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Richmond Fed Conference on Climate Change Economics

The Macroeconomic Impact of Europe's Carbon Taxes

NBER WP 27488, July 2020

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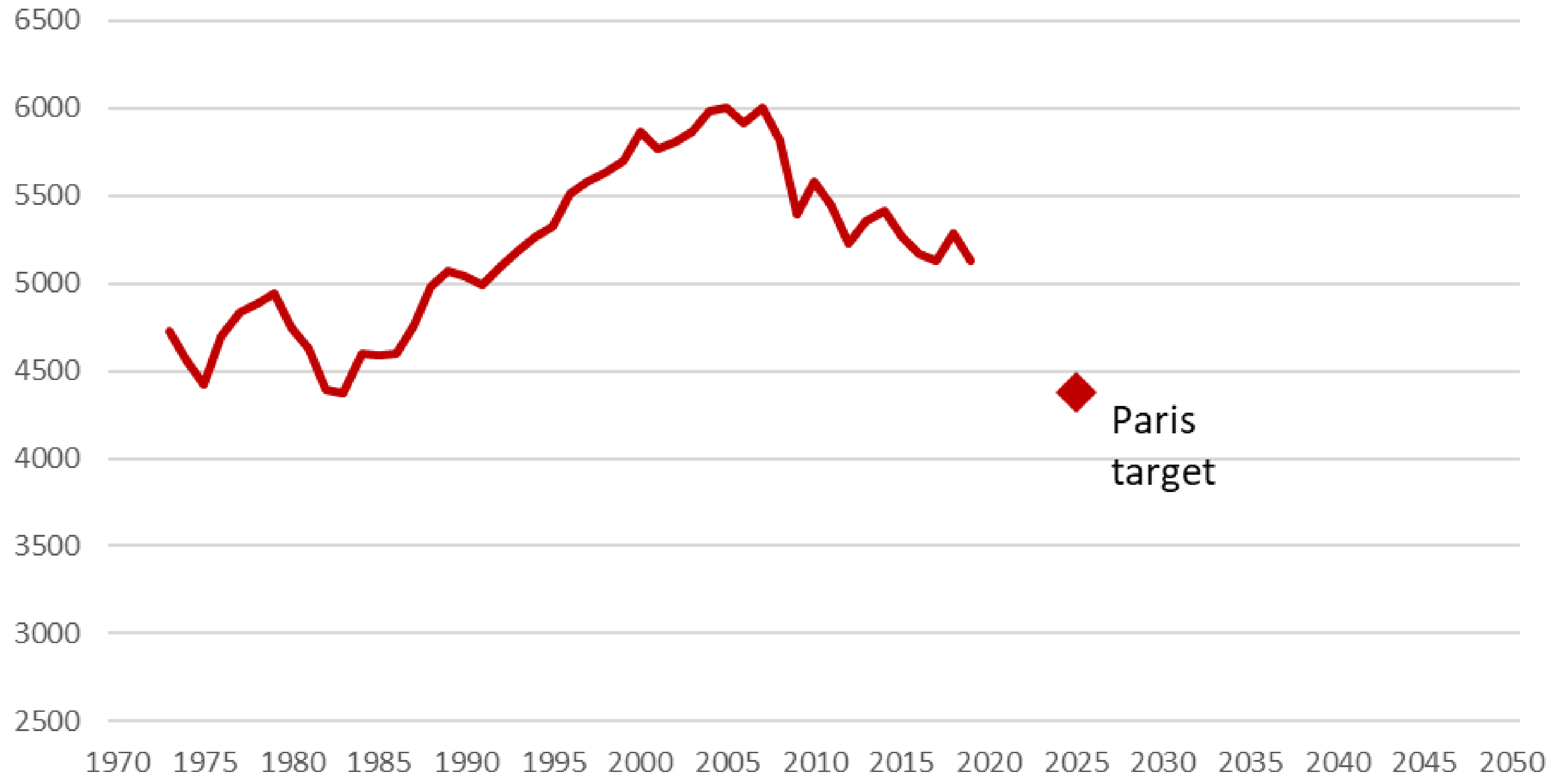
US CO2 emissions: US Energy Information Administration projections (pre-COVID-19)

The switch from coal to natural gas and, now, renewables for electricity production has driven emissions reductions…



Source: Energy Information Administration, *Monthly Energy Review* (June 2020) and 2020 *Annual Energy Outlook*, reference case.

US CO2 emissions: US Energy Information Administration projections (pre-COVID-19)

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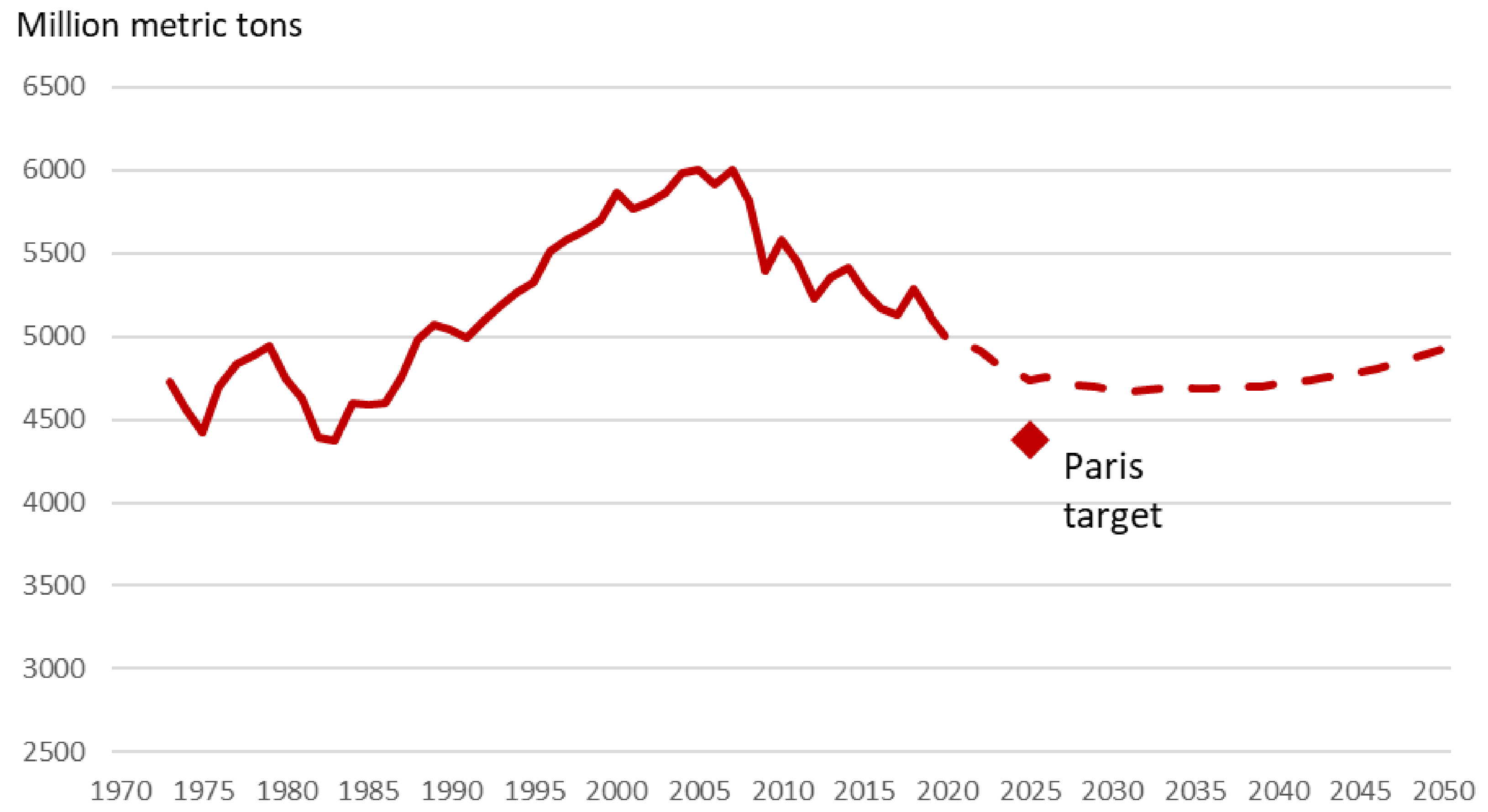


Source: Energy Information Administration, *Monthly Energy Review* (June 2020) and 2020 *Annual Energy Outlook*, reference case.

