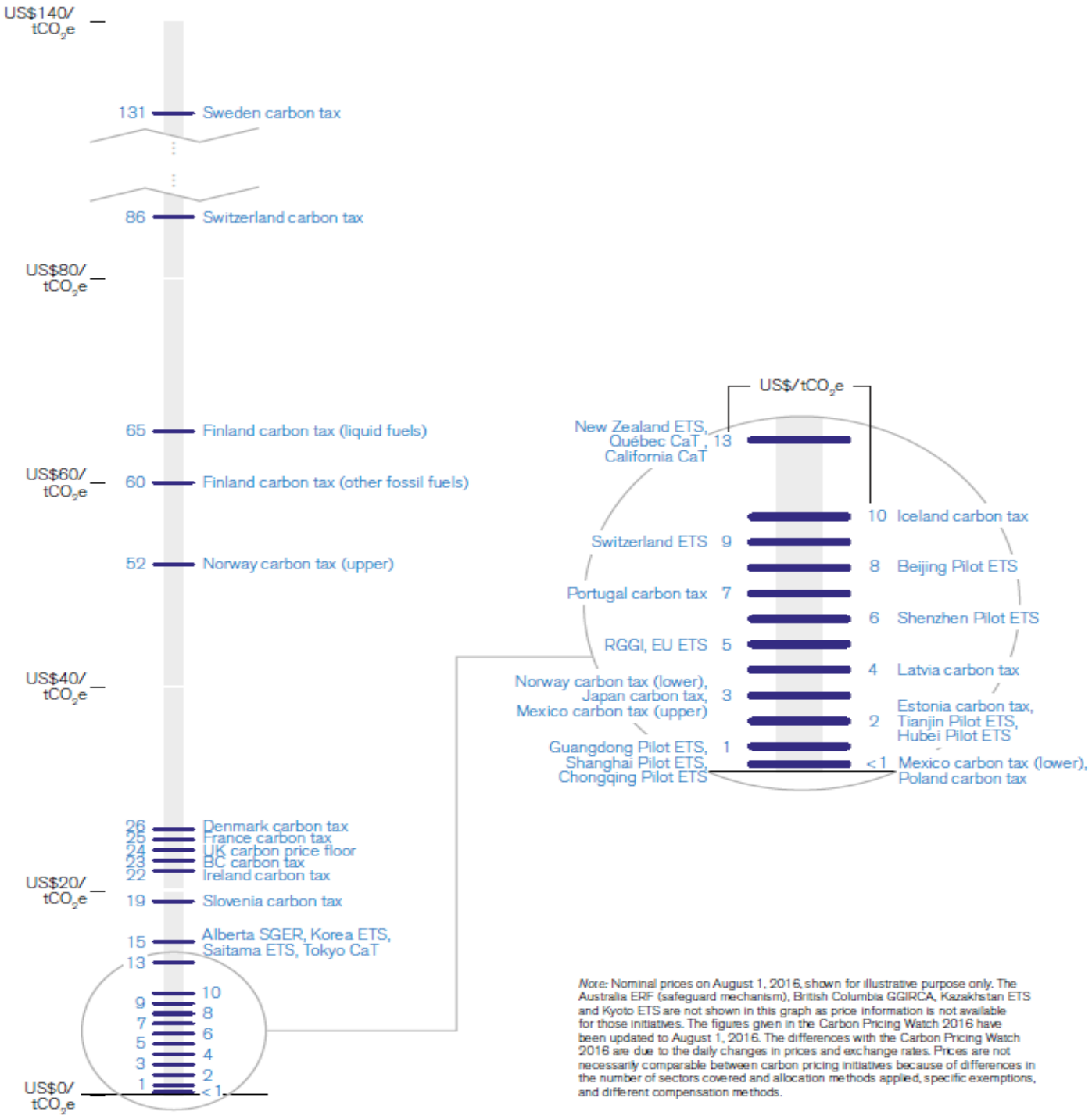
Why the Scope of the Carbon Tax Matters

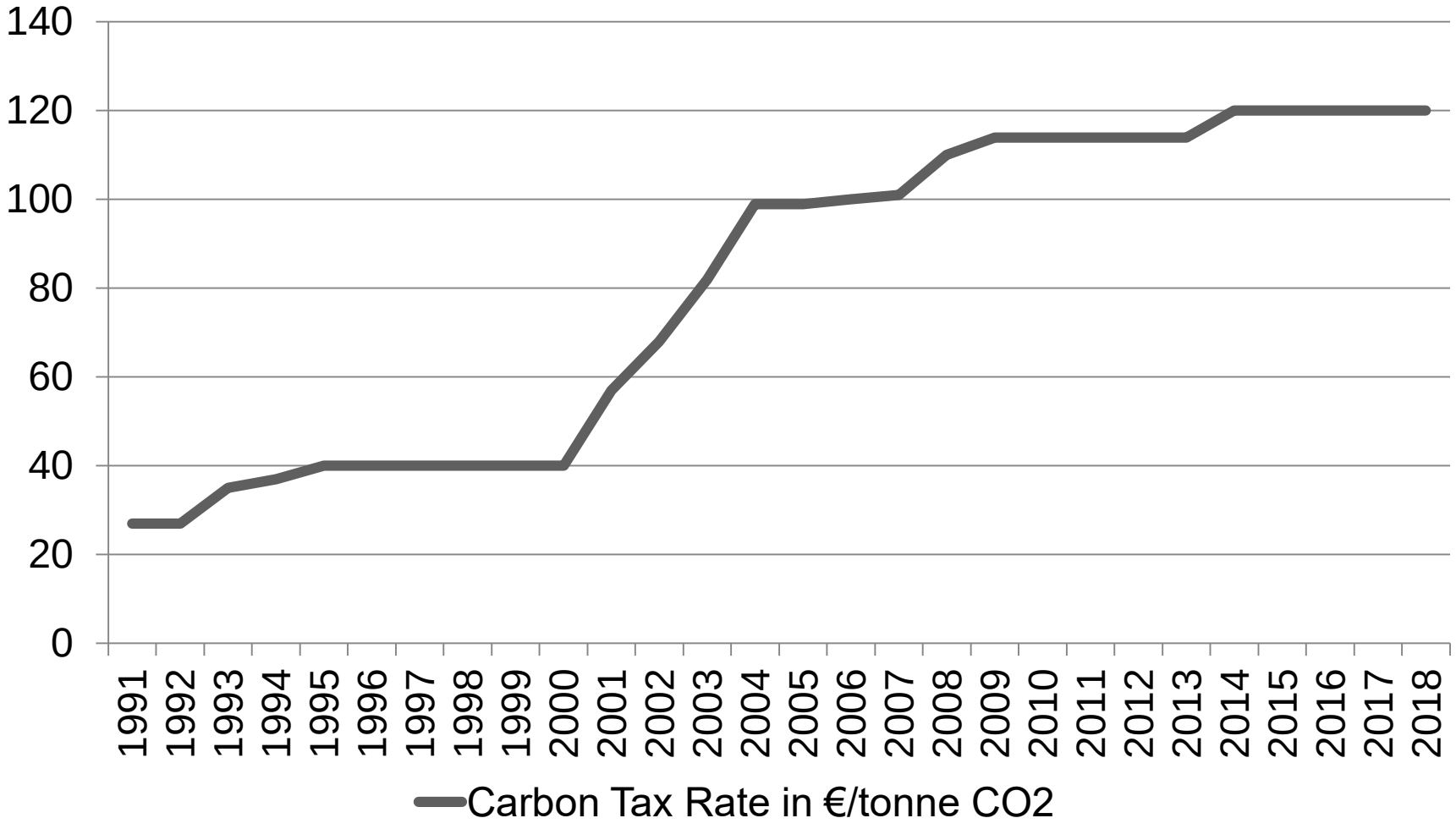
Evidence from the Swedish Residential Building Sector

Anita Thonipara, Petrik Runst



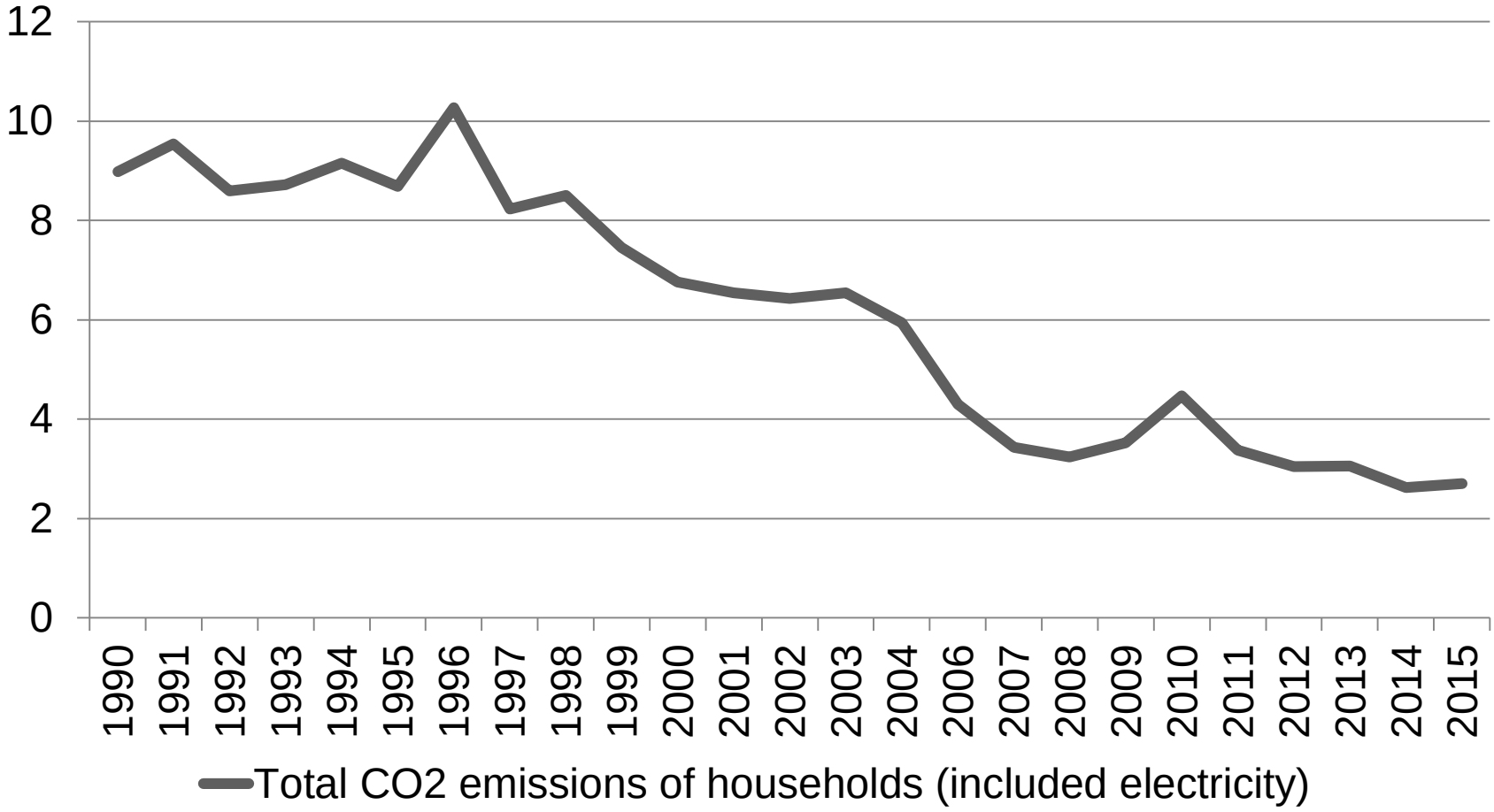
Note: Nominal prices on August 1, 2016, shown for illustrative purpose only. The Australia ERF (safeguard mechanism), British Columbia GGIRCA, Kazakhstan ETS and Kyoto ETS are not shown in this graph as price information is not available for those initiatives. The figures given in the Carbon Pricing Watch 2016 have been updated to August 1, 2016. The differences with the Carbon Pricing Watch 2016 are due to the daily changes in prices and exchange rates. Prices are not necessarily comparable between carbon pricing initiatives because of differences in the number of sectors covered and allocation methods applied, specific exemptions, and different compensation methods.

