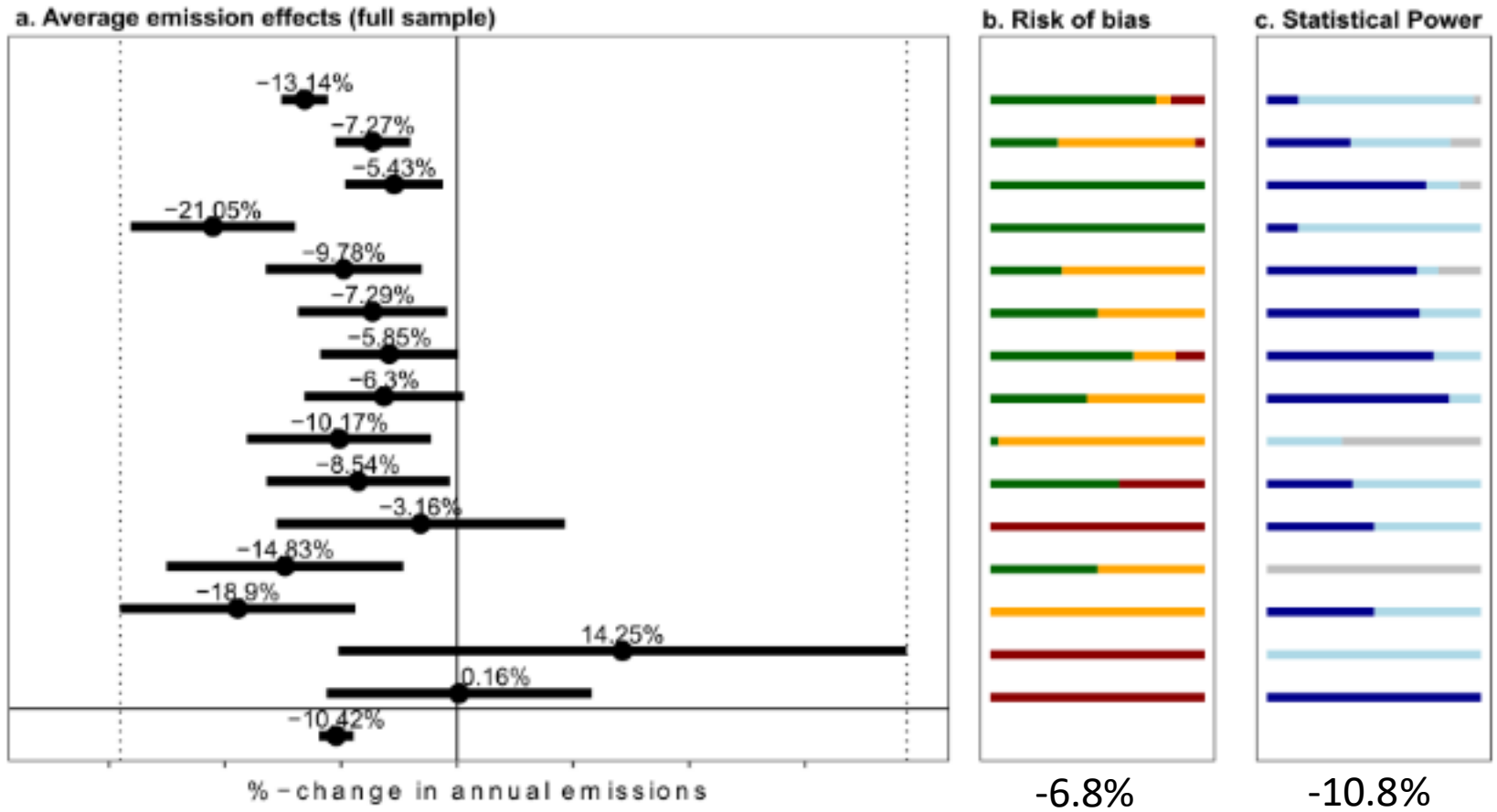


-6.8%

-10.8%

Empirical evaluation of the South African Carbon Tax

Institutional context:

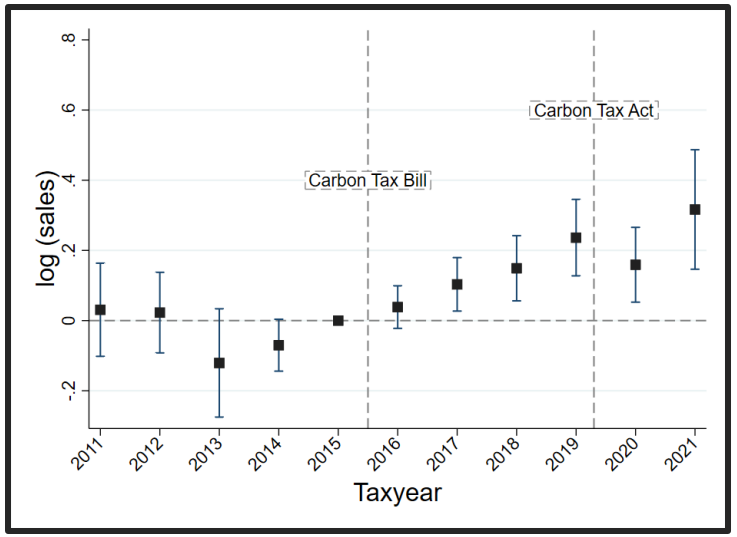
- South Africa implemented a national carbon tax in 2019 despite strong resistance from various interest groups
- Around 300 carbon tax firms responsible for 80% of national emissions
- Generous transition period with up to 95% of allowances reducing effective tax rate

Research design:

- Compare similar firms over time that only differ in being liable for the carbon tax
- Estimate the economic impact on firm sales, capital and employment

Results:

- Positive economic impacts for carbon tax firms
- Temporary positive impacts might stem from firm anticipation of expensive future, when effective carbon tax rate will increase
- **No robust evidence on emission reductions**



Source: Gallé et al. (2025)

Effectiveness – what do we know?

RESEARCH

CLIMATE POLICY

Climate policies that achieved major emission reductions: Global evidence from two decades

Annika Stechemesser[1,2,3]*, Nicolas Koch[1,2,4]*, Ebba Mark[5,6,7], Elina Dilger[1], Patrick Klösel[1,2], Laura Menicacci[1], Daniel Nachtigall[8], Felix Pretis[5,9], Nolan Ritter[1,2], Moritz Schwarz[1,5,6,10], Helena Vossen[1], Anna Wenzel[1]

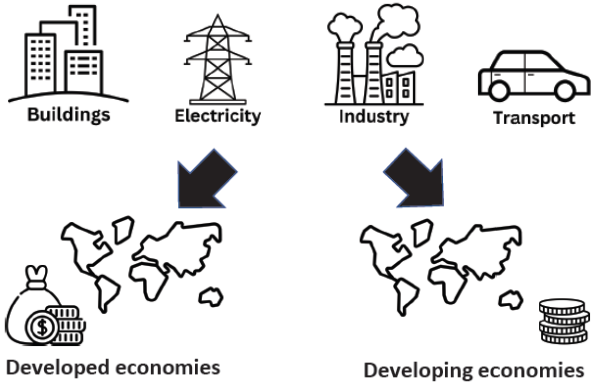
Policy mixes – A data driven approach

› Most empirical analyses focus on headline policy instruments

› Looking at instruments in isolation prevents systematic learning about prevalent policy mixes