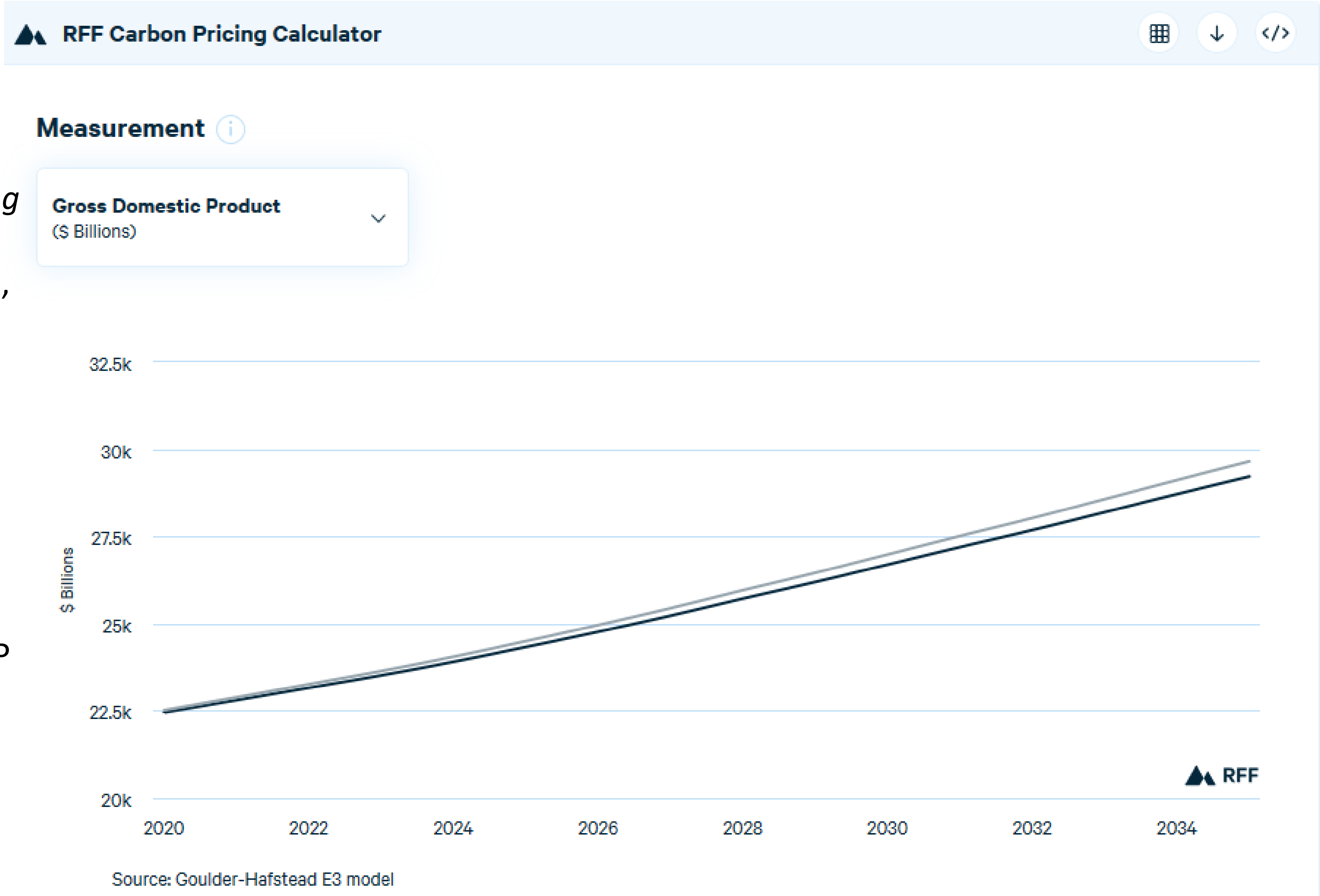
But we have a long ways to go.

Lots of policy proposals!
.. but the economists love a **carbon tax**.

Impacts of a carbon tax: theory

1. Computable general equilibrium models
   a) GDP effect (e.g. Goulder and Hafstead, *Confronting the Climate Challenge* (2018); Jorgenson (2013), etc.; [RFF Carbon Pricing Calculator](https://www.rff.org/cpc/)

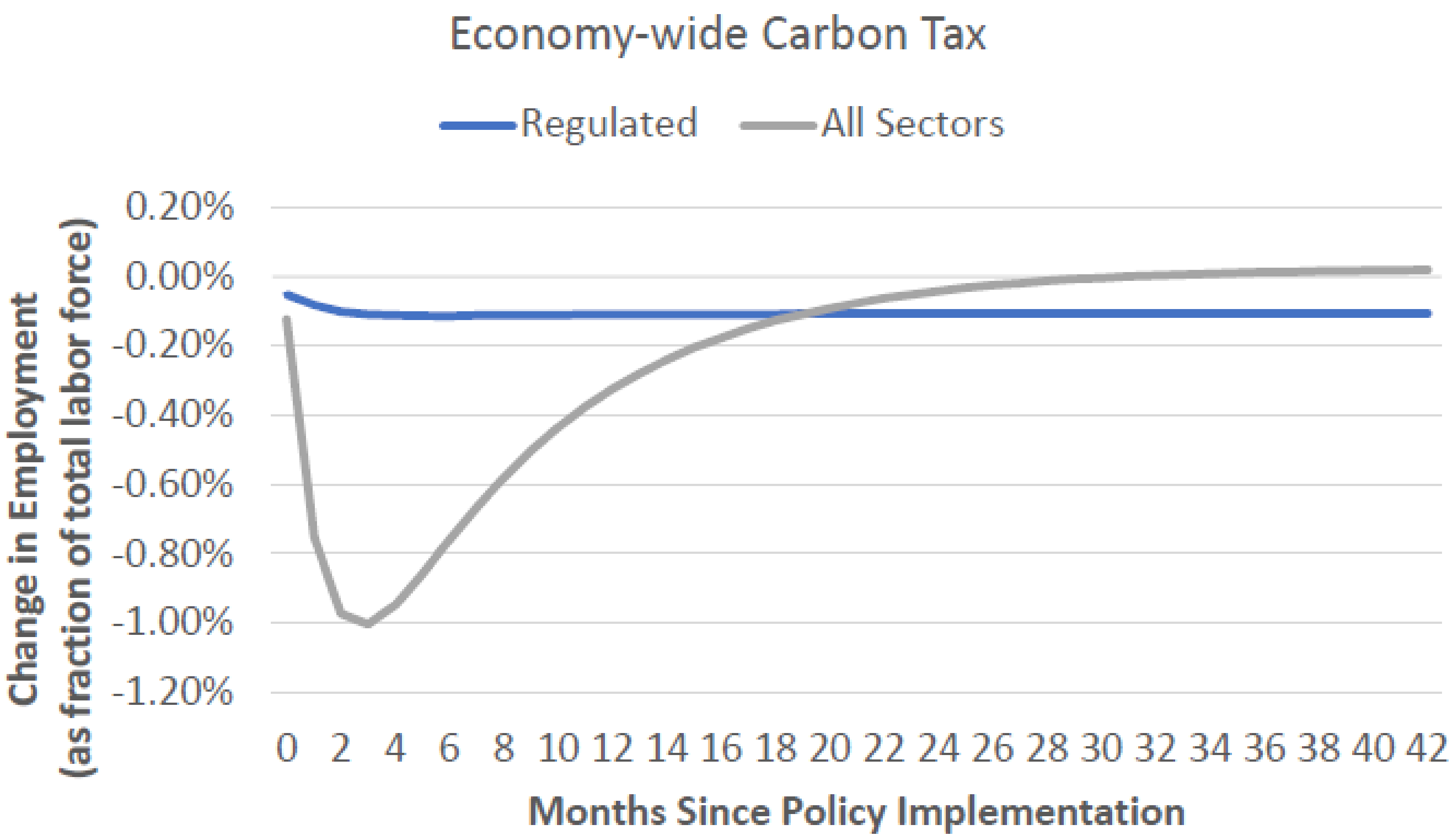
- **Parallel shift down**
- Importance of revenue recycling method
- Example:
  Tax of $40/ton @5%/year GDP loss in 2035 =
  -1.5% (tax & dividend)
  -1.2% (payroll tax cut)



Source: RFF Carbon Pricing Calculator at https://www.rff.org/cpc/

Impacts of a carbon tax: theory

1. Computable general equilibrium models
   a) GDP effect (e.g. Goulder and Hafstead, *Confronting the Climate Challenge* (2018); Jorgenson (2013), etc.
   b) **Employment effect: Hafstead and Williams, NBER EEPE, (2019)**