Swedish Carbon Tax Rate in €/tonne CO_2



Data drawn from Statistics Sweden

Total CO_2 emissions of households (including electricity)



Data drawn from Odyssee – Mure Database

Research Purpose

- What effect did the augmentation of the carbon tax have on residential carbon emissions?

- Method:
  - Synthetic Control Method
  - Difference in Differences

Synthetic Control Method

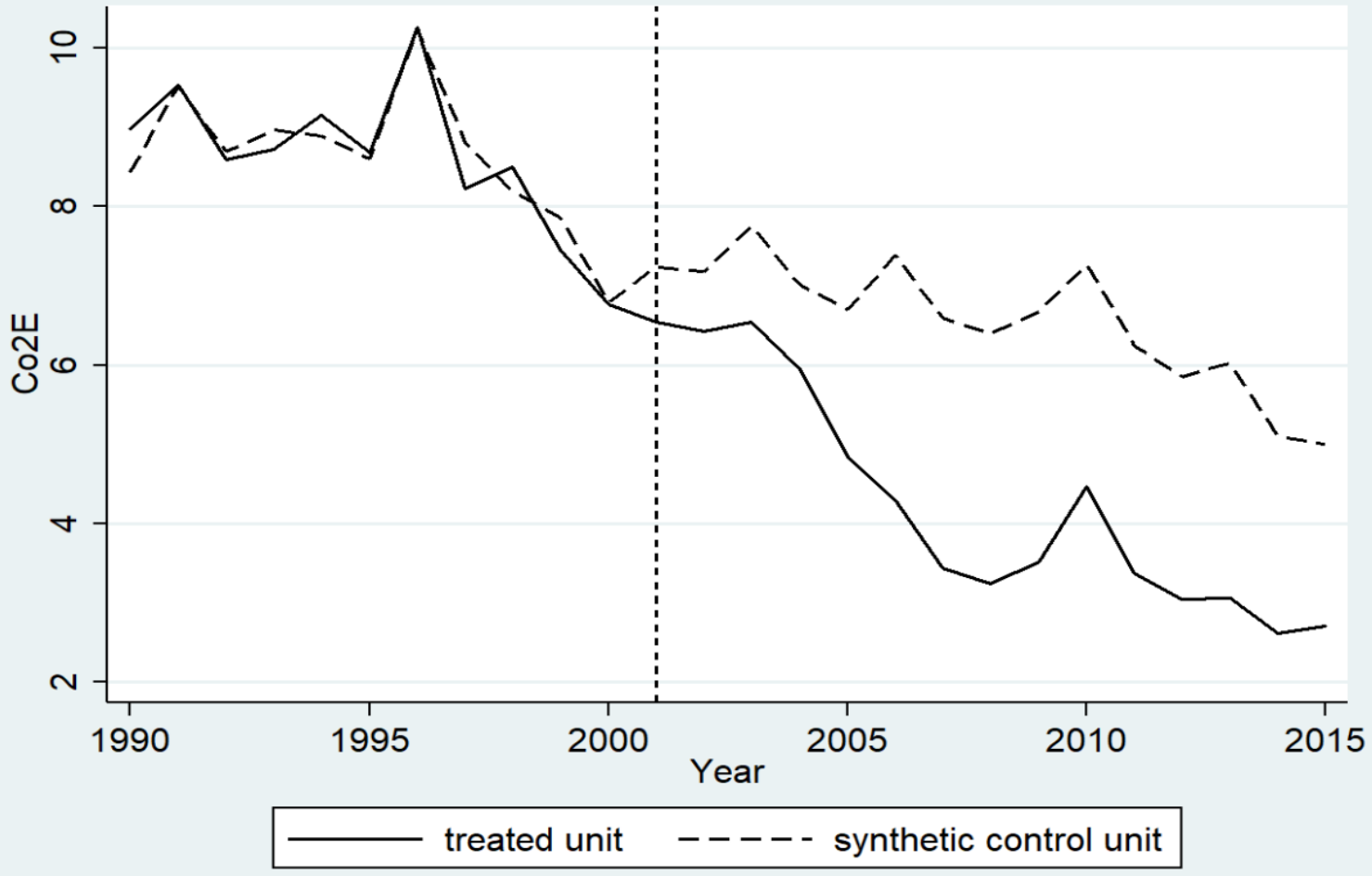
- How would CO2 emissions of Swedish residential buildings have developed without the 2001 carbon tax augmentation?

$$\sum_{m=1}^{k} v_m \left(X_1 - X_{0m}W\right)^2$$

  - X_1: pre−intervention characteristics of the treated unit
  - X_{0m}: pre-intervention characteristics of the units of the donor pool
  - v_m: weight assigned to each control unit in the donor pool
  - $W*$: choses wheigts W such that the difference $(X_1 - X_{0m}W)$ is minimized

- Intervention Year: 2001
  - Year of the strong tax augmentation

Synthetic Control Method



Donor Pool

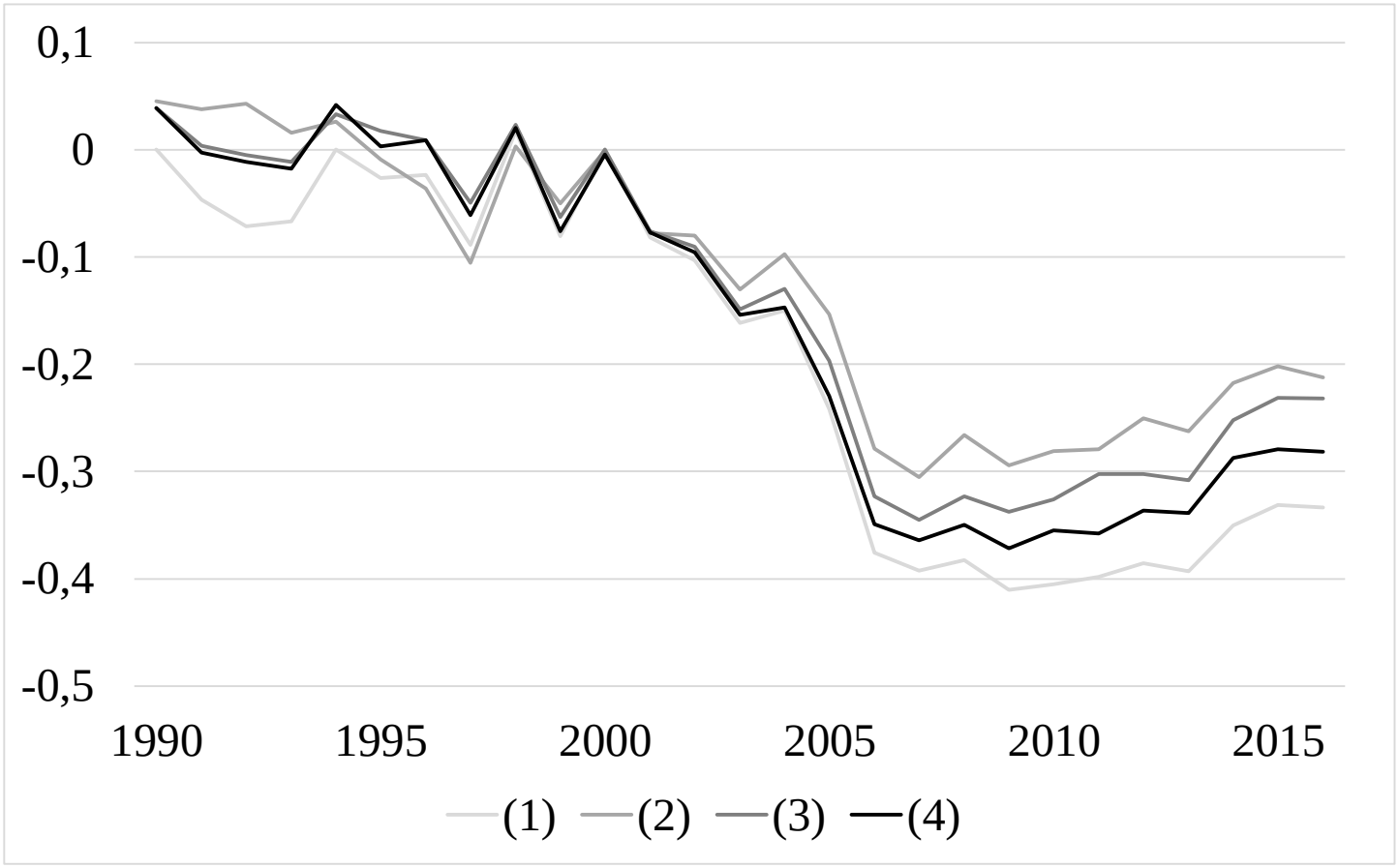
Sample 1	Sample 2	Sample 3
All countries	No carbon tax countries	Carbon tax countries
All countries of the EU + Norway, Switzerland without Luxembourg	Sample 1 minus all countries with a carbon tax higher than 20 Euros (Switzerland, Finland, Norway, Denmark, UK, Ireland)	All countries with a carbon tax higher than 20 Euros

Specifications

	1	2	3	4
Lags	1990, 1994, 2000	1996, 1997, 1998, 1999, 2000	All Lags	1990, 1994, 2000
HDD				Yes
GDPpC				Yes
Price oil				Yes
Price electricity				Yes
RMSPE	0.05	0.04	0.03	0.03

SCM Results
(sample 1 = all countries)

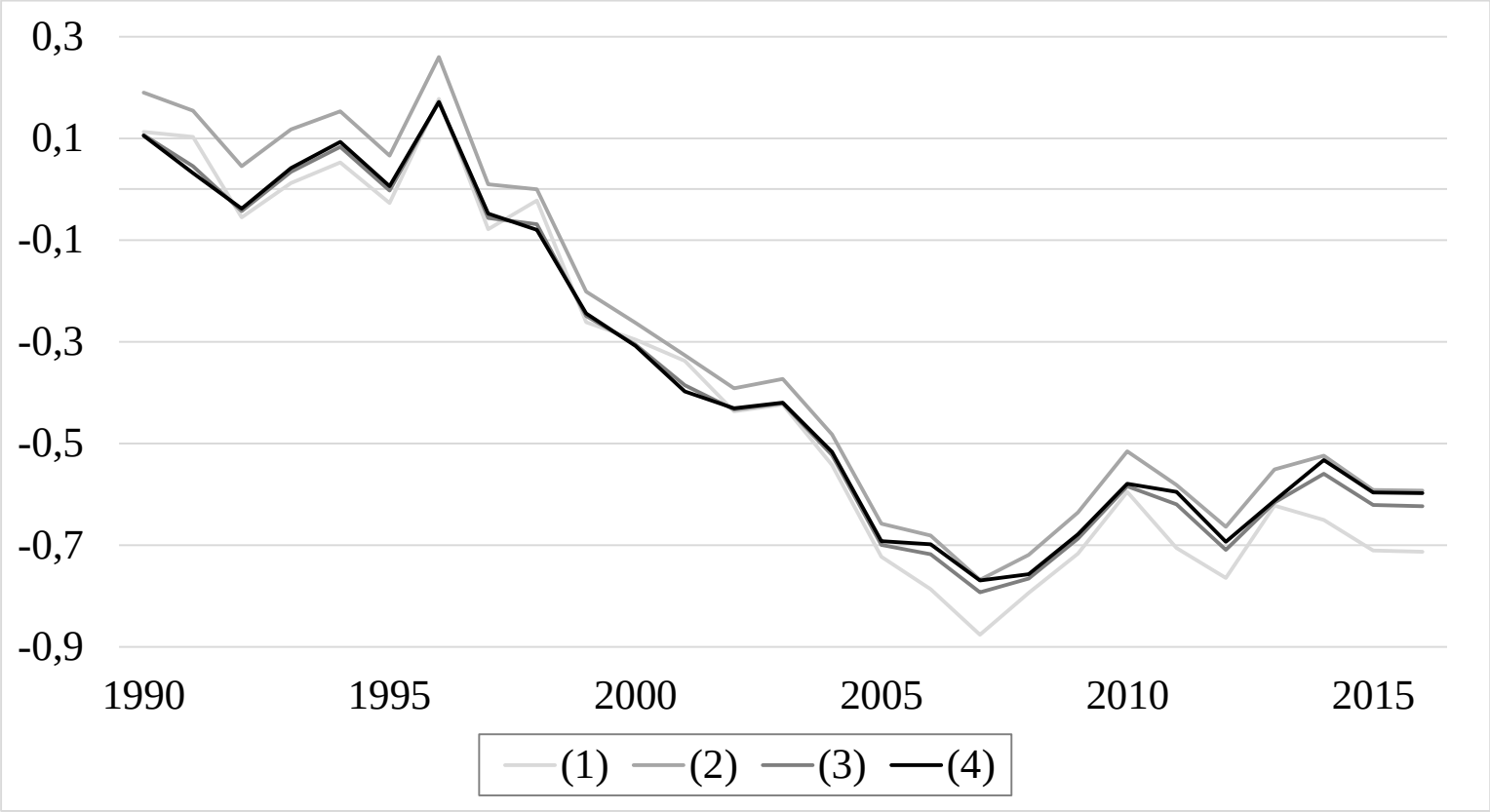
Tons of CO_2 per capita



200-400 kg CO2 per capita less emitted in Sweden due to carbon tax augmentation

SCM Results (sample 2 = countries with low / no carbon tax, no tax increases)