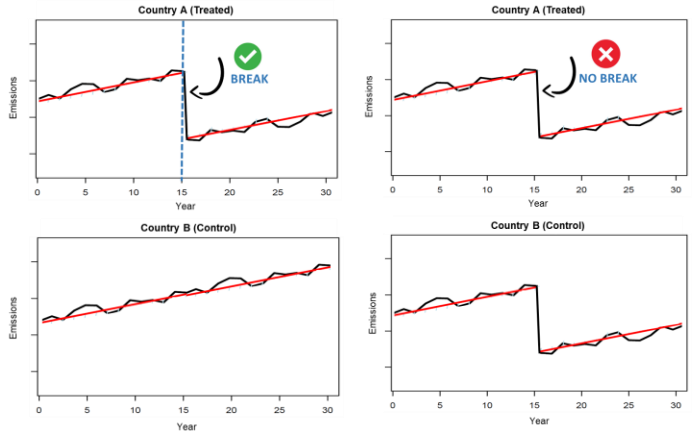
Step 1: Detecting emission breaks

CO_2 Emissions data from 4 sectors (2000-2020)

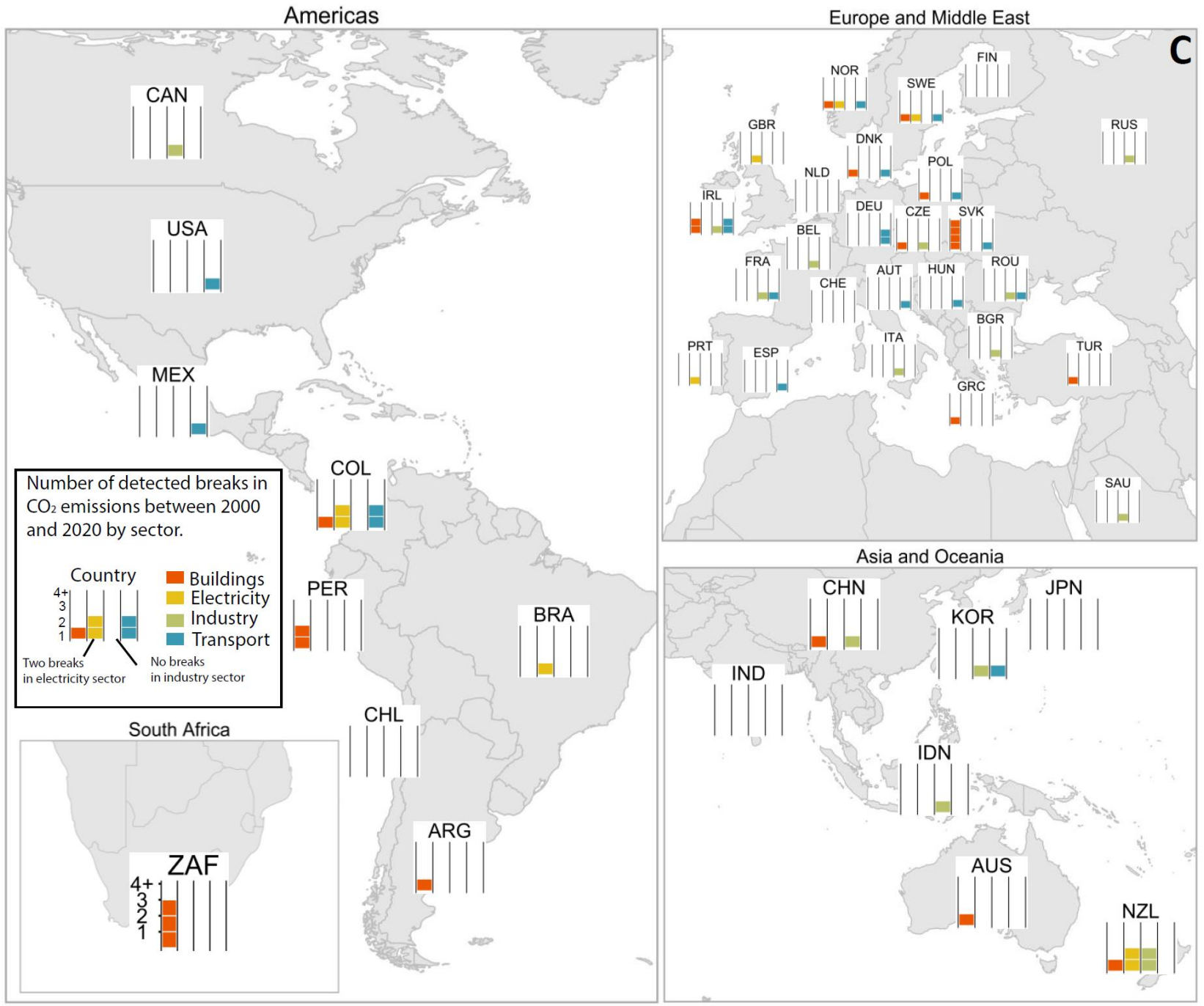


(EDGAR) Emissions Database for Global Atmospheric Research
Sector-level CO_2 emissions data across 41 countries

… in a causal framework **with control group**



NB: Approach targets large emission reductions (required min. effect ≈ 5–10%)



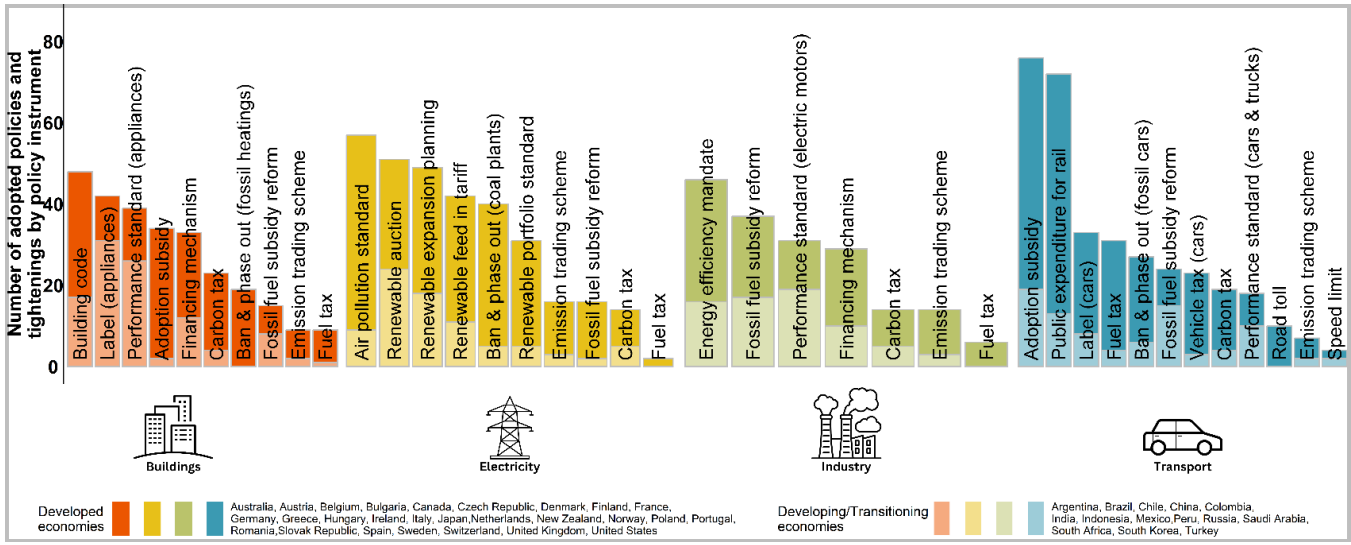
69 breaks with average emission reduction of 19 percent

Emission reductions on a magnitude that matches zero-emission targets are possible