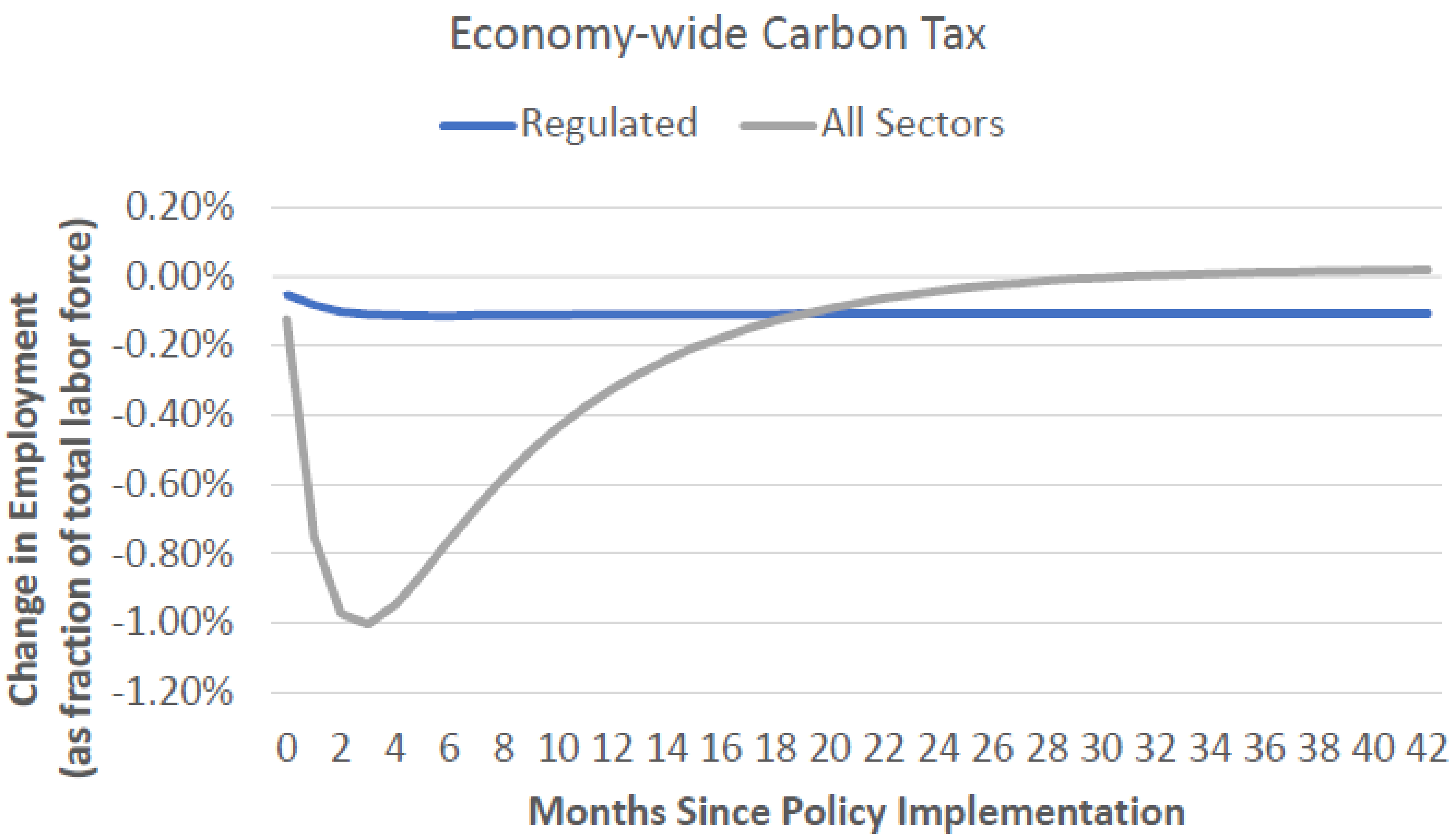
Source: Hafstead and Williams (2019, Fig. 1)

Impacts of a carbon tax

1. Computable general equilibrium models
   a) GDP effect (e.g. Goulder and Hafstead, *Confronting the Climate Challenge* (2018); Jorgenson (2013), etc.
   b) Employment effect: Hafstead and Williams, NBER EEPE, (2019)

2. **NEMS and IAMS**
   - Weak or nonexistent macro modules

Survey: Metcalf (*BPEA*, 2019)



Source: Hafstead and Williams (2019, Fig. 1)

Impacts of a carbon tax: Empirical evidence

A fair number of studies examine carbon tax effect on emissions: partial list

Lin and Li (2011) – Scandinavia + Netherlands
Rivers and Schaufele (2012) – BC transportation emissions
Murray and Rivers (2015) – review of older literature on BC carbon tax
Haites et. al. (2018) – carbon pricing generally, effectiveness and political economy
Dolphin, Pollitt, and Newberry (2019) – political economy of carbon tax rates (not effectiveness)
Pretis (2019) – BC
Andersson (2019) – Sweden (carbon tax + VAT on fuel)
Runst and Thonipara (2019) – Swedish residential sector
Hajek et al (2019), energy sector emissions (SWE, FIN, DNK, IRE, SLO)
He at al (2019) OECD environmental taxes
Fauceglia et al. (2019) – Swiss industry
Abrell et al. (2019) – UK Carbon Price Support on top of EU-ETS, plant-level
Rafaty, Dolphin, Pretis (2020) - OECD

Fewer study the effect on GDP and employment

Elgie and McClay (2013) – BC income
Yamazaki (2017), Yip (2018) – BC employment
Metcalf (2015, 2019) – BC (2015) and EU (2019)
Bernard et. al. (2018) – BC carbon tax and provincial income (VAR on with-tax fuel price)
Olale et. al. (2019) – BC carbon tax and net farm income
Mundaca (2017) – eliminating fuel tax subsidies in Middle East/North Africa

This paper: Evidence from Europe

Data set:

- EU + Iceland + Norway + Switzerland (n = 31) – all countries in the European emissions trading system
  - Of which, 15 also have a carbon tax, almost entirely on emissions not covered by the ETS
- Annual, 1985 - 2018
  - EU ETS started in 2005 (power sector and certain energy-intensive industries) (subsequently expanded to aviation)

Sources:

- Carbon prices: World Bank (new carbon price data)
  - Carbon tax rates are real local currency, scaled to 2018 USD using 2018 PPP
  - Some countries have multiple tax rates, WB data set has highest and lowest rate and fuels to which it applies; we used the highest rate (typically this is the rate on gasoline & diesel)
  - Weighted for coverage of tax
  - Sensitivity check with new data from Dolphin et al (2020)
- GDP, population: World Bank except
  - Norway – we use mainland GDP
  - Ireland – we use Ireland official statistics
- Employment: Eurostat
- Fuel prices and fuel taxes: IEA
- Emissions: Eurostat; Dolphin et al (2019)
  - emissions in road transport, commercial & institutional, and household sectors
  - Alternatively, emissions from fuel consumption

Data description

Carbon taxes in 2018

Source: World Bank

https://carbonpricingdashboard.worldbank.org/

Country	Year of Adoption	Rate in 2018 (USD)	Coverage (2019)
Finland	1990	$70.65	0.36
Poland	1990	0.16	0.04
Norway	1991	49.30	0.62
Sweden	1991	128.91	0.40
Denmark	1992	24.92	0.40
Slovenia	1996	29.74	0.24
Estonia	2000	3.65	0.03
Latvia	2004	9.01	0.15
Switzerland	2008	80.70	0.33
Ireland	2010	24.92	0.49
Iceland	2010	25.88	0.29
UK	2013	25.71	0.23
Spain	2014	30.87	0.03
France	2014	57.57	0.35
Portugal	2015	11.54	0.29