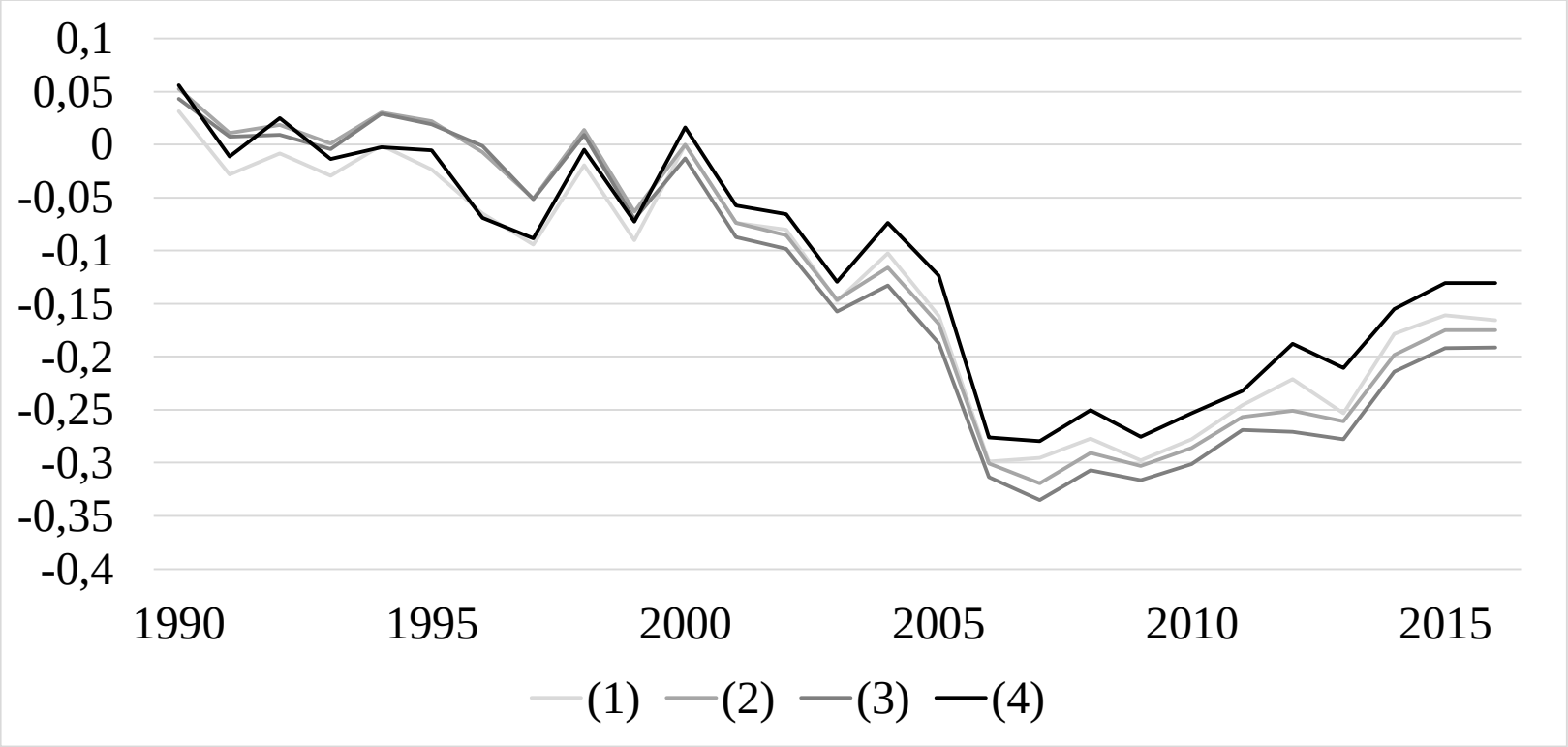
Tons of CO_2 per capita



Stronger effect: 800 kg less CO_2 per capita

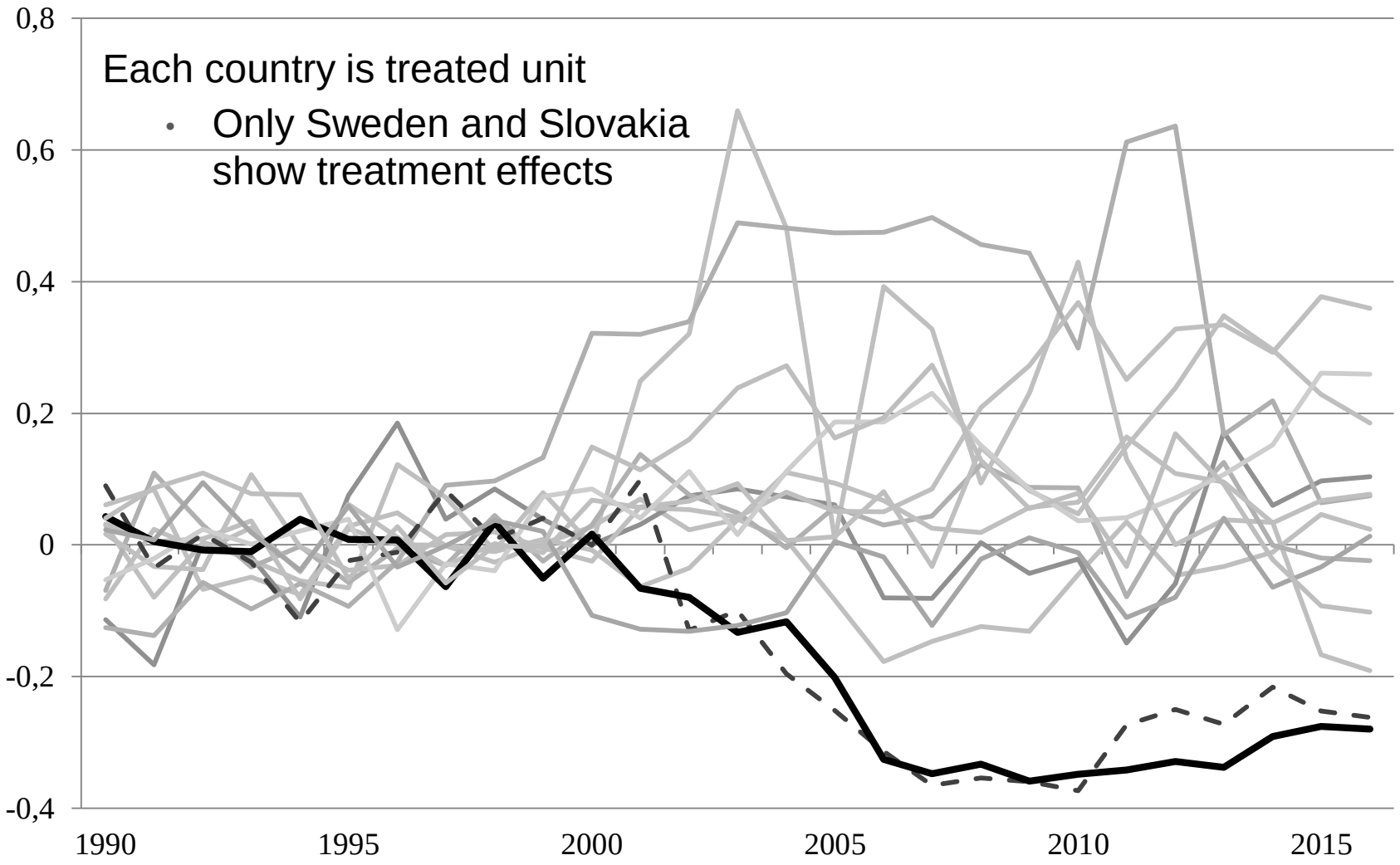
SCM Results
(sample 3 = countries with carbon tax)

Tons of CO_2 per capita



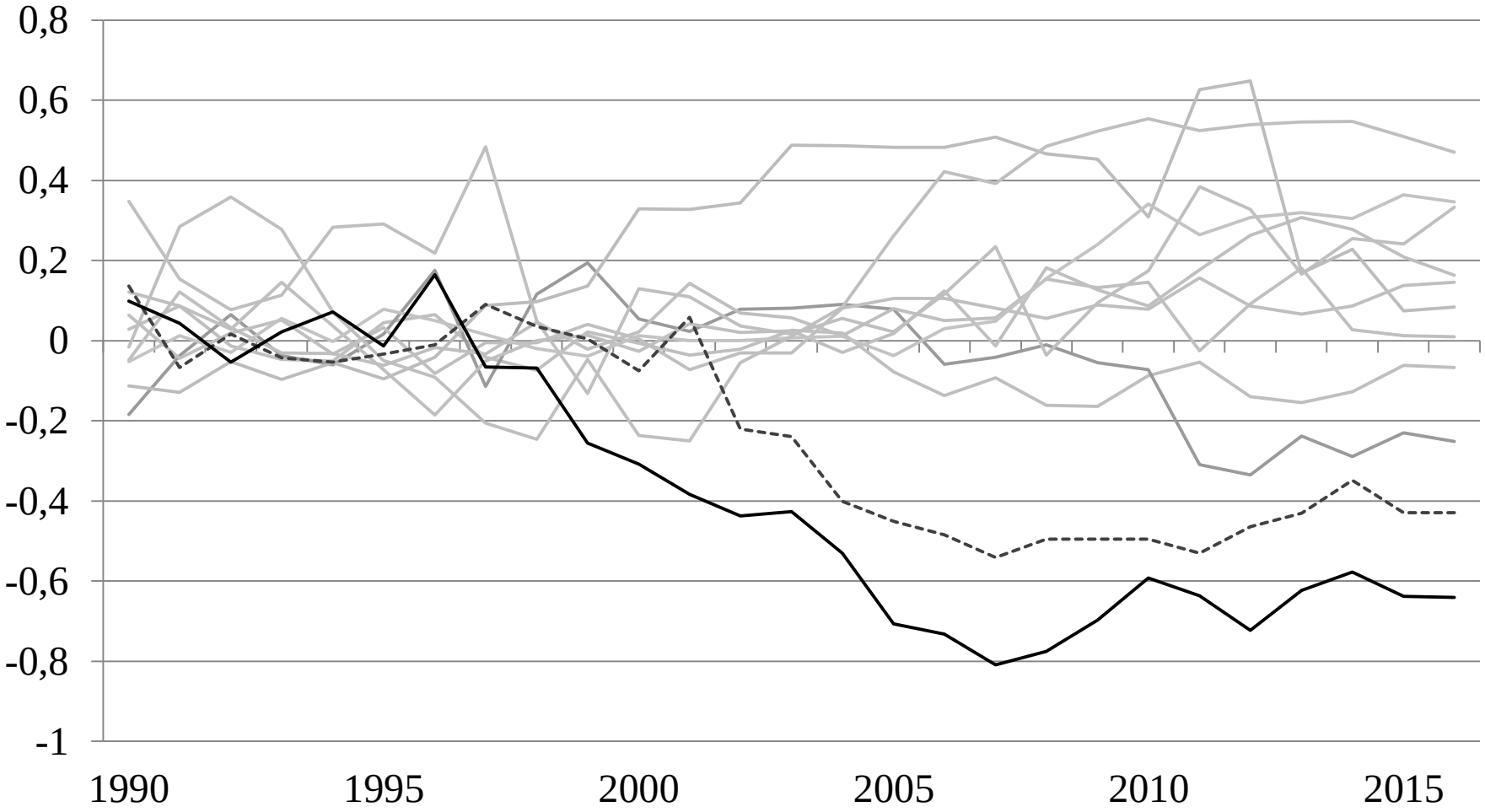
- Weaker effect: around 250kg and 300 kg CO_2 per capita