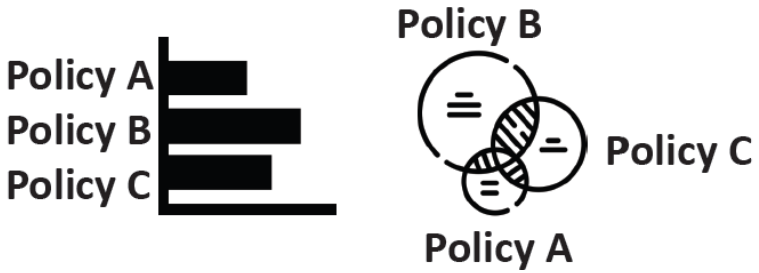
Step 2: Policy Attribution

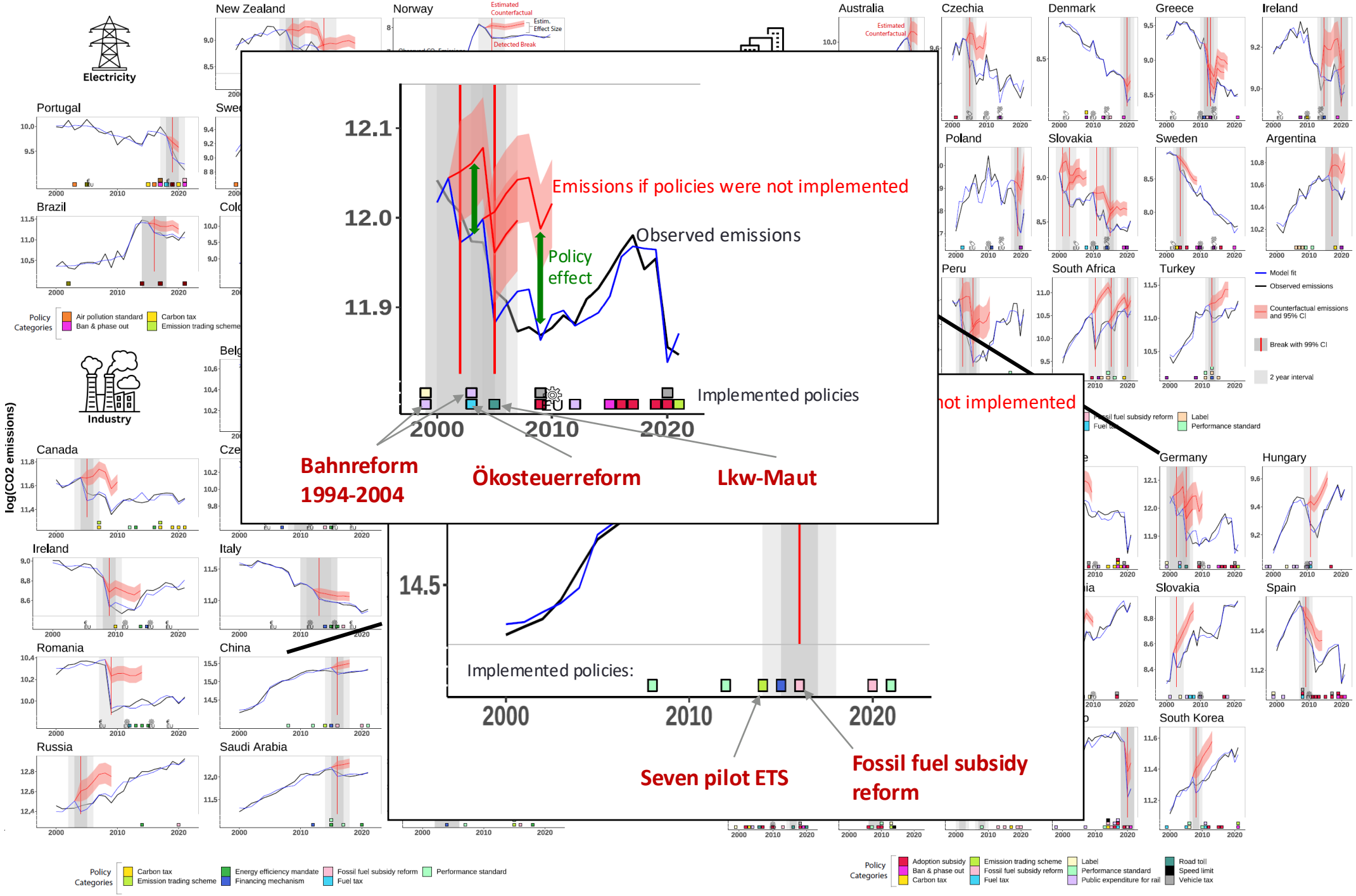
Specify policy instruments behind breaks based on comprehensive, internationally-harmonized policy inventory

(CAPMF) Climate Actions and Policies Measurement Framework
OECD database of policies implemented from 2000-2022