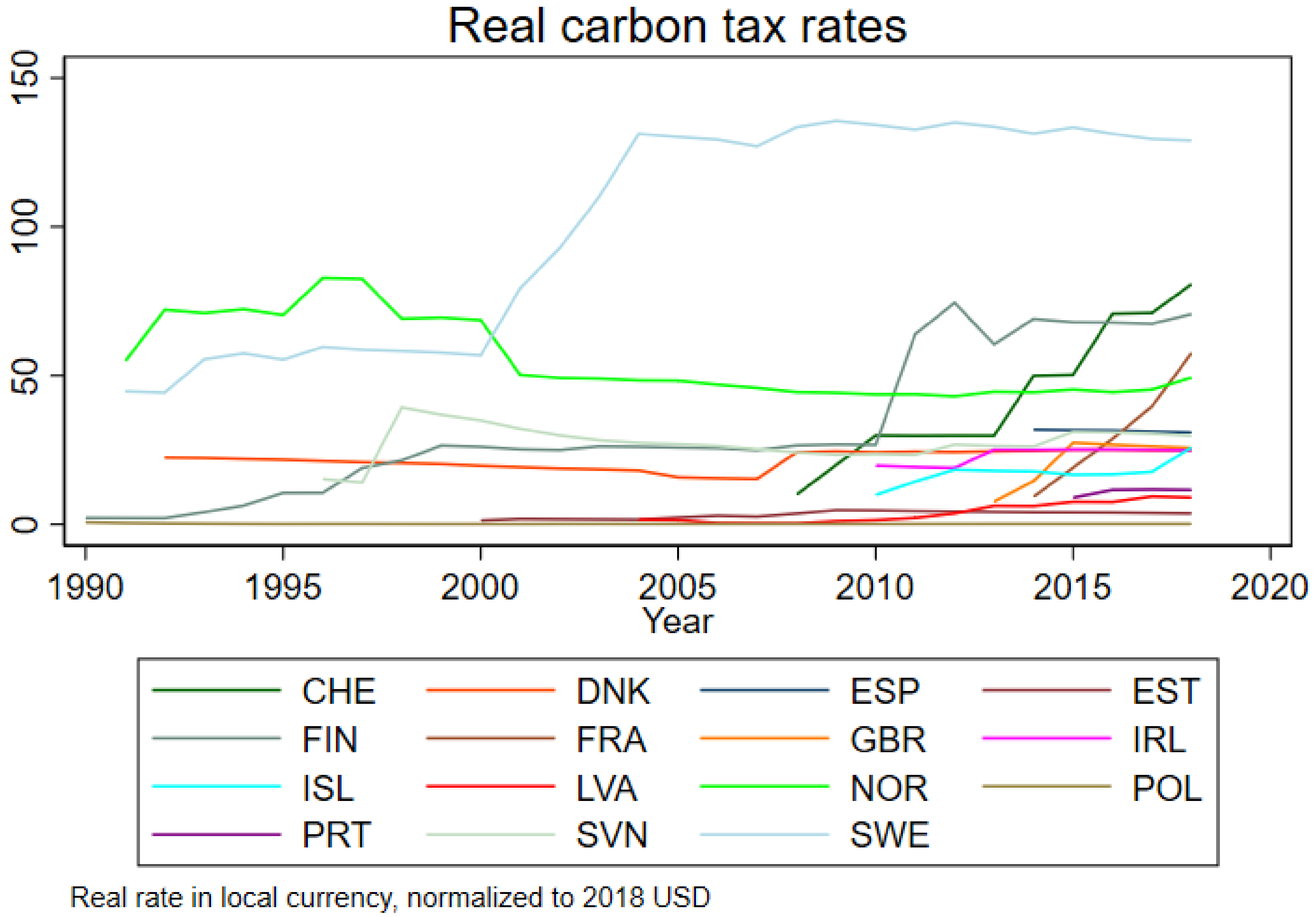
Data description

Carbon tax history for the 15 countries with carbon taxes

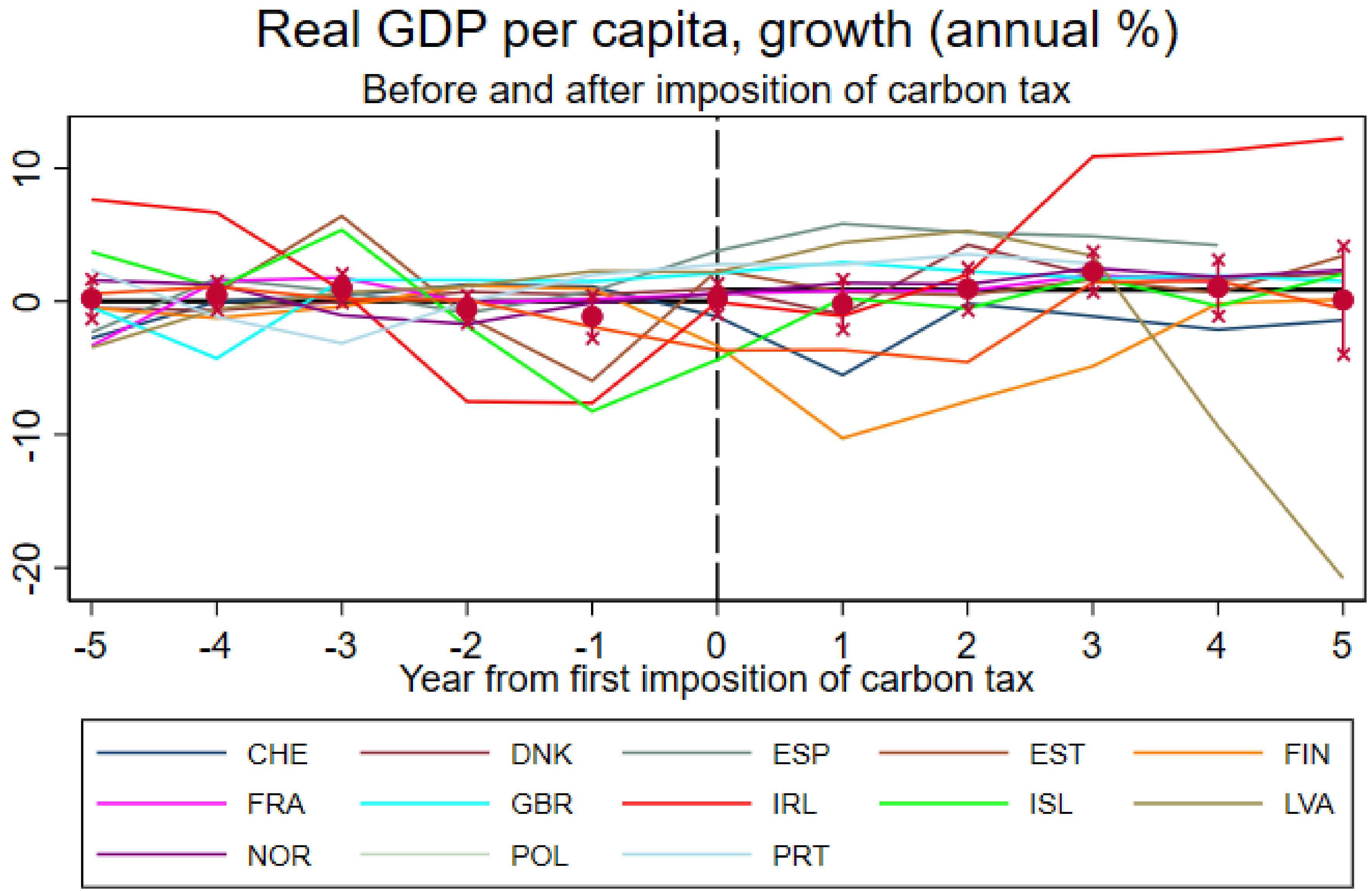
Data source: World Bank (carbon price data in press)

Carbon tax rates are real local currency, scaled to 2018 USD using 2018 PPP

GDP growth: World Bank (except as noted below)

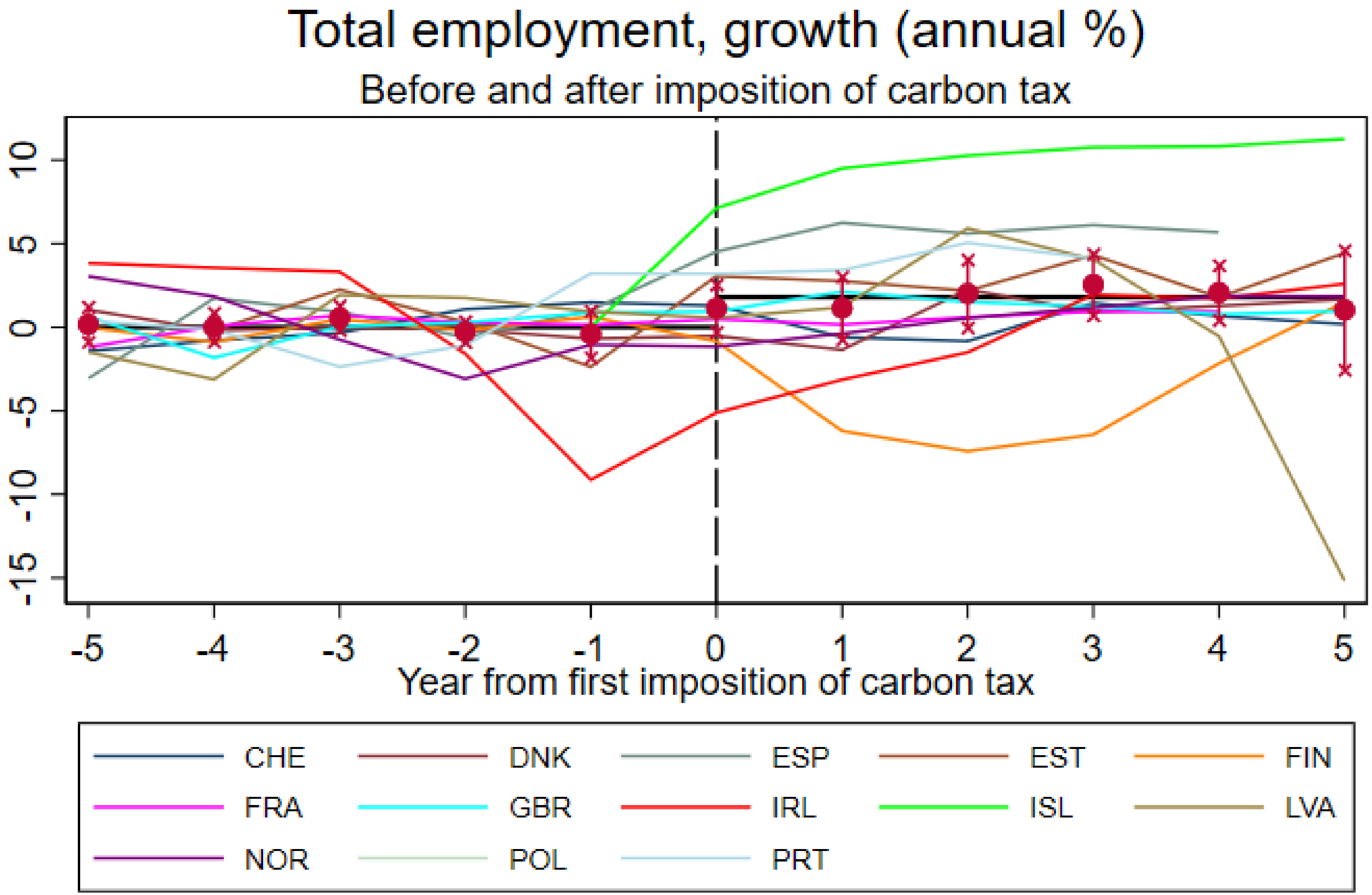


Data description



Deviated from country's pre-tax mean. Horizontal lines are pre/post means.
Dots and bars denote mean and 90% confidence interval by year.