Placebo tests (sample 1)

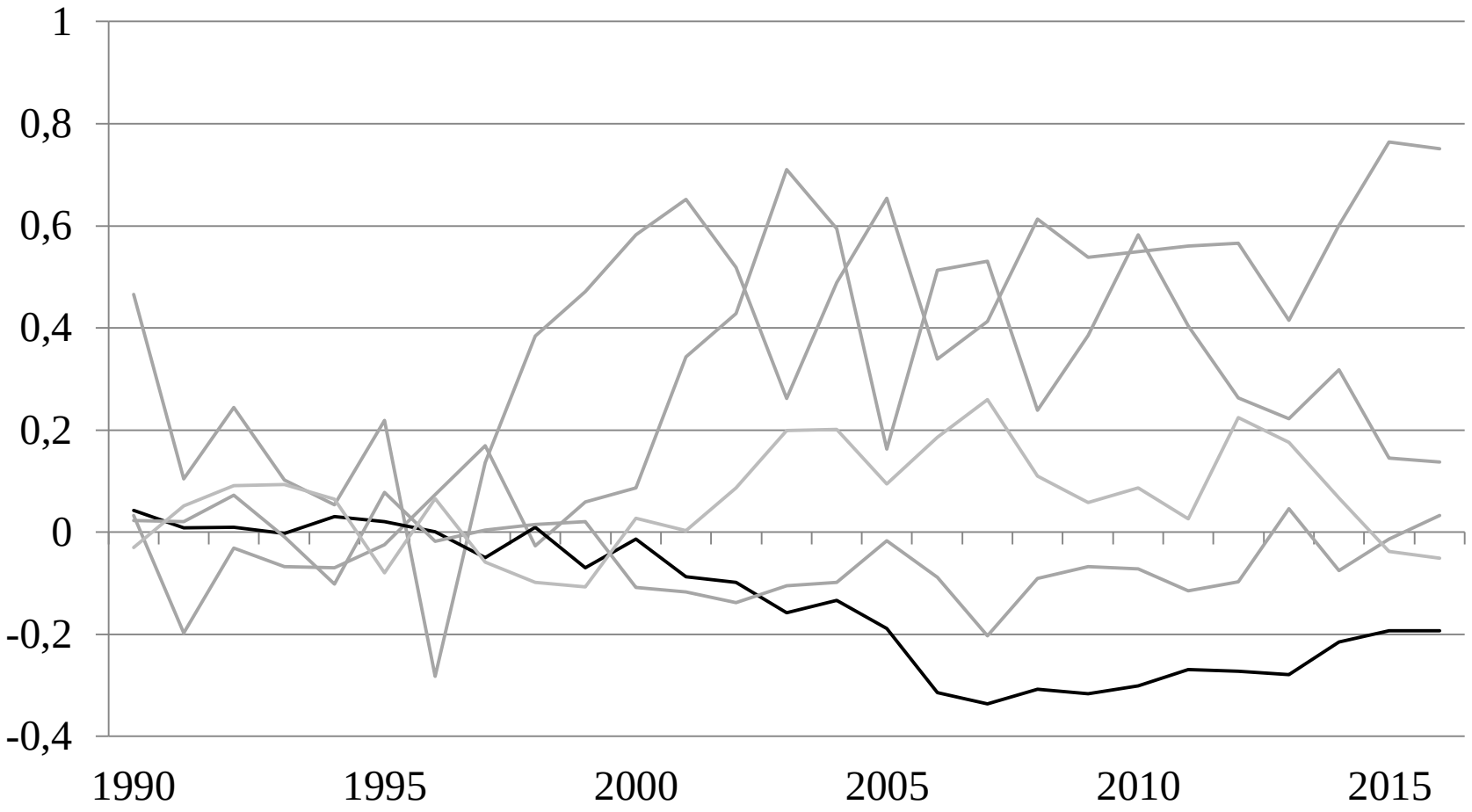


Placebo tests (sample 2)

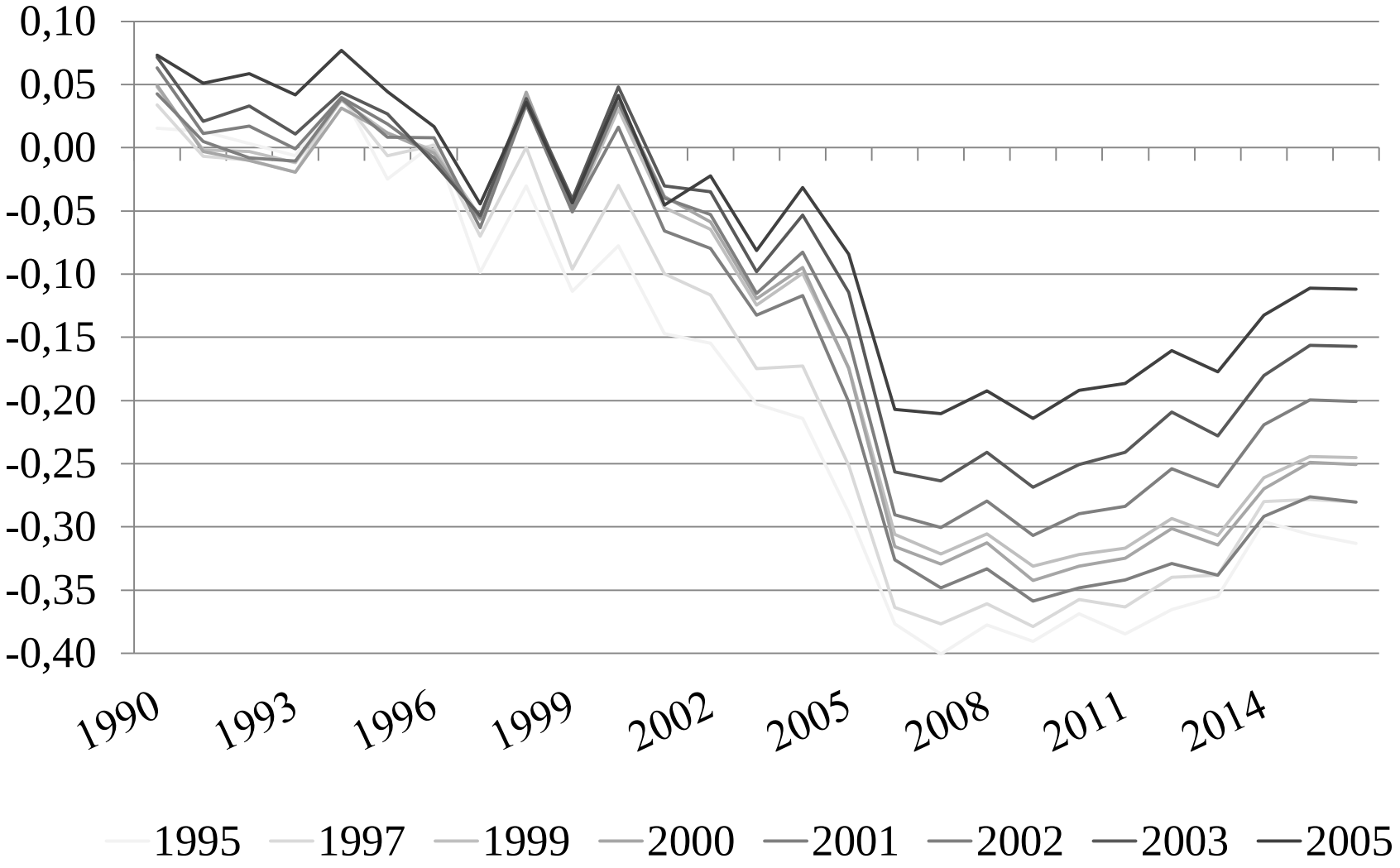
Only Sweden and Slovakia show treatment effects



Placebo tests (sample 3)



In time placebo (sample 1: all countries)



Results:

- Minimization of pre-treatment differences of the outcome variable was successful
- Strong robust effects of carbon tax augmentation on residential carbon emissions
- Effect size range from 200 to 800 kg of CO_2 per capita per year

Difference-in-differences Model

- $\frac{CO_2}{capita_{it}} = \alpha + \beta_1 dSweden_i + \bar{\beta}_2 dYear_t + \beta_3 (dB_i * dYear_t) + \sigma \bar{X}_{it} + \varepsilon_{it}$

- ***dB:*** dummy variable (1= Sweden / 0 = control group)
- ***dT:*** time dummy (0 = pre-period / 1= post-period)
- $\bar{X}_{it}$**:** vector of explanatory variables
- β_1**:** difference between treatment and control group prior to policy
- β_2**:** aggregate factors which cause changes in CO_2 /capita even in the absence of policy
- β_3**:** effect attributed to the policy

Results

	All countries	*Only non-tax countries*
treatment*1995	-0.0359	-0.0448
treatment*1996	-0.0084	0.0193
treatment*1997	-0.0844**	-0.1039**
treatment*1998	0.0154	-0.0240
treatment*1999	-0.0348	-0.0932
treatment*2000	0.0225	-0.0868
treatment*2001	-0.2128**	-0.3341**
treatment*2002	-0.2043**	-0.3348**
treatment*2003	-0.2404**	-0.3314*
treatment*2004	-0.2295*	-0.3513
treatment*2005	-0.2885**	-0.4440*
treatment*2006	-0.3606***	-0.4723**
treatment*2007	-0.3723***	-0.5251**
treatment*2008	-0.2894*	-0.4721*
treatment*2009	-0.2996**	-0.4841**
HDD	0.0003	0.0003
GDP per capita	0.0000	0.0001
GDP per capita squared	0.0000	0.0000
Constant	0.7213	0.2493
Observations	286	175