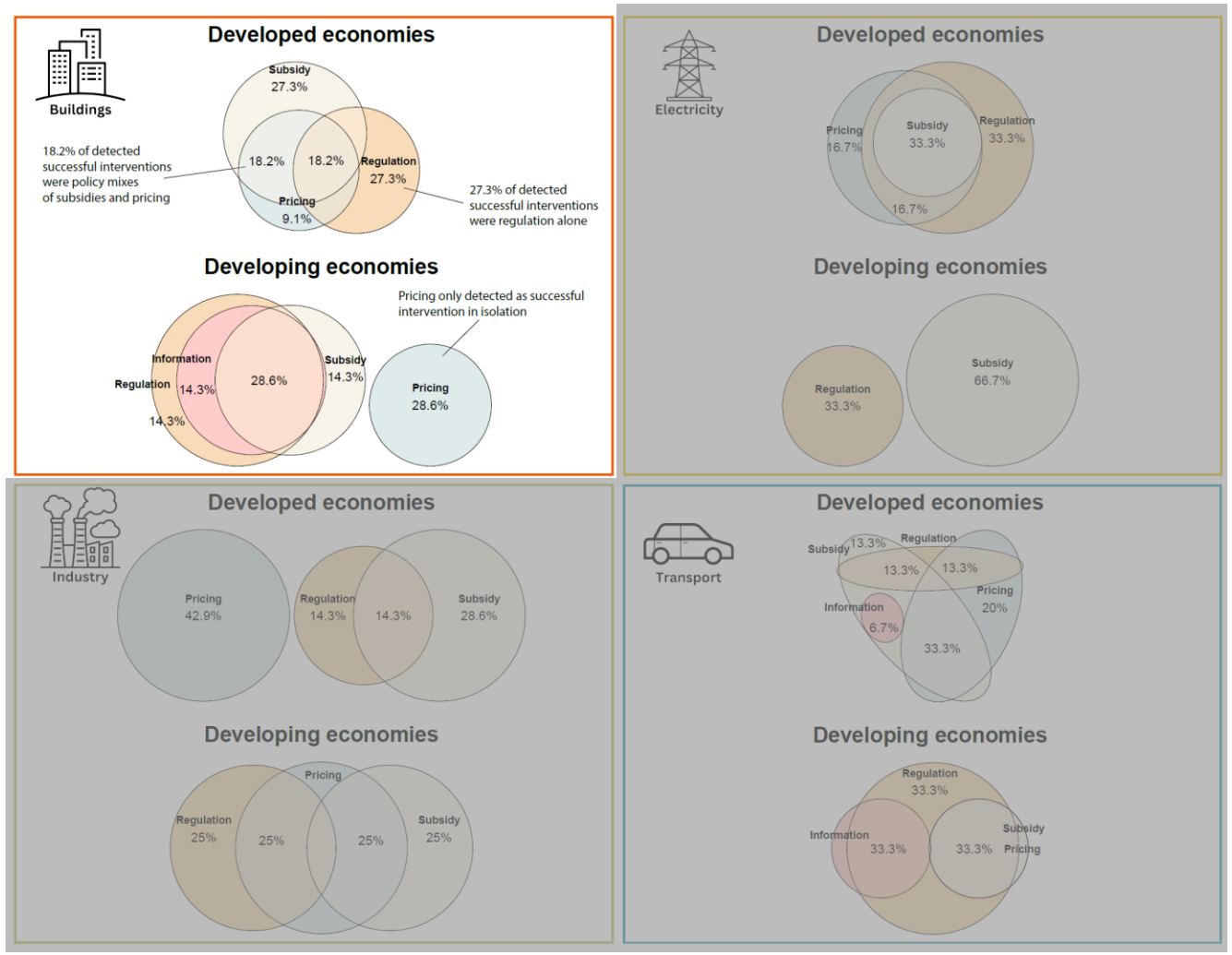


Analyze successful policies and policy mixes




Electricity
Industry
New Zealand
Norway
Estimated Counterfactual
Estim. Effect Size
Detected Break
Australia
Czechia
Denmark
Greece
Ireland
Portugal
Poland
Slovakia
Sweden
Argentina
Brazil
Peru
South Africa
Turkey
Model fit
Observed emissions
Counterfactual emissions and 95% CI
Break with 99% CI
2 year interval
Policy Categories
Air pollution standard
Ban & phase out
Carbon tax
Emission trading scheme
Canada
Germany
Hungary
Ireland
Italy
Slovakia
Spain
Romania
China
South Korea
Russia
Saudi Arabia
log(CO2 emissions)
12.1
12.0
11.9
Emissions if policies were not implemented
Observed emissions
Policy effect
Implemented policies
2000
2010
2020
Bahnreform 1994-2004
Ökosteuerreform
Lkw-Maut
not implemented
Fossil fuel subsidy reform
Label
Performance standard
14.5
Implemented policies:
Seven pilot ETS
Fossil fuel subsidy reform
Policy Categories
Carbon tax
Emission trading scheme
Energy efficiency mandate
Financing mechanism
Fossil fuel subsidy reform
Fuel tax
Performance standard
Policy Categories
Adoption subsidy
Ban & phase out
Carbon tax
Emission trading scheme
Fossil fuel subsidy reform
Fuel tax
Label
Performance standard
Public expenditure for rail
Road toll
Speed limit
Vehicle tax