Data description



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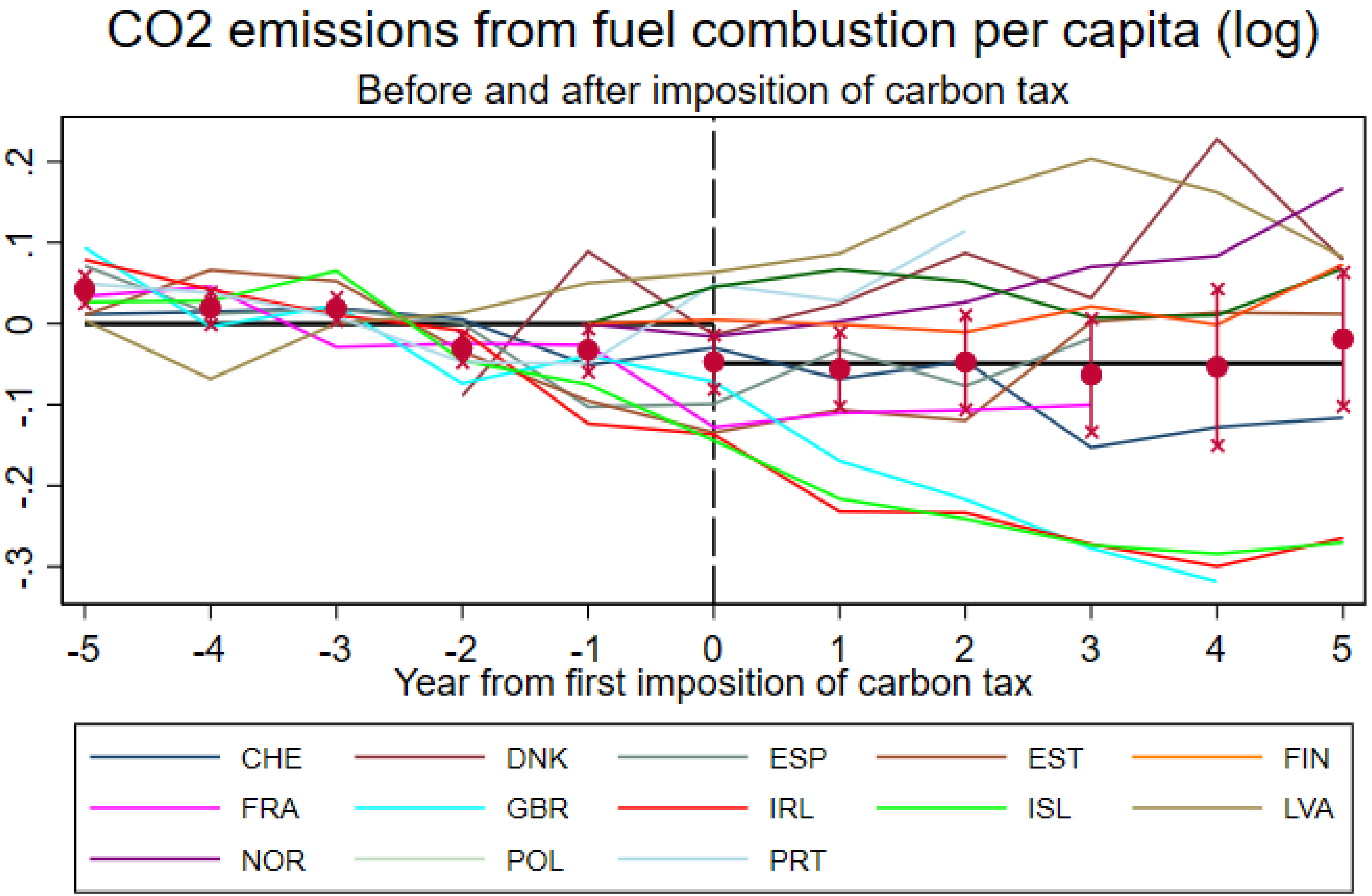


Deviated from country's pre-tax mean. Horizontal lines are pre/post means.
Dots and bars denote mean and 90% confidence interval by year.

Methods: Regressions and identifying assumptions

- Estimand: cumulative dynamic causal effect of change in tax rate on real variables
- Two methods, one exogeneity condition (identifying assumptions)

Local projections (panel)

$$\ln(GDP_{t+h} / GDP_{t-1}) = \Theta_{yx,h}\tau_t + \beta(\mathrm{L})\tau_{t-1} + \delta(L)\Delta\ln(GDP_{t-1}) + \gamma(\mathrm{L})W_t + u_t$$

Exogeneity condition:

$$E\left(u_t \mid \tau_t, \tau_{t-1}, \ldots, \Delta\ln(GDP_{t-1}), W_t, W_{t-1}, \ldots\right)$$
$$= E\left(u_t \mid \tau_{t-1}, \tau_{t-2}, \ldots, \Delta\ln(GDP_{t-1}), W_t, W_{t-1}, \ldots\right)$$

Note: $\Theta_{yx,h}$ *is h-period ahead cumulative impulse response function in VAR jargon*

Panel VAR: Same identifying assumption as LP

Restricted or unrestricted: Impose zero long-run effect on growth (restricted), or not (unrestricted)

Identification is coming from the time series variation: *think "SVAR", not "event study"*

Methods: Odds and end

Odds and ends

- All regressions include country & year fixed effects
- Carbon tax enters weighted by coverage share
- Standard errors: heteroskedasticity-robust for SVAR and LP (Plagborg-Møller and Wolf (2019))
- Effects calibrated to $40 carbon tax at 0% real increase
  - Tax innovations in are solved from IRF of tax shock to tax rate IRF (Sims (1986) method)
- 4 lags of control variables used (base case) (BIC selects 2, AIC selects 4 in VAR)

Results: Tests of parallel paths restriction

***t*-statistics** testing long-run effect of change carbon tax *level* on the *growth rate* of $y = 0$
(p-values in second line)