Results

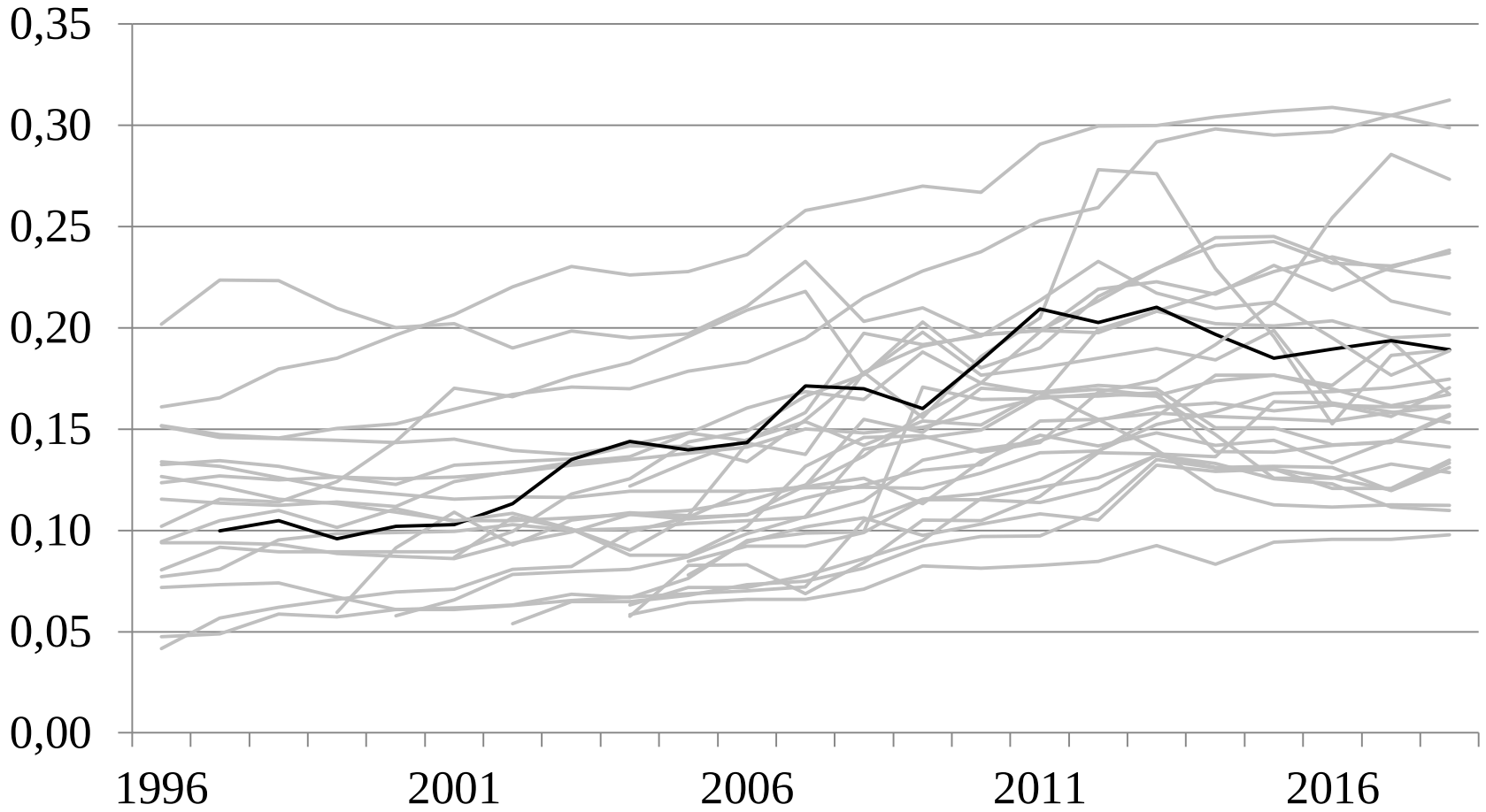
- Parallel trends assumption partially violated
- Yearly interaction terms before treatment are insignificant except for the year 1997
- Points towards negative effect of carbon taxation on carbon emissions.
- Effect sizes range between 200 and 525 kg of CO_2 per capita per year

Confounding factors

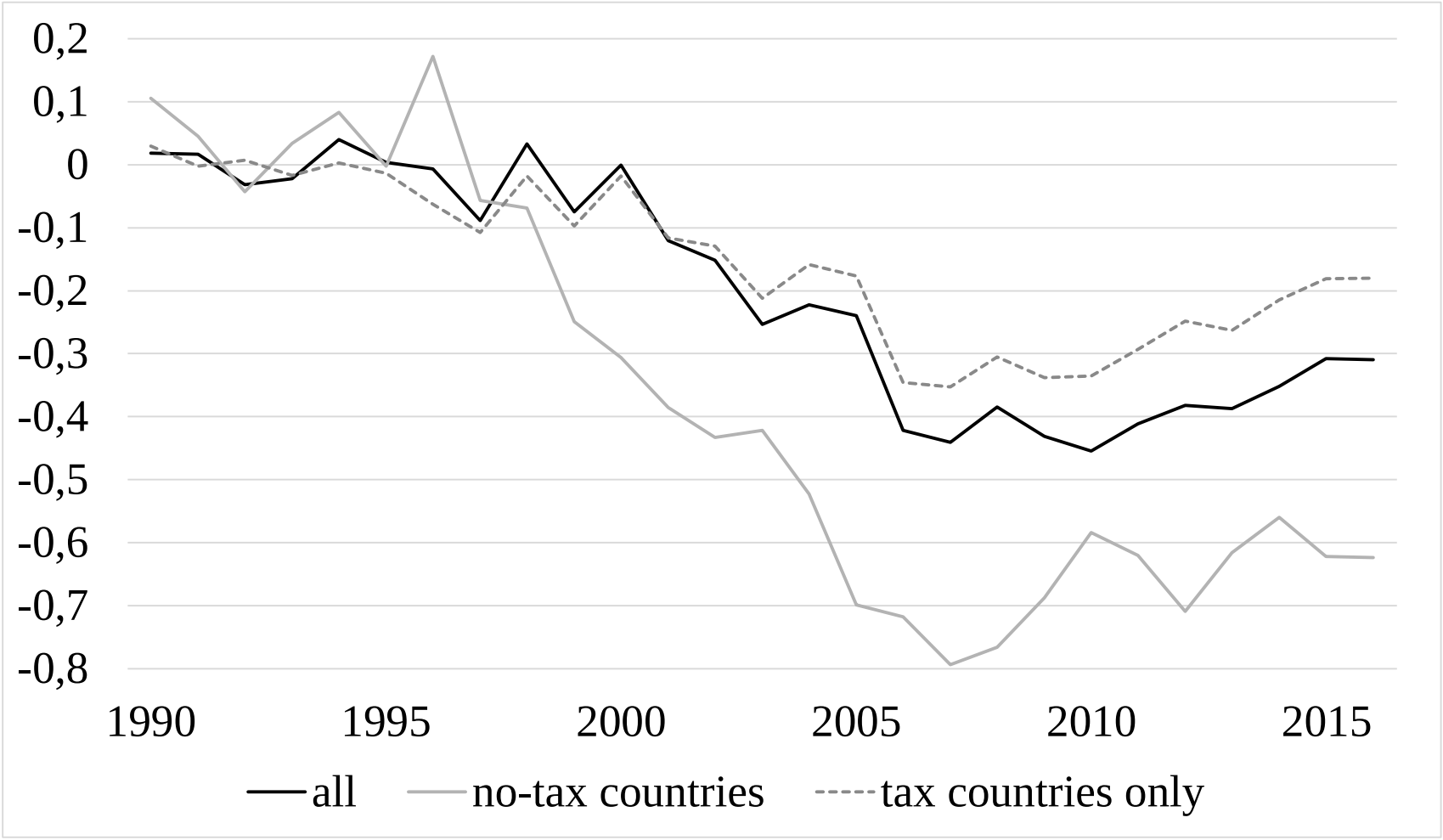
Policy	Year of implementation	Mure Impact Evaluation
Technology procurement groups	1989	Low
Energy and carbon tax (in household sector)	1991	High
Labelling of domestic appliances and windows	1995	Low
Investments grants for small scale biofuel-fired heating systems and more energy efficient windows	2006	Low
Support for conversion from direct electric heating systems in households to system based on renewable fuels, district heating, solar heating or heat pump	2006	Medium
Energy Performance of Buildings (2002/91/EC)	2008	Unknown
Investment support for photovoltaic cells	2013	Low

European Electricity Prices

Euro per Kilowatt-hour
(all taxes and levies included)



SCM including share of district heating



Summary

- Both methods: suggest evidence for possible causal relationship between carbon taxation and emission in residential sector

- Effect sizes range between
  - 200 and 800 kg of CO_2 per capita per year in SCM
  - 200 and 500 kg of CO_2 per capita per year in DiD

- Analysis of confounding factors shows that no other policy could have driven the CO_2 emissions reductions
  - Leveraging the effectiveness of the carbon tax

- Limitations
  - No clean pre-treatment period
  - Disregard low treatment intensity in pre-period
  - Overall tax effect is underestimated
  - Confounding factors on country level data

Thank you for your attention!

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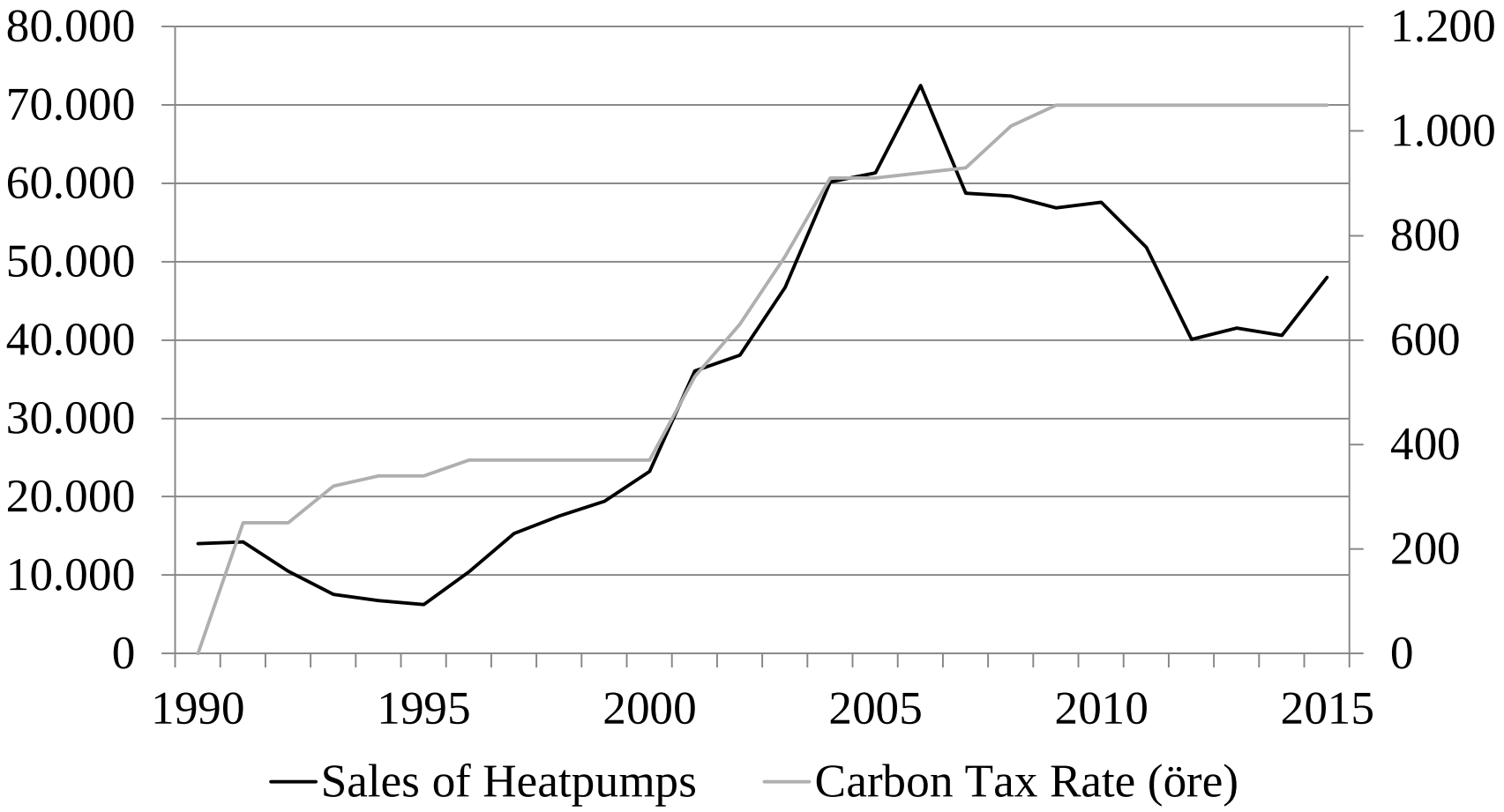
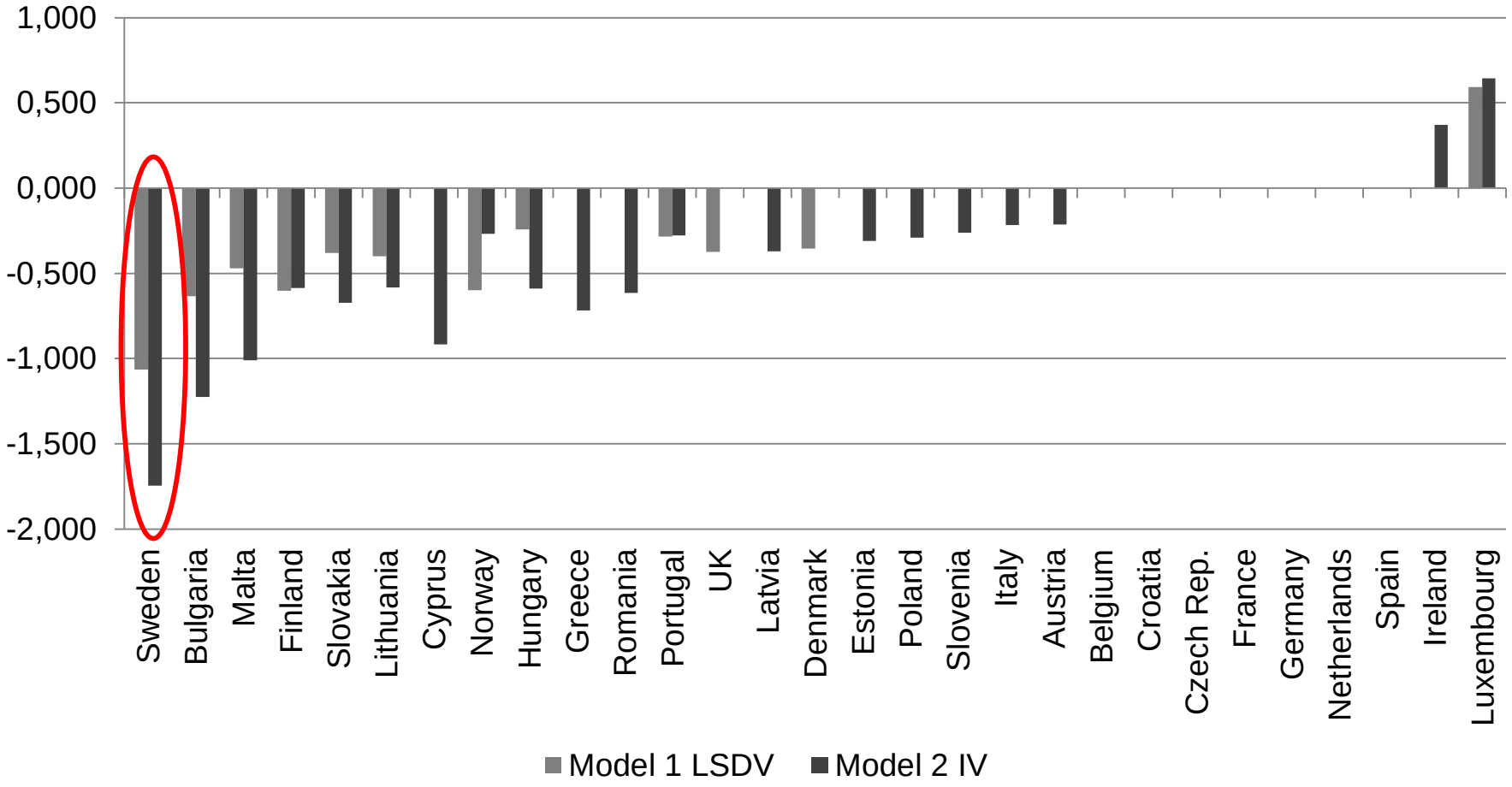
Appendix