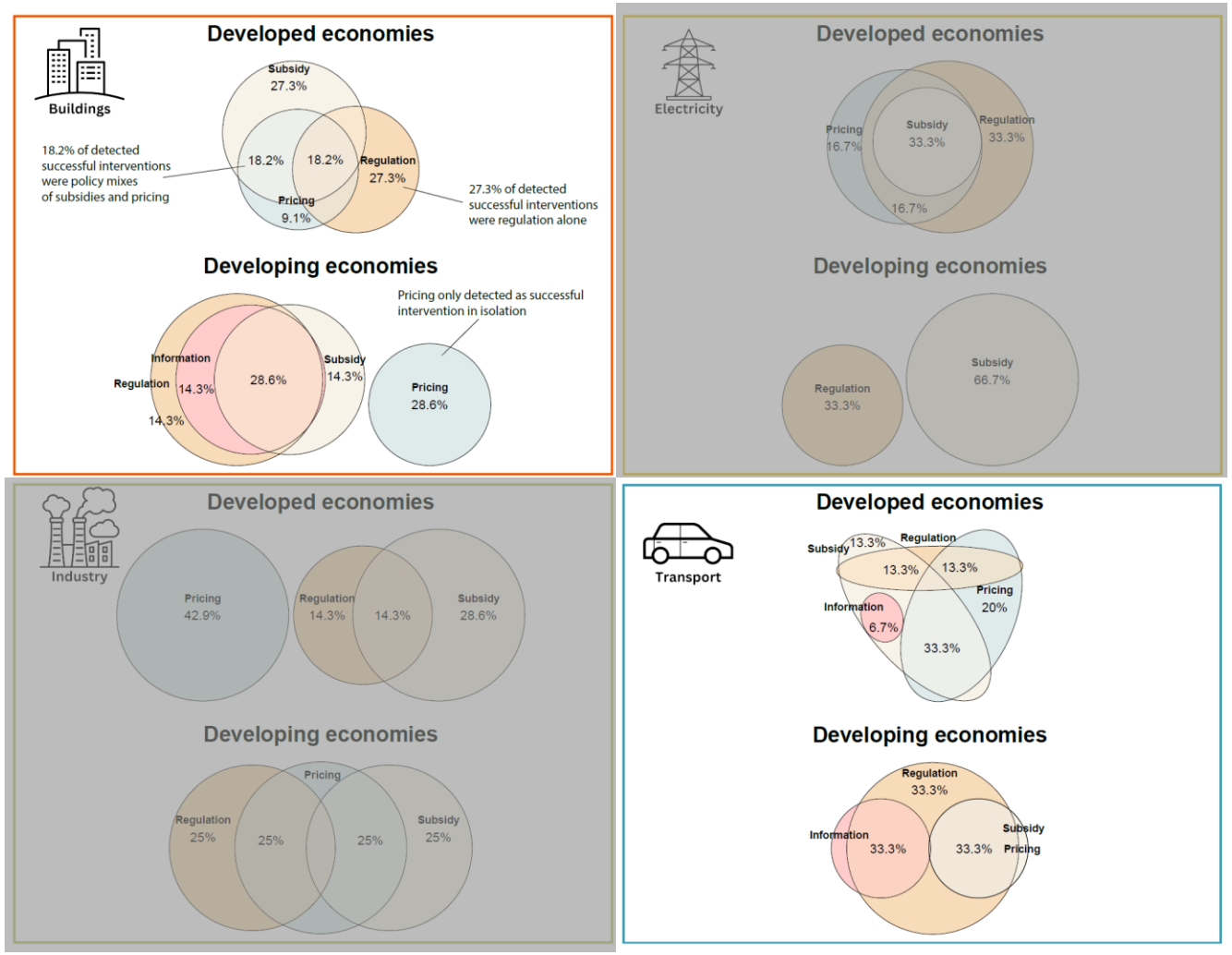
No one-size-fits-all



Effective policies differ across sectors & country groups

- Most complementarities in sectors with private consumers

No one-size-fits-all



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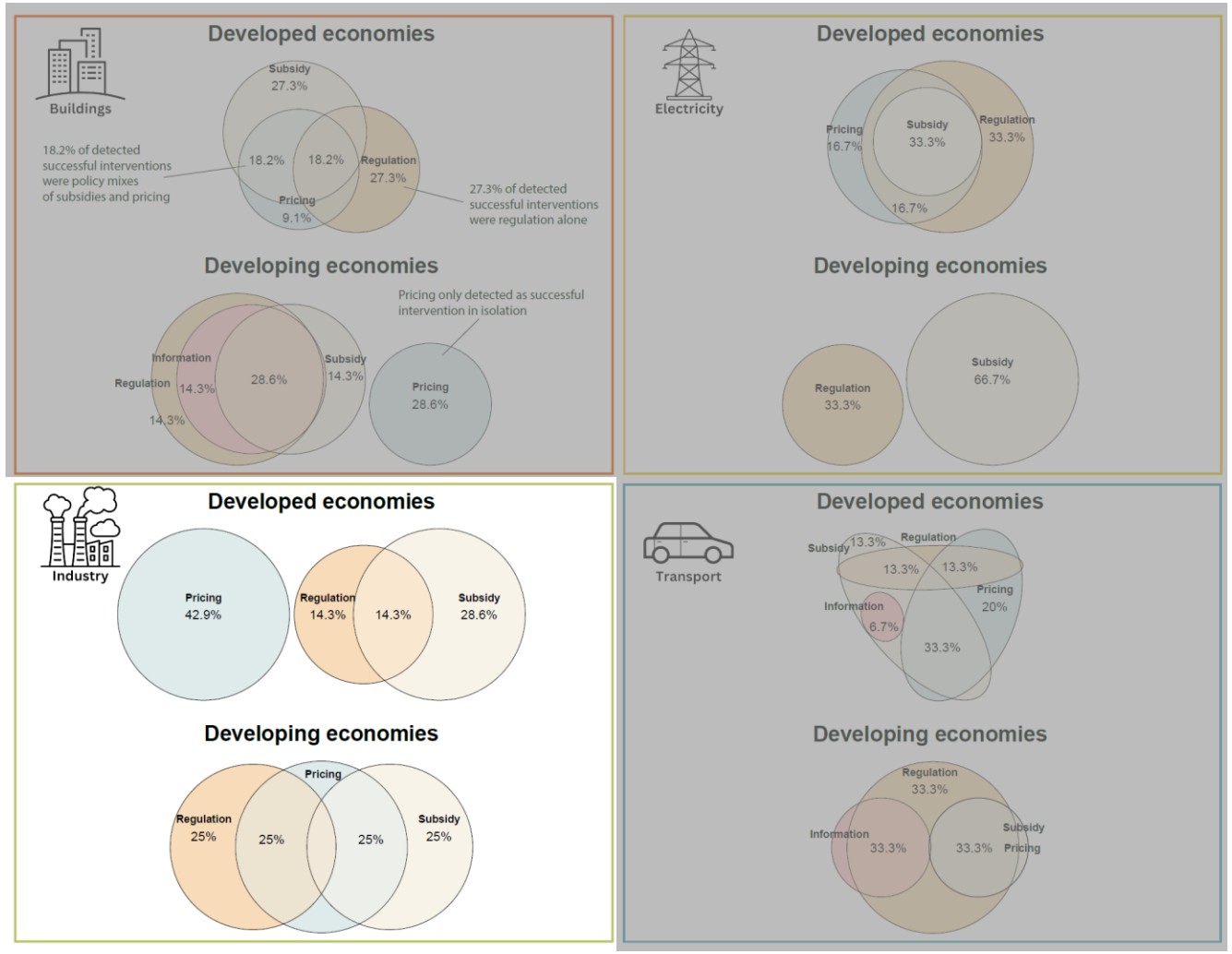
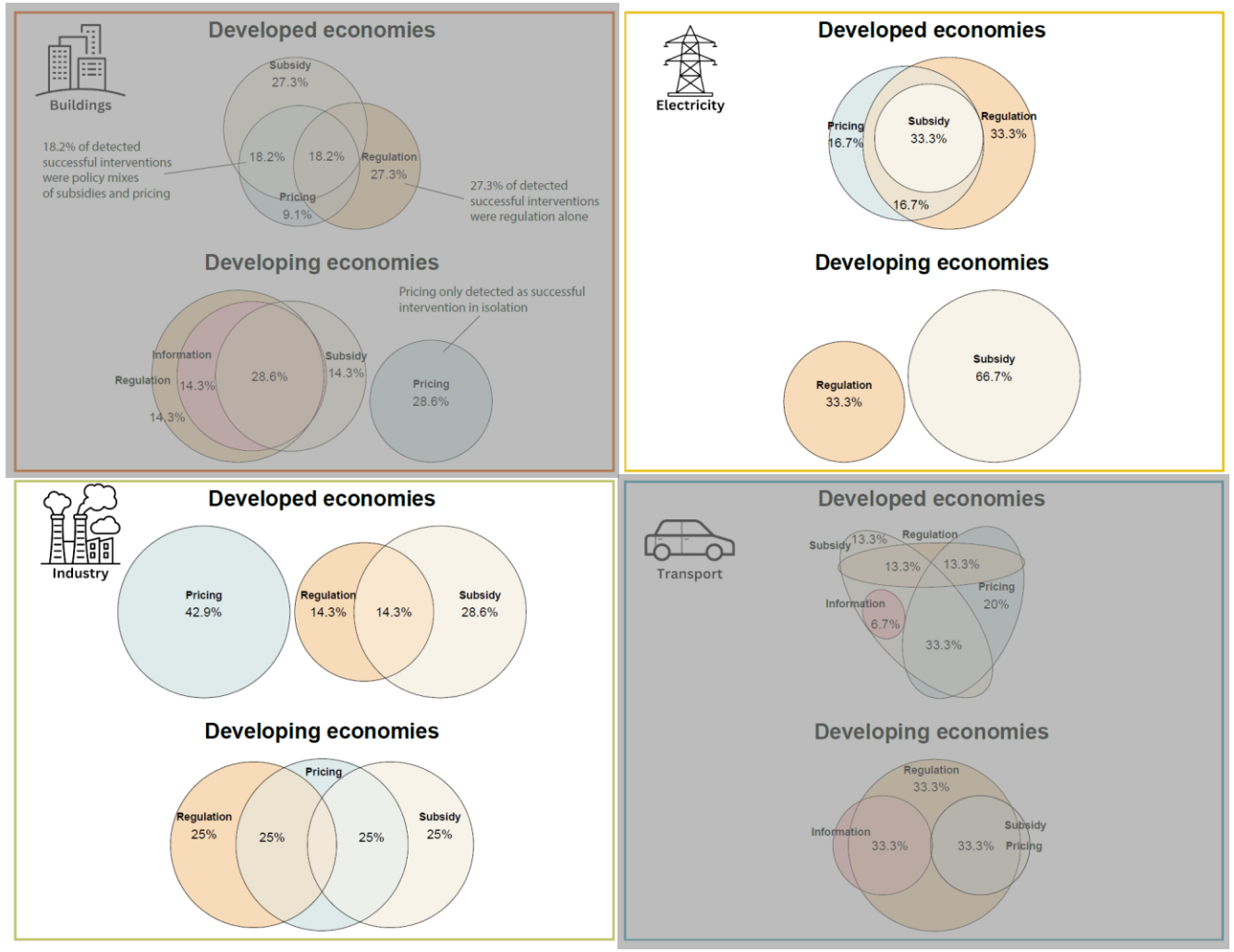


Effective policies differ across sectors & country groups

- Most complementarities in sectors with private consumers
- Pricing particularly effective in context w/ profit-maximizing firms

No one-size-fits-all



Effective policies differ across sectors & country groups

- Most complementarities in sectors with private consumers
- Pricing particularly effective in context w/ profit-maximizing firms
- No successful pricing intervention in electricity sector of developing countries
  - Role of liberalized markets & other price distortions
  - Role of policy sequencing
  - Role of institutions/state capacity
  - …

Can we expect carbon prices to be effective in LMICs?

Why should it be different from theory / developed countries?

› Effectiveness in light of differing market structures and political economy

› Interaction with other externalities and/or market failures (including health)