- For SVAR, this is implied long-run IRF
- For LP, this is 8-year effect

➢ Fail to reject "parallel paths" restriction

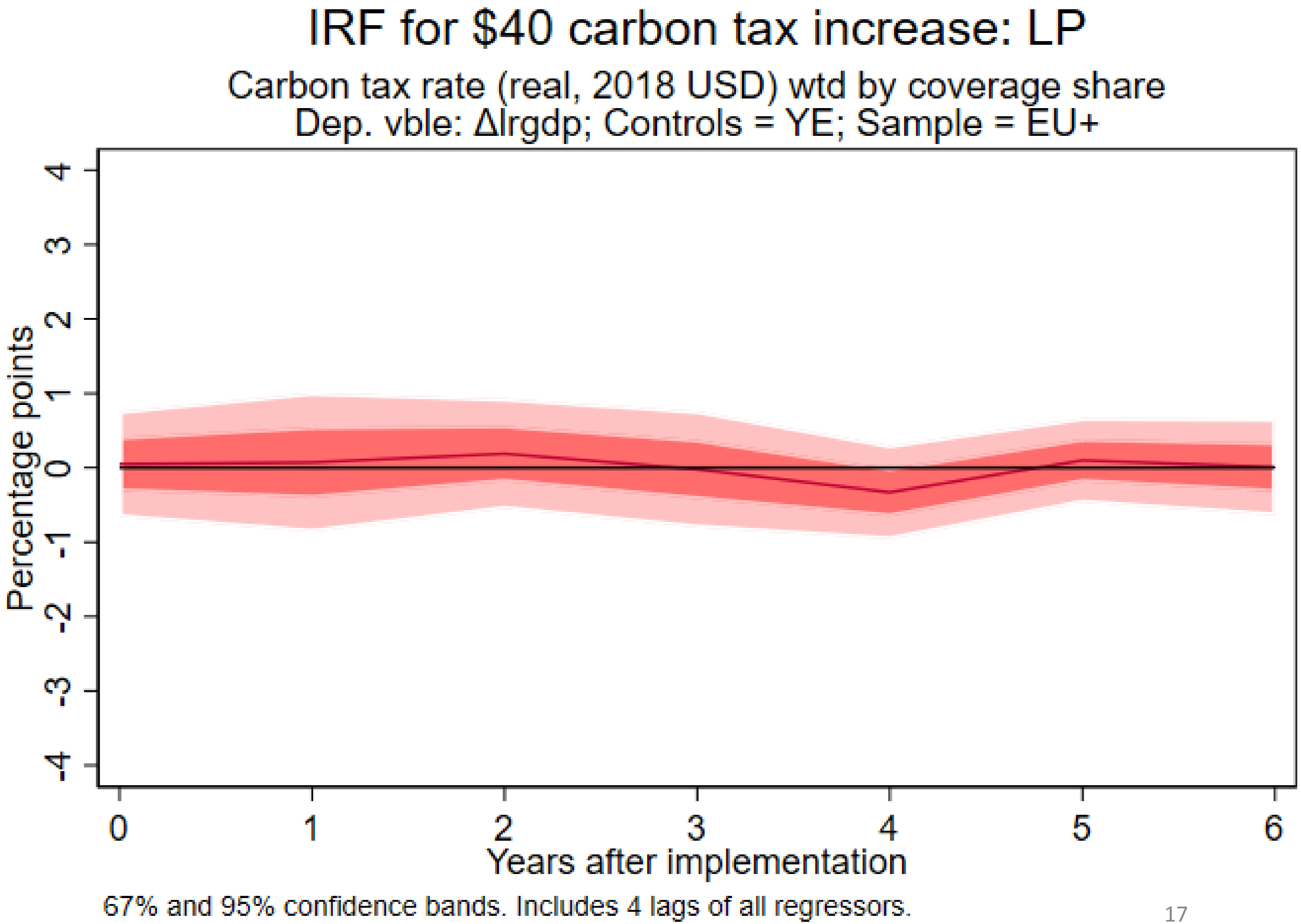
➢ **Results shown today impose the "parallel paths" restriction**

	GDP	Employment	Emissions
LP	0.33 0.75	-0.63 0.53	-2.09 0.04
SVAR	1.34 0.18	0.62 0.53	-1.26 0.21
Revenue Recycling Countries			
LP	0.05 0.96	-0.72 0.47	-0.95 0.34
SVAR	1.39 0.16	0.17 0.87	-0.40 0.69
Large Carbon Tax Countries			
LP	-0.41 0.69	0.14 0.89	-0.53 0.60
SVAR	1.00 0.32	1.23 0.22	-0.34 0.73
Scandinavian Countries			
LP	-0.44 0.66	0.80 0.42	0.19 0.85
SVAR	0.95 0.34	1.04 0.30	0.16 0.87

Results: GDP growth

Sample: **EU+**

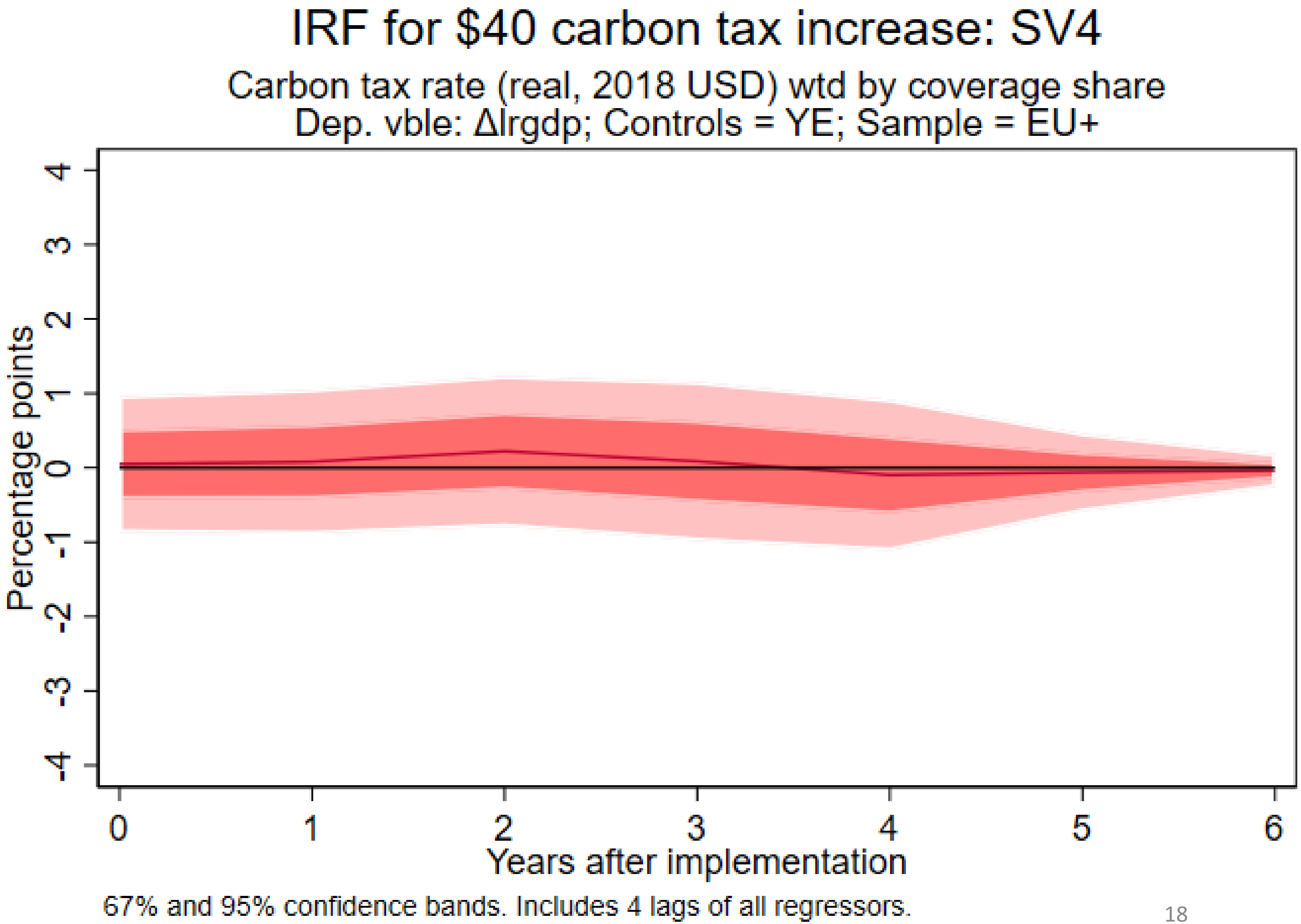
Method: **Linear Projection Restricted**