Annual Sales of Heatpumpts

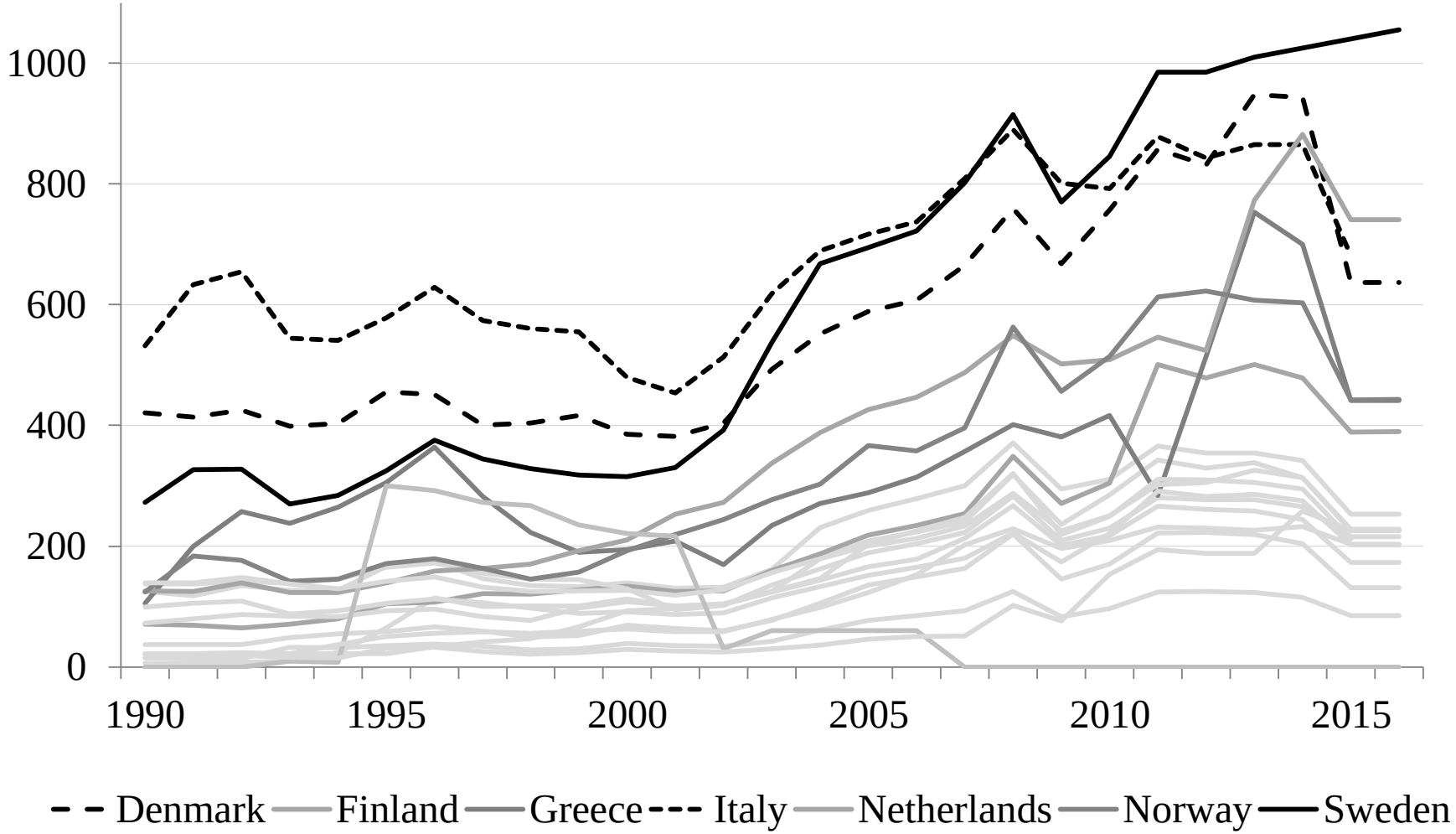


Background

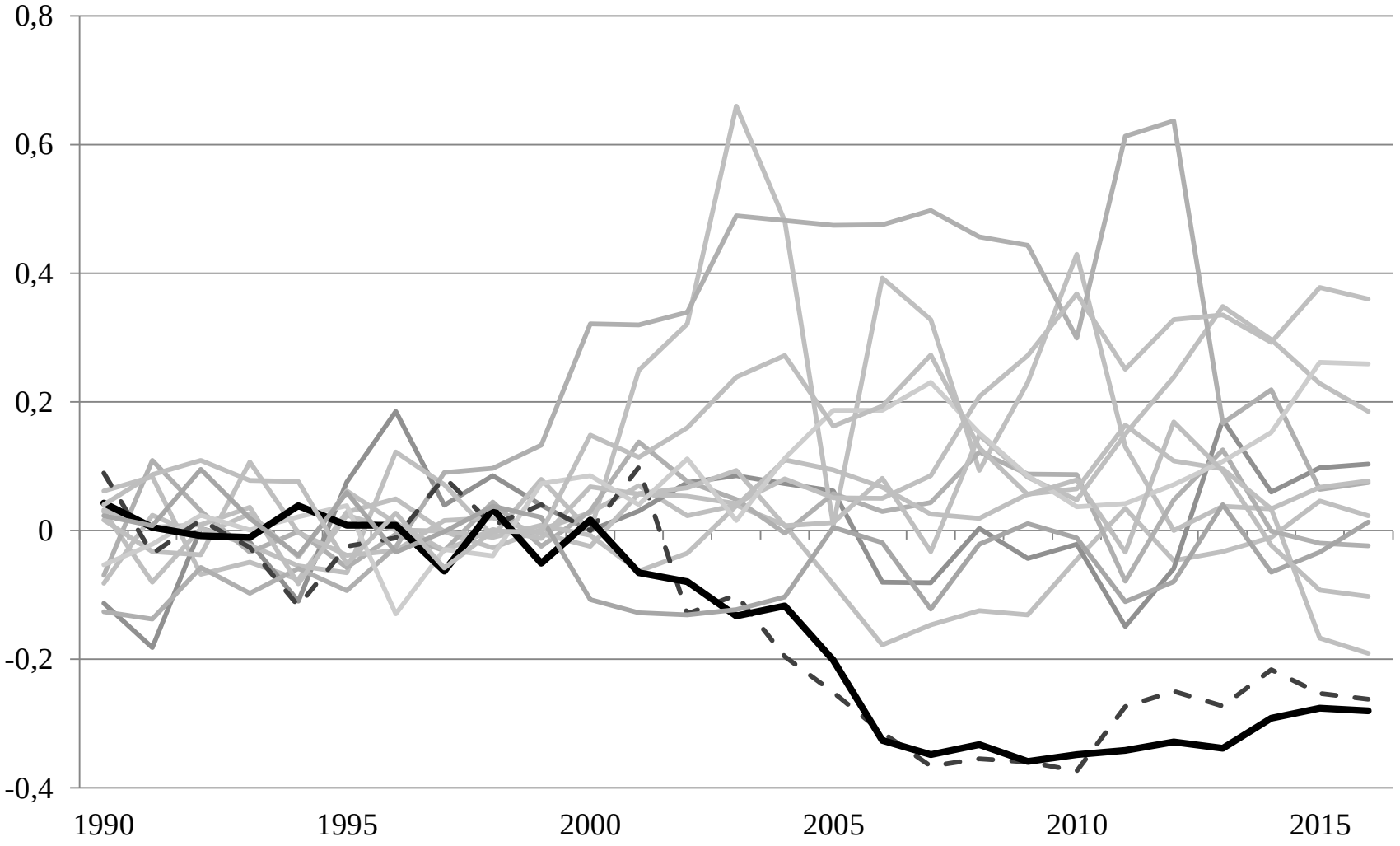


Source: Thonipara et al. 2019

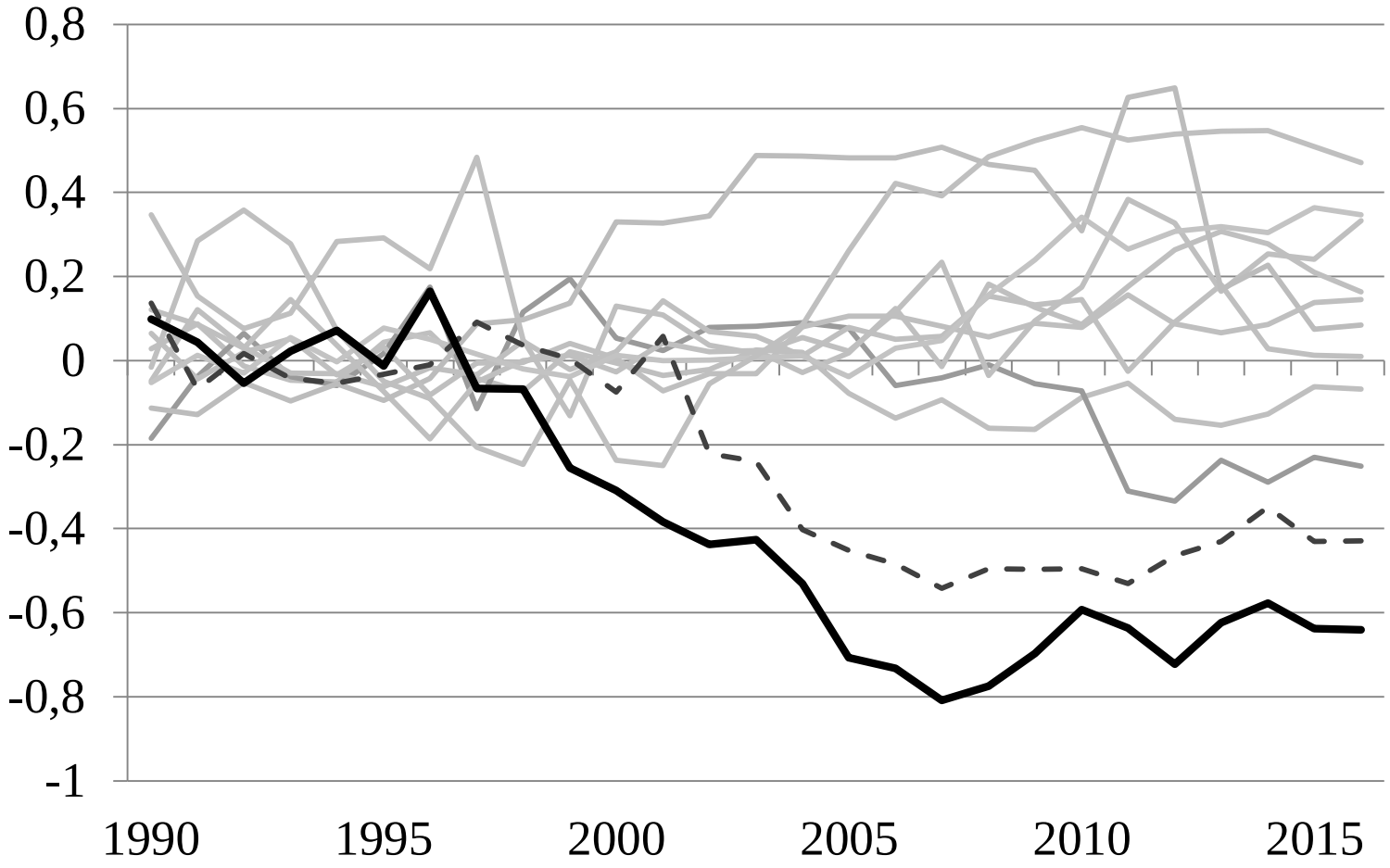
„problematic“ countries



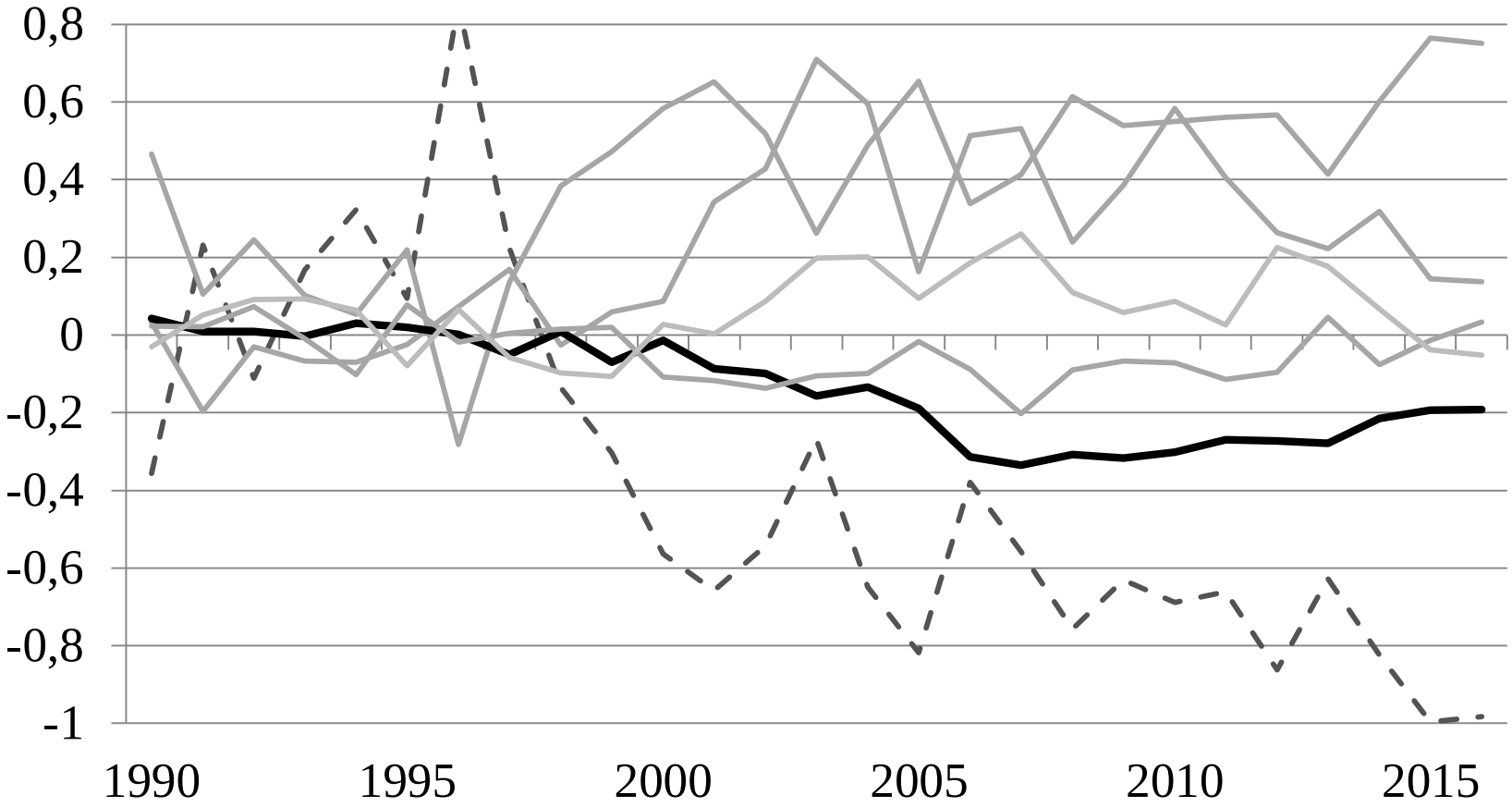
Placebo Tests (sample 1)



Placebo Test (sample 2)



Placebo Test (sample 3)



Difference in Difference Regression