› Different distributional consequences and possibilities to alleviate

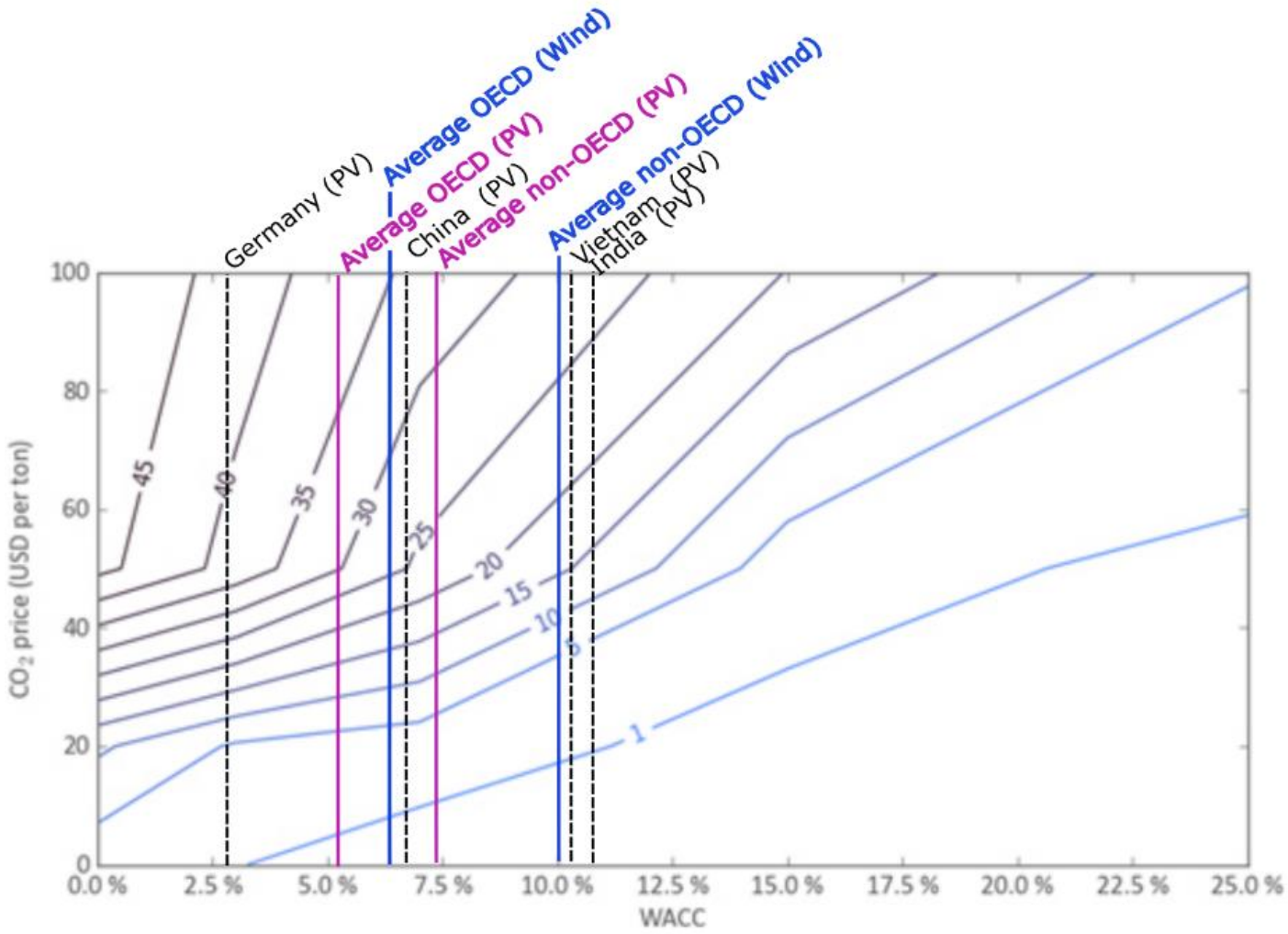
› Different institutional capabilities, e.g. to manage revenues

Emerging understanding of key determinants

› Little primary evidence on effectiveness of policies / policy mixes ex-post, relatively little ex-ante modeling

› **Effectiveness:**
  › Capital costs (Hirth and Steckel, 2016, multiple works by Steffen et al.)
  › Credibility and time-consistency (Kalkuhl et al. 2020; Kalk & Sorger, 2023)
  › State capacity (e.g. to measure, monitor and enforce) (Sudarshan et al. 2025)
  › Market design (Borenstein & Kellog, 2023)
  › …

Capital costs and the effectiveness of carbon pricing



Hirth and Steckel (2016); Steffen (2020)

- Contour lines show the expected **share of renewable energies,** given a certain CO_2-price and certain capital costs (WACC).
- Vertical lines show the **average capital costs** for investments in renewables in selected countries and regions.
- **Capital costs affect the effectiveness of a CO_2-price!**

Emerging understanding of key determinants

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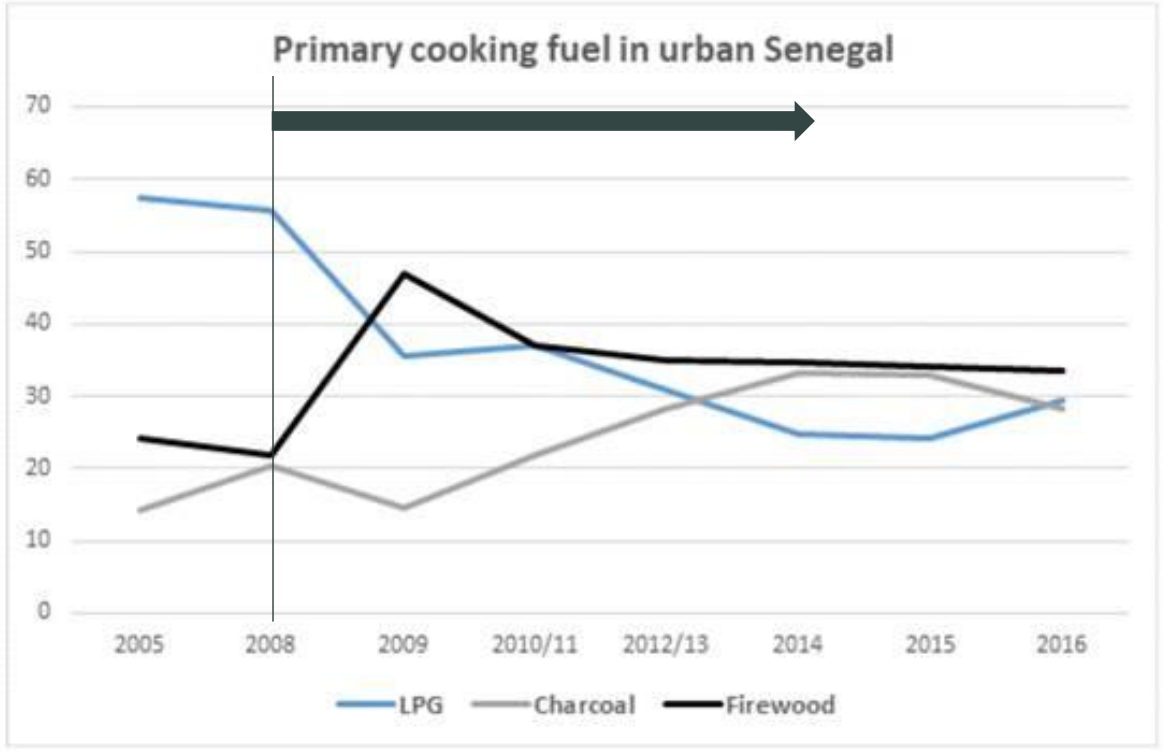
  › …

› **Equity:**
  › Informal markets (Bento et al. 2018)
  › Sustainable development trade-offs (Greve and Lay, 2023; Aggarwal et al., 2024)
  › Distributional effects (Dorband et al. 2019)
  › Institutional capabilties to organize compensation (Missbach et al. 2024)
  › Acceptability (Mohammadzadeh-Valencia et al. 2024)
  › …