Results: GDP growth

Sample: **EU+**

Method: **SVAR**
Restricted



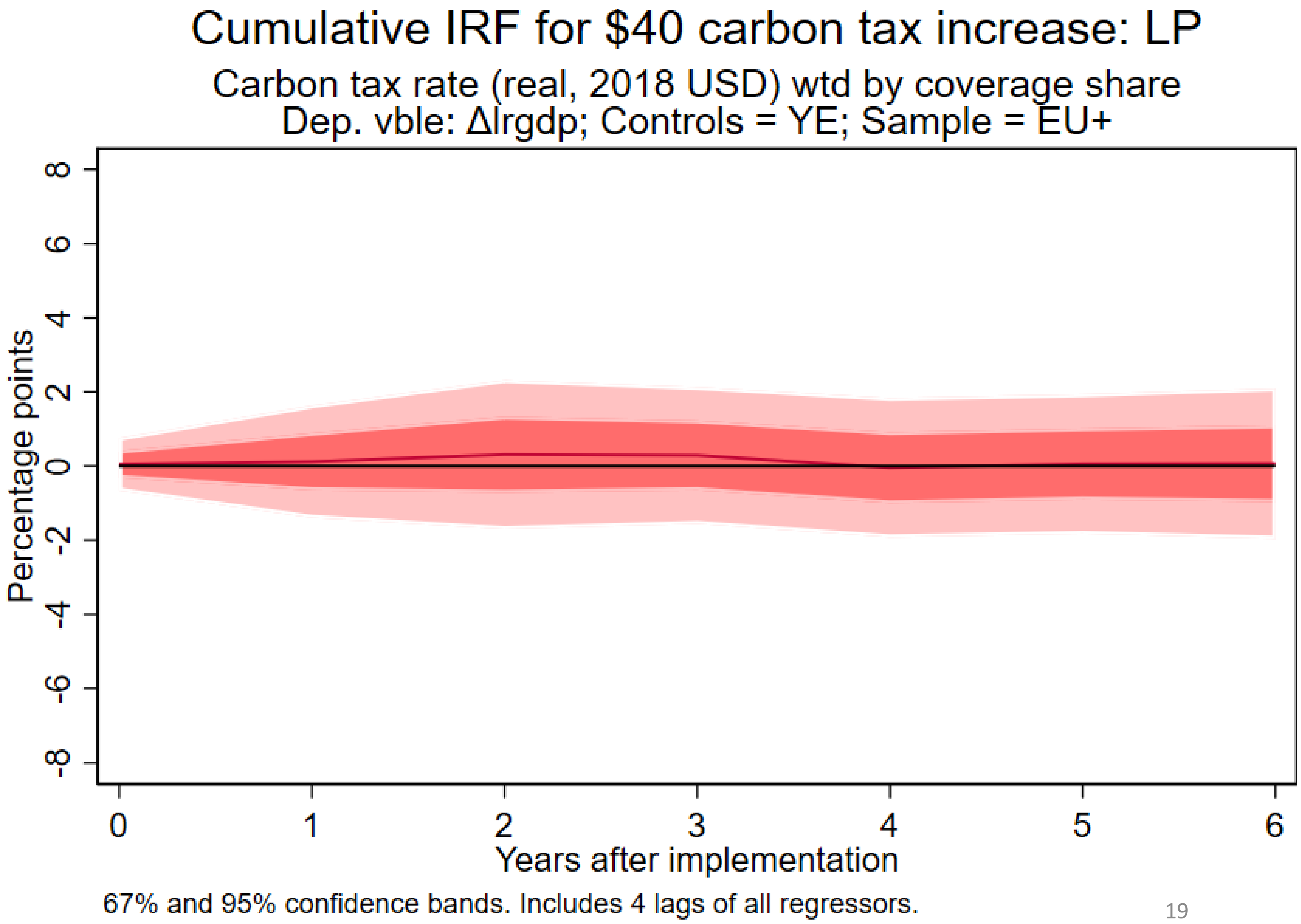
Results: GDP log level

Sample: **EU+**

Method: **LP**
Restricted

This cumulative IRF is the estimated effect of the tax increase on the *level* of log(GDP), imposing the "parallel path" assumption

- This is the empirical counterpart to the CGE counterfactual



Results: GDP log level

Sample: **EU+**

Method: **SVAR Restricted**

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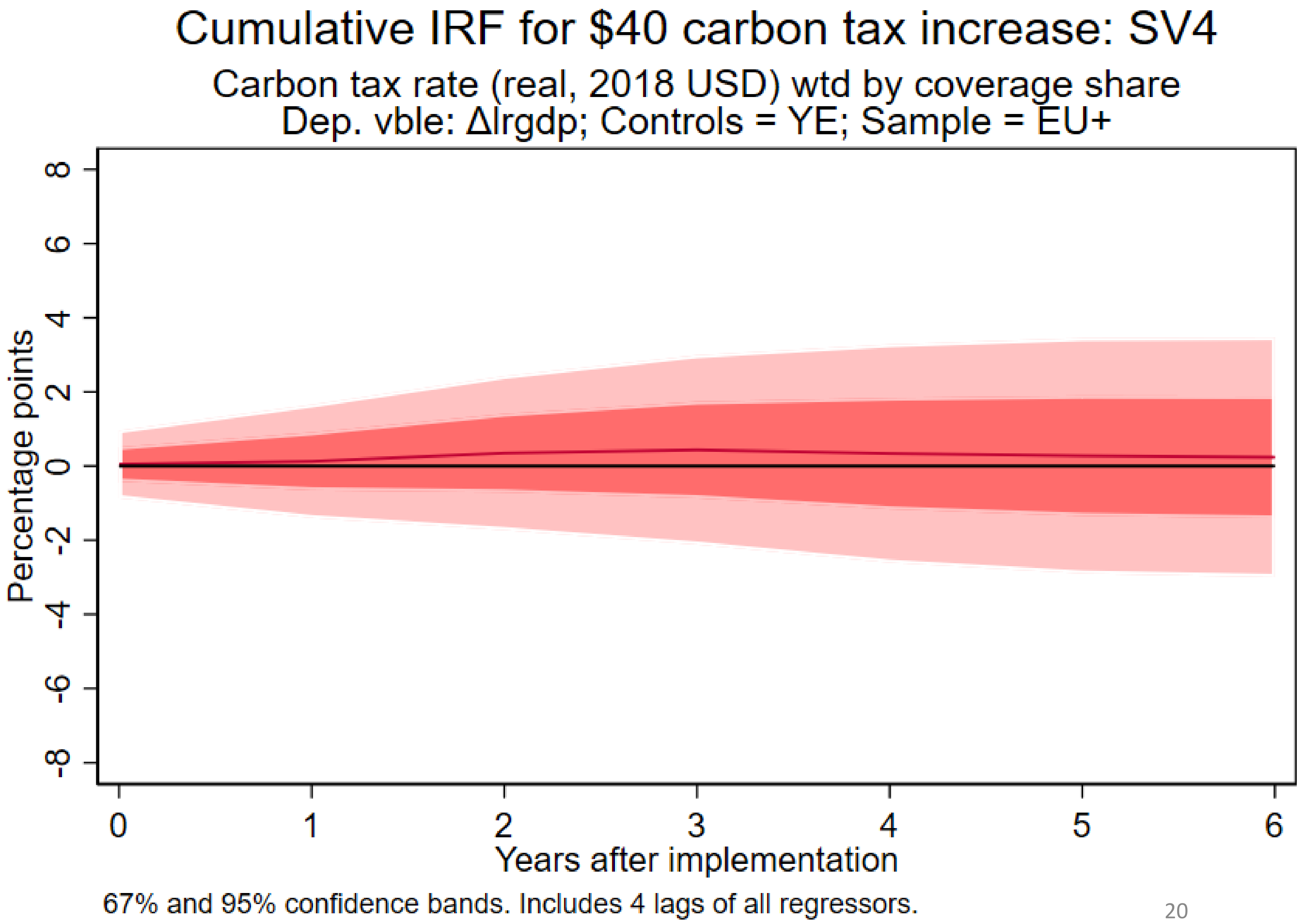
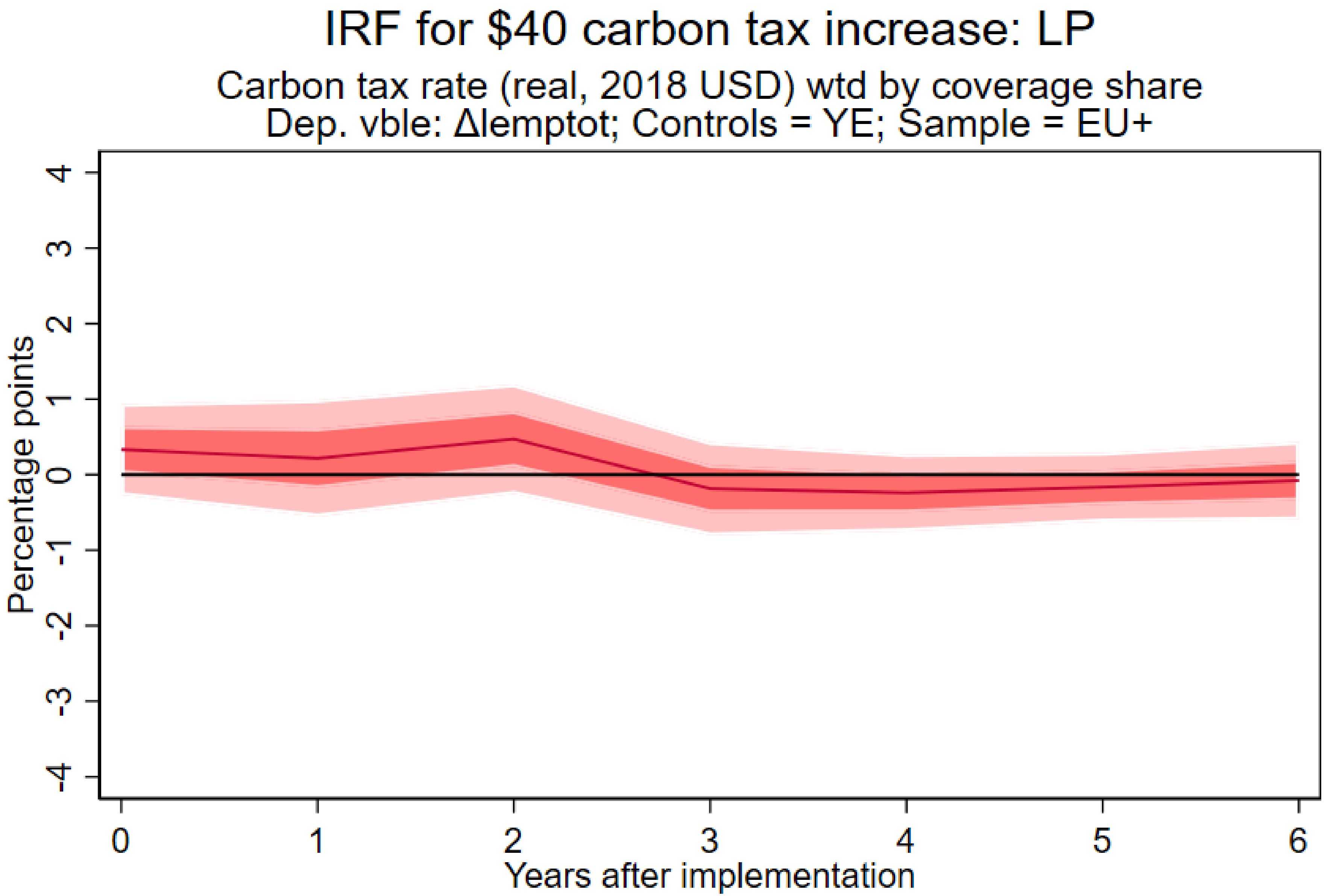