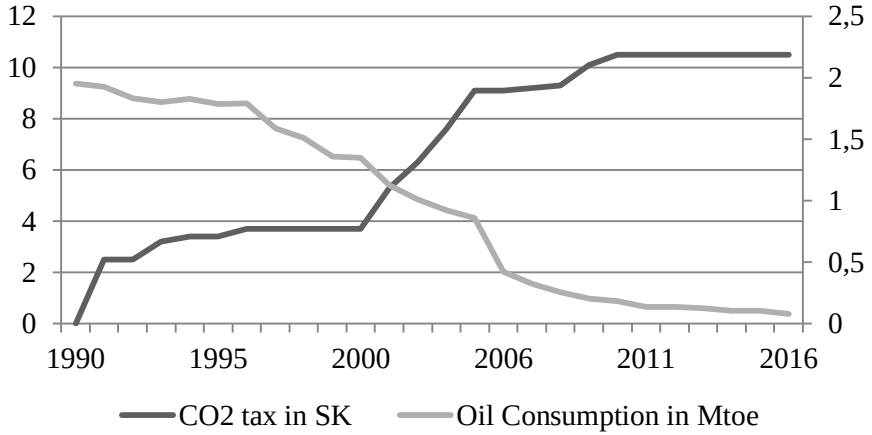
- Paneldaten 1990-2016
- CO2 Emissionen
- Starke Erhöhung 2001

$$CO_2/capita_{it} = \alpha + \beta_1 * Sweden_i + \beta_2 Year_t + \beta_3 (Sweden_i * Year_{)t} + \sigma \bar{X}_{it} + \varepsilon_i$$

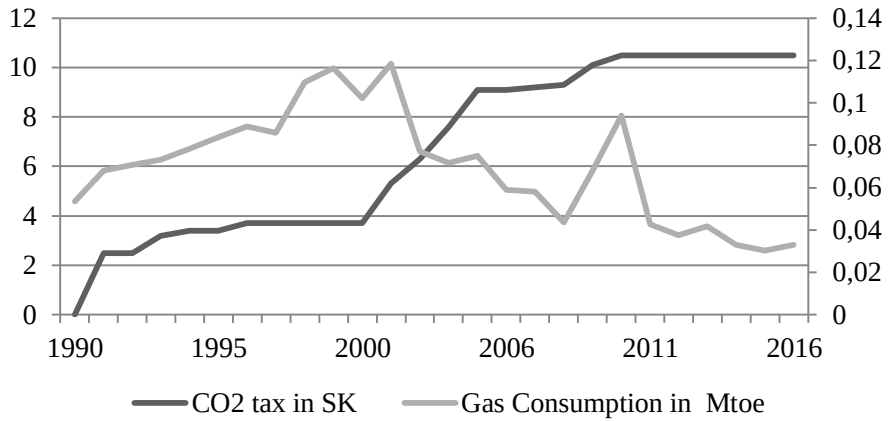
- Zeigt starke Korrelation aber:
- Parallel trends assumption teilweise verletzt
  - Deshalb keine kausale Aussage möglich