Sustainable Development Trade-offs

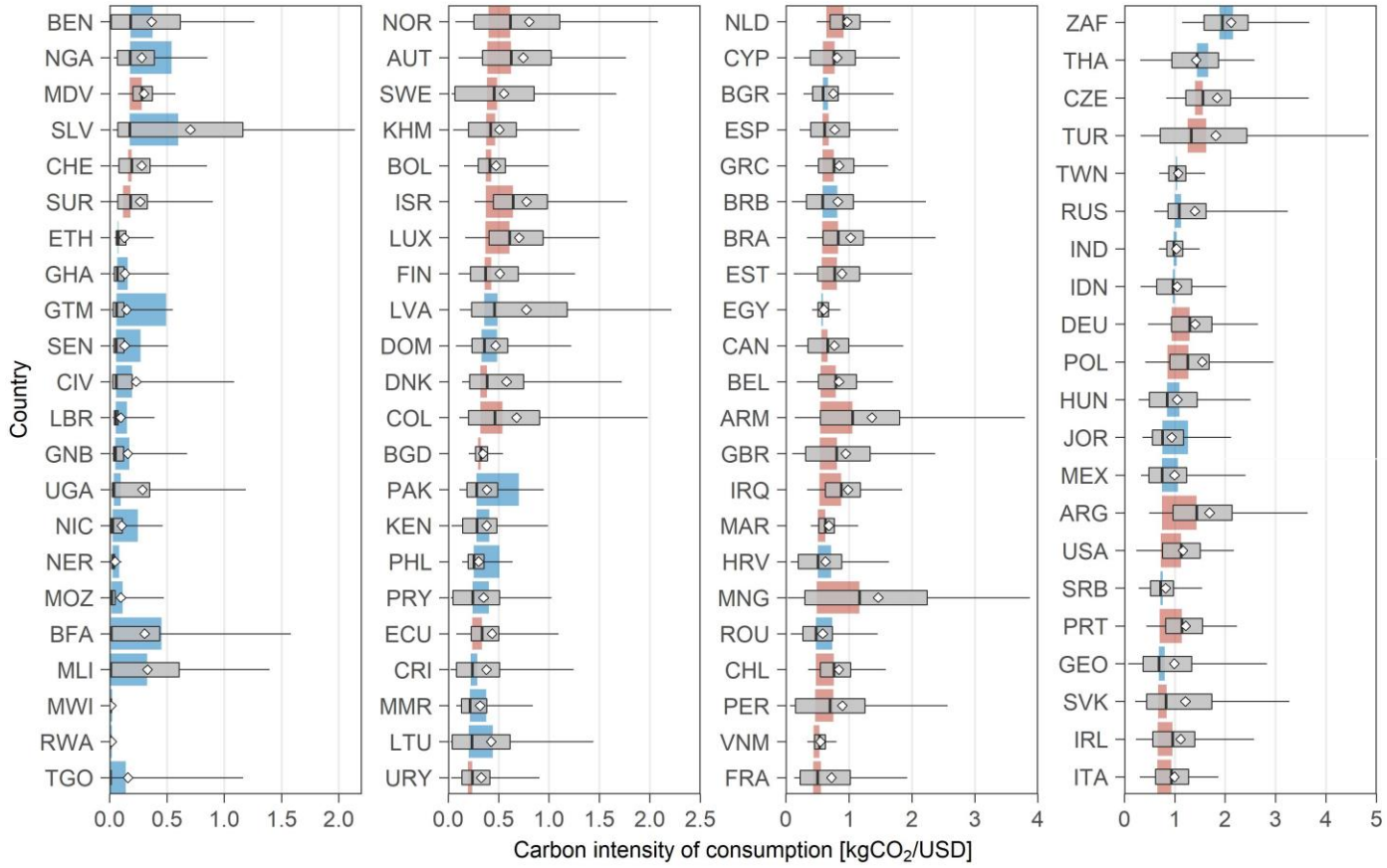
- Carbon pricing will lead to a reduction in fuel consumption
  - But, what's the alternative?
- Households may increase use of traditional biomass in response to higher fossil fuel prices
  - Adverse impacts on health through indoor air pollution
- In addition: potential shifts in diets; negative effects on calorie and nutrient intake (e.g. in Uganda, see Aggarwal et al., 2024)
- Transfers to protect from negative impacts are pivotally important



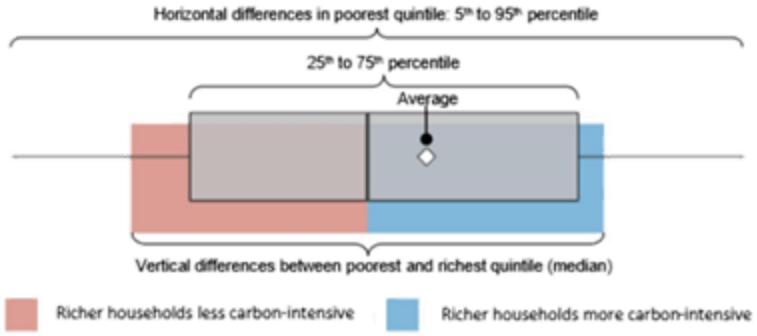
Source: Rose et al. 2022

Who is affected depends on country specifics

Comparison between vertical differences (in blue/red) and horizontal spread for first expenditure quintile in selected countries.



- Vertical differences (in red/blue) between poorest and richest households miss a large part of the heterogeneity.
- Whether specific households are affected depends on their specific consumption patterns, e.g. do they own a car? How do they heat? Where do they live? etc. …



Source: Missbach & Steckel 2024

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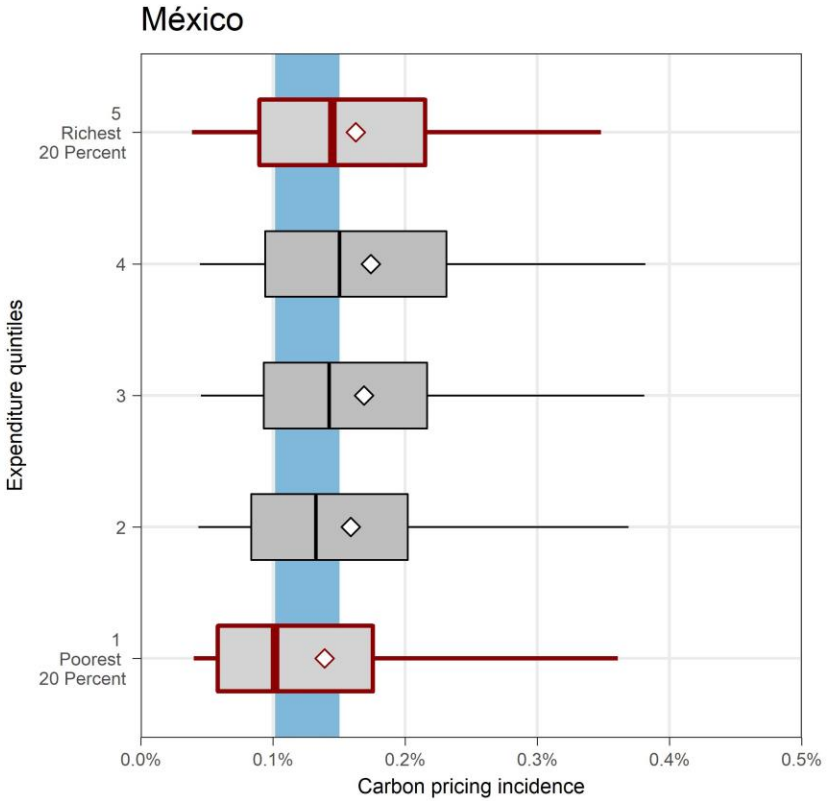
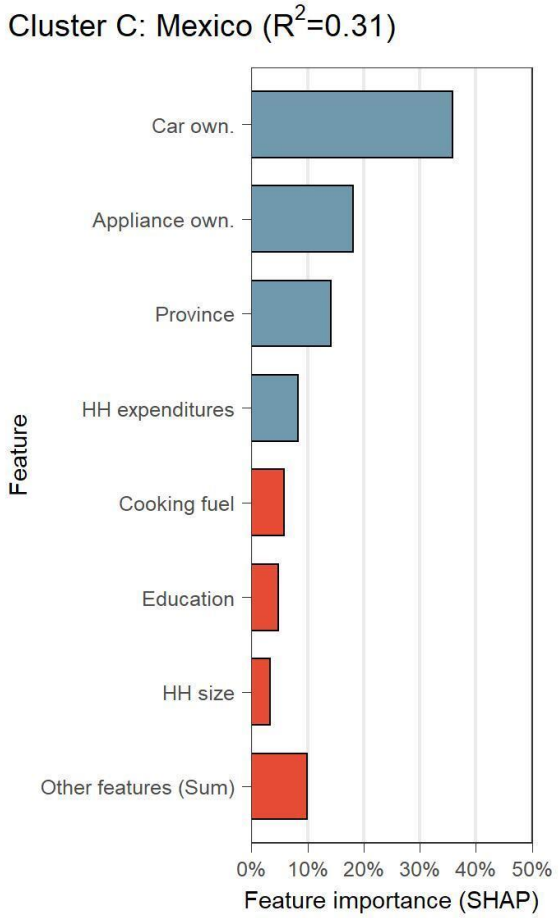
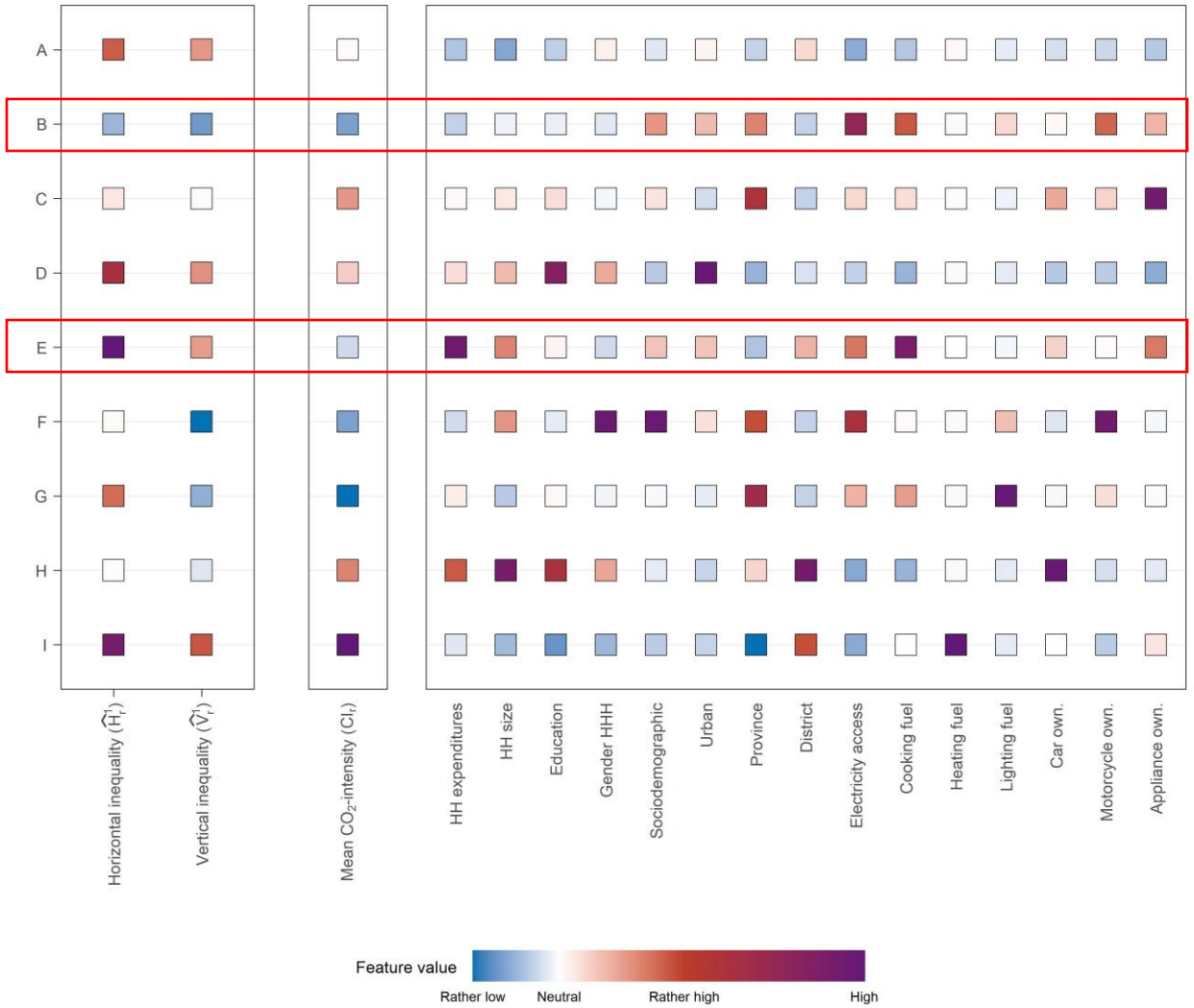




- Large differences within poorer and richer households
- Factors beyond income matter

Source: Missbach & Steckel (2024)

Towards a systematic understanding of distributional effects



- Cluster B:
  - Progressive, horizontal inequality (rich), **electricity access, cooking fuel use and vehicle ownership** as important predictors
  - Examples: Kenya, Ghana, Senegal
- Cluster E:
  - Regressive, horizontal inequality (poor), **household expenditures** and **cooking fuel use** as important predictors
  - Examples: Peru, Bolivia, Ecuador

Based on harmonized data for 88 countries. Browse results at cpic-global.net

The development context of emission reduction policy

How those play out for the effectiveness of carbon pricing needs to be better understood!

Table I Development context of emission reduction policy

Economic context	Business environment	Public institutions
Urgent development needs	Infrastructure gaps	Limited state capacity
Aid dependence	Rule-of-law gaps	Influential state-owned enterprises
High informality	Administrative barriers	Low tax base
Resource dependence	Access to finance gaps	Corruption
Demographic shifts (young population)	High real interest rates	Political instability
		Short-term horizons
Weak exchange rate		
Indebtedness		

Source: Caucheteux et al. 2025

Backup

Literature

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Sustainable Development Trade-offs

Country	Fuel	Climate Benefits (Per '000 Persons) (US$)	Climate Costs (Per '000 Persons) (US$)	Health Benefits (Per '000 Persons) (US$)	Health Costs (Per '000 Persons) (US$)	Δ (Costs - Benefits) (Per '000 Persons) (US$)	Cost-Benefit Ratio
Cambodia	Electricity	60	-0.3	28	-172	-260	-2
	LPG	11	38	-	1,406	1,432	127
Ghana	LPG	126	346	-	10,625	10,844	87
Honduras	Electricity	69	20	62	4,256	4,145	33
	LPG	227	17	-	4,770	4,561	21
India	LPG	91	21	-	8,274	8,205	91
Kenya	Kerosene	54	-2	-	-276	-332	-5
	LPG	44	275	-	2,719	2,950	68
Myanmar	Electricity	28	-0.4	16	105	61	2
	LPG	38	2	-	200	164	5

Note: Benefits and costs are calculated for 1% price increases for fossil-based fuels. The carbon price applied is US$ 80 per t$CO2$, and the price on methane emissions applied is US$ 1,680 per t$CH4$. Detailed calculations for each of the costs and benefits (climate benefits, climate costs, health benefits and health costs) are presented in Appendix A.4.

Systematic review

Steps of a systematic review		
Literature search	Web of Science, Scopus, JSTOR, RePEc; compehensive query, tested against known relevant studies	>16,000 articles identified
Eligibility screening	Criteria: carbon tax or ETS, ex-post causal inference, effect on emissions	4,300 abstracts screened by hand →374 potentially relevant →80 relevant after full text screening
Data extraction	Estimates of emission reduction caused by carbon pricing	483 effect sizes extracted
Critical appraisal	Appraisal: selection of treatment/control group, control variables, estimation method	46% of studies have medium or high risk of bias
Synthesis	Meta-Analysis	

Robustness

Study quality

- Critical appraisal flagged 46% of studies to have medium or high risk of bias
  - Control group (countries, firms, etc.) likely not comparable to treatment group
  - Omitted control variables
  - Inconsistencies in data or methods
- Excluding these studies has minor effect: -10.8%

Publication bias

- Precision effect test shows presence of publication bias
- WAAP method (Ioannidis et al., 2017)
  - Calculate statistical power of each effect size
  - Estimate average effect based on effect sizes with power >0.8 only
- Average emission effect decreases to -6.8%

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Effect size harmonisation

Common metric: percentage change in emissions

Treatment effect: log-level regression

$$\theta = \left(e^{\beta} - 1\right) * 100$$

Treatment effect: level-level regression

$$\theta = \frac{\beta}{CO_{2_{mean}}} * 100$$

Price elasticity: log-level regression

$$\theta = \left(e^{\beta * p_{mean}} - 1\right) * 100$$

Price elasticity: level-level regression

$$\theta = \frac{\beta * p_{mean}}{CO_{2_{mean}}} * 100$$

With θ being the harmonized effect size, β being the effect size reported in the study and p_{mean} the carbon price during the study period.

Standard errors are transformed accordingly