Consumption Patterns

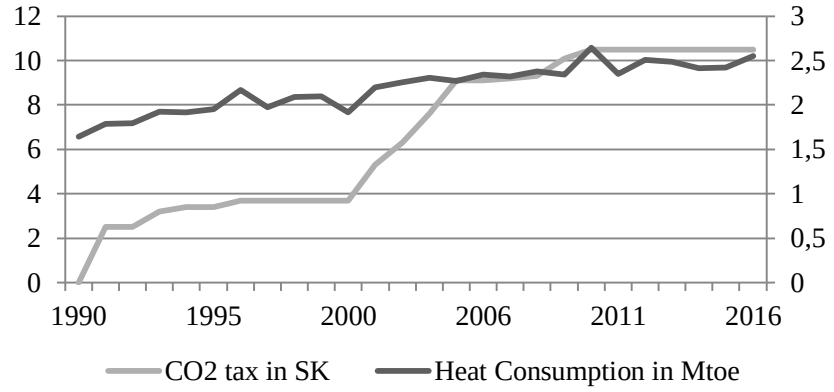
Oil



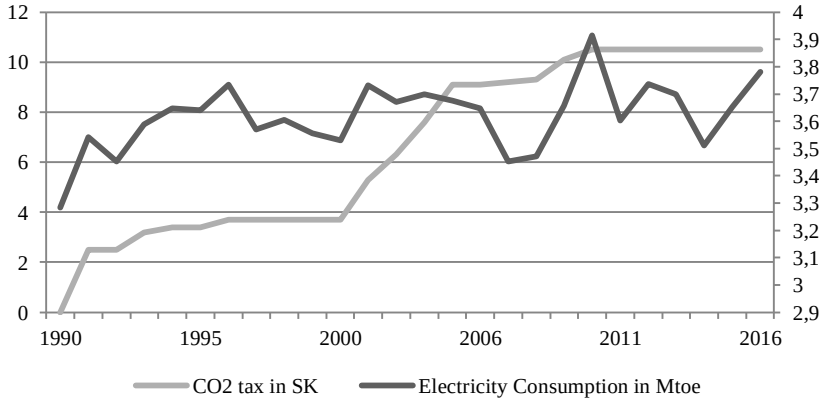
Gas



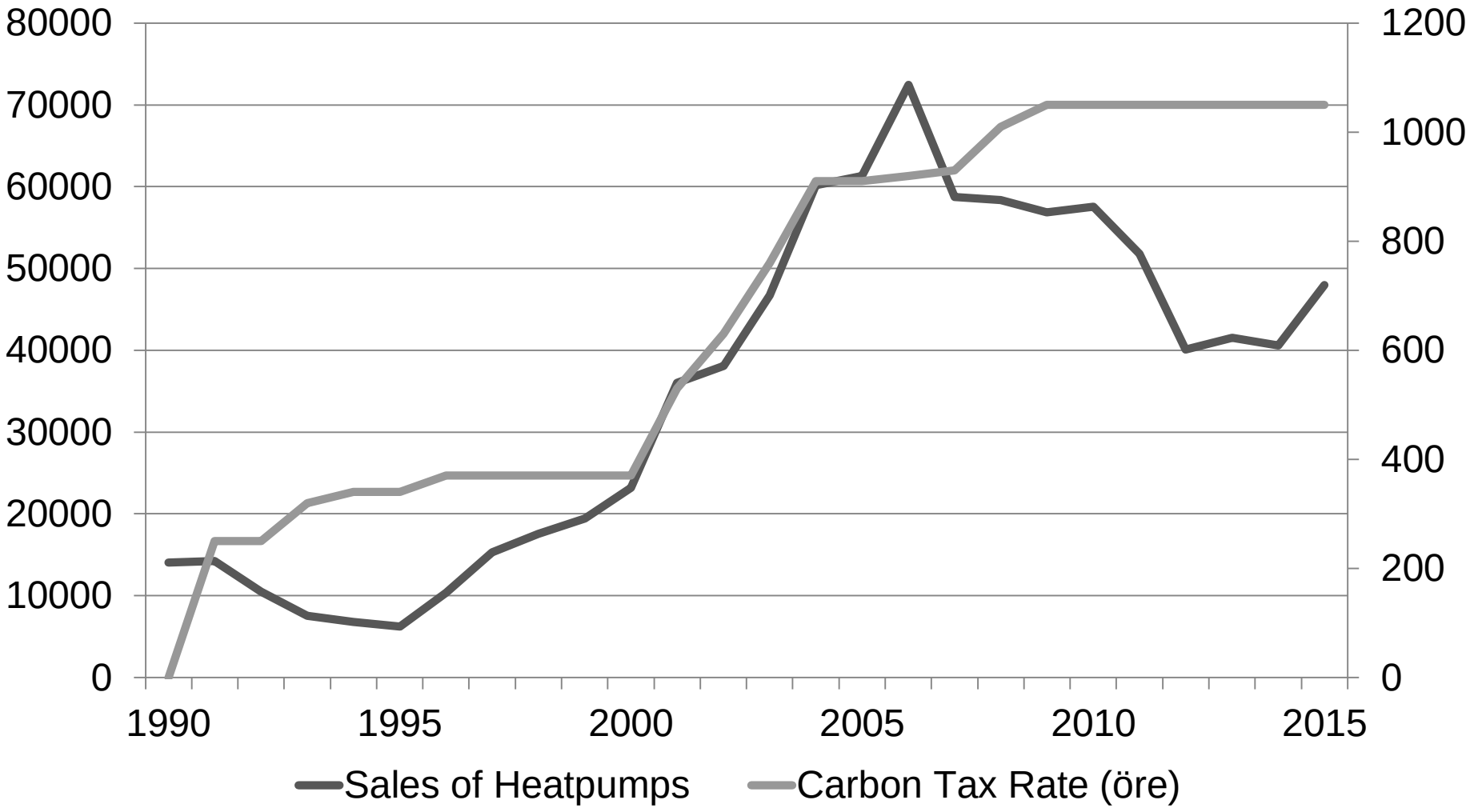
District Heating



Electricity



Investments in more efficient technologies



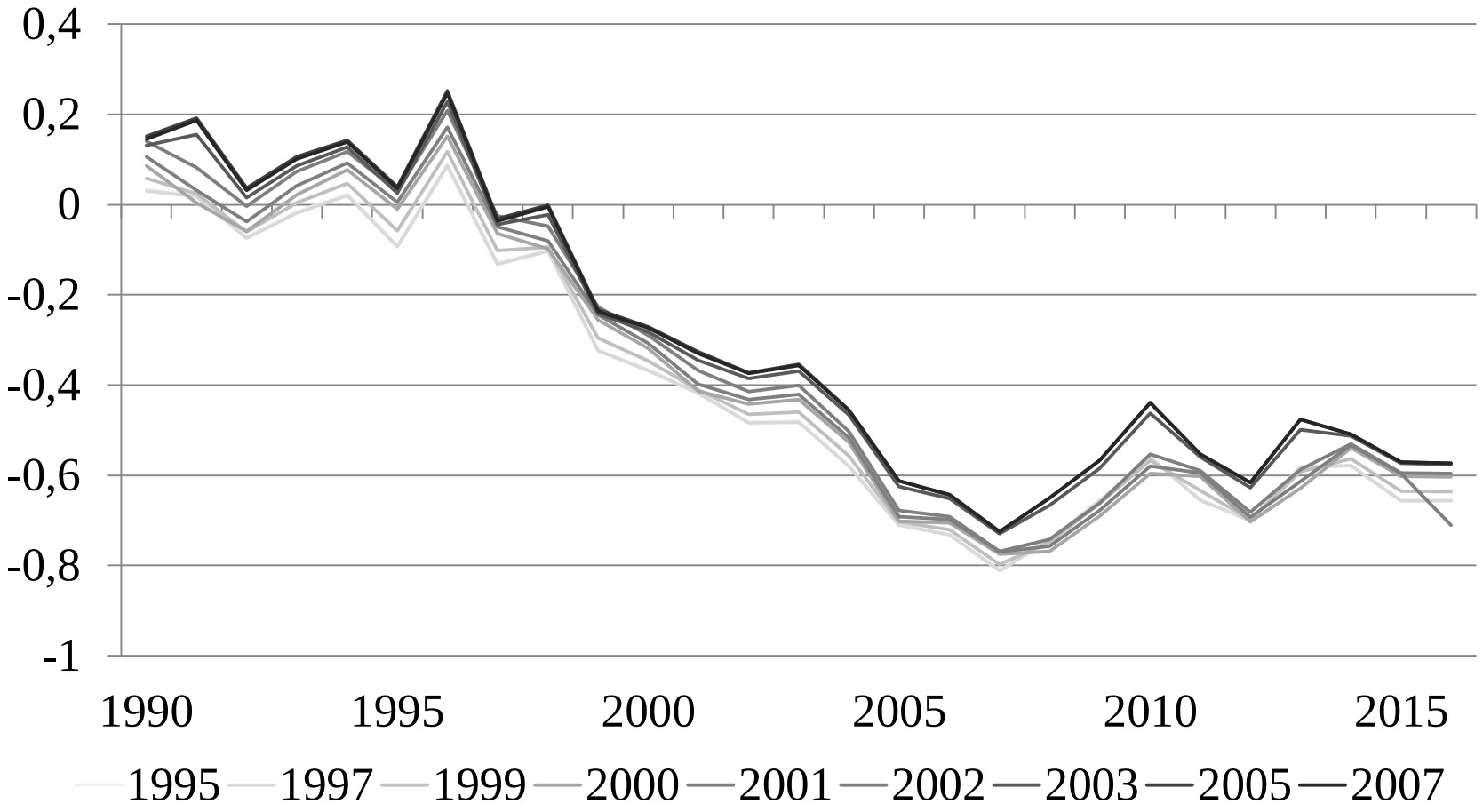
Research Purpose

- Which instruments are most efficient in reducing residential CO2 Emissions?

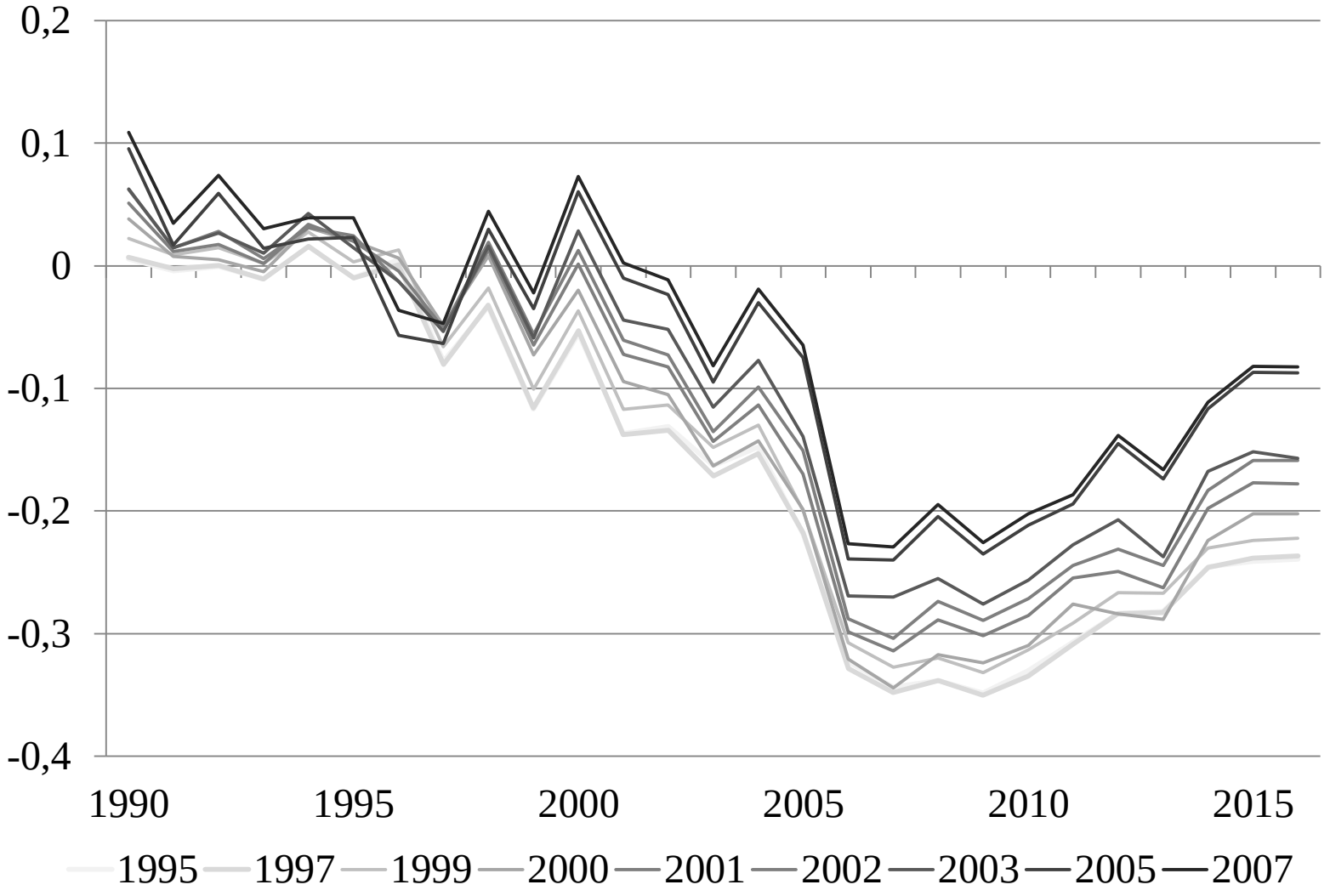
- Literature:
  - Regulatory Measures
  - Informative Measures
  - Financial Incentives

  - Carbon Taxation ???
    - *Not on residential carbon emissions: Lin / Li 2011*

In time placebo (sample 2: no carbon tax countries)



In time placebo (sample 3: carbon tax countries)



Development of energy carriers specific consumption in the Swedish residential sector