Results: Employment growth

Sample: **EU+**

Method: **LP**
Restricted

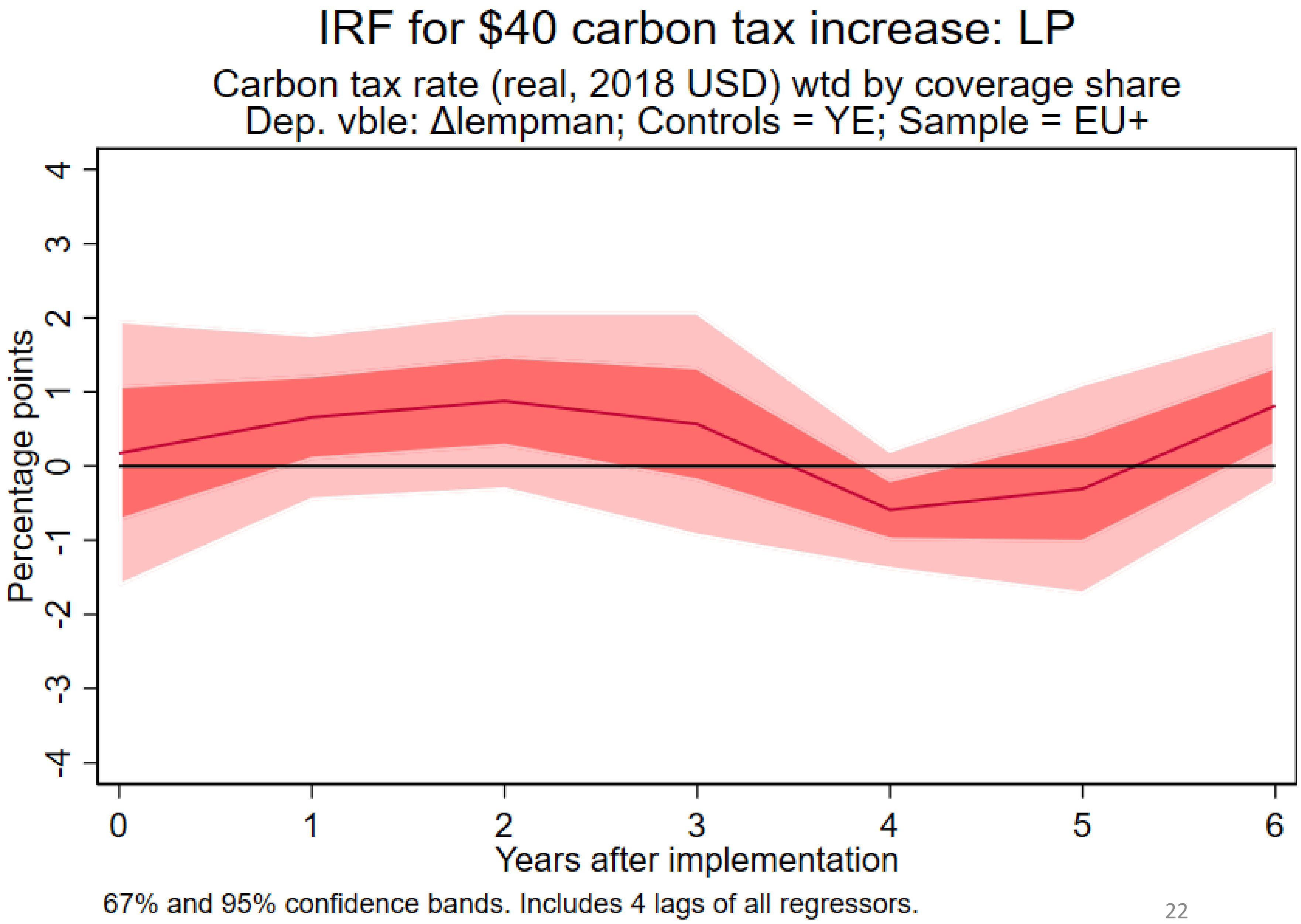


67% and 95% confidence bands. Includes 4 lags of all regressors.

Results: Manufacturing employment growth

Sample: **EU+**

Method: **LP**
Restricted



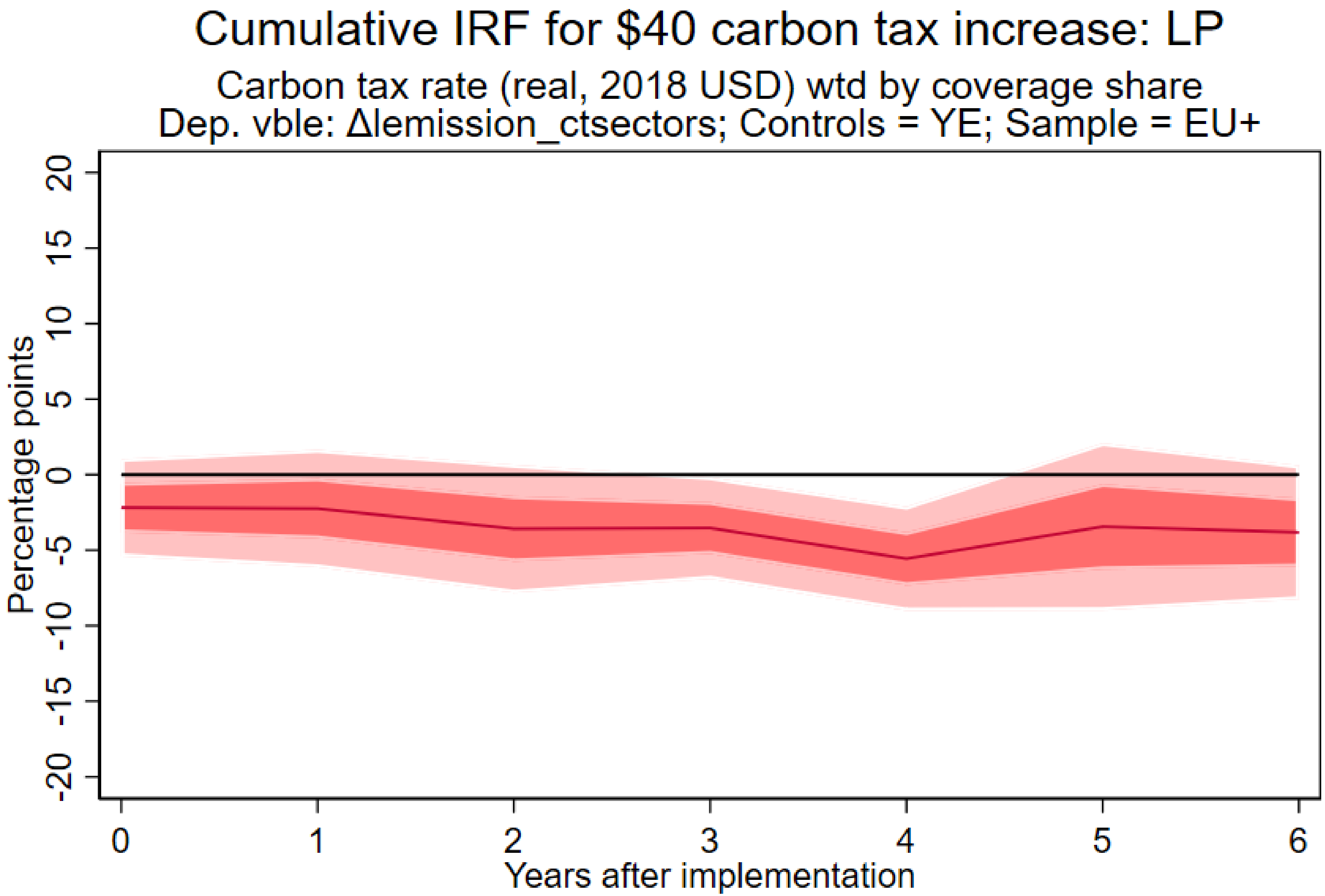
Results: Emissions log level

Sample: **EU+**

Method: **LP**
Restricted
Cumulative IRF

This cumulative IRF is the estimated effect of the tax increase on the *level* of log(emissions), imposing the "parallel path" assumption

Emissions series:
Emissions in sectors exposed to the carbon tax



67% and 95% confidence bands. Includes 4 lags of all regressors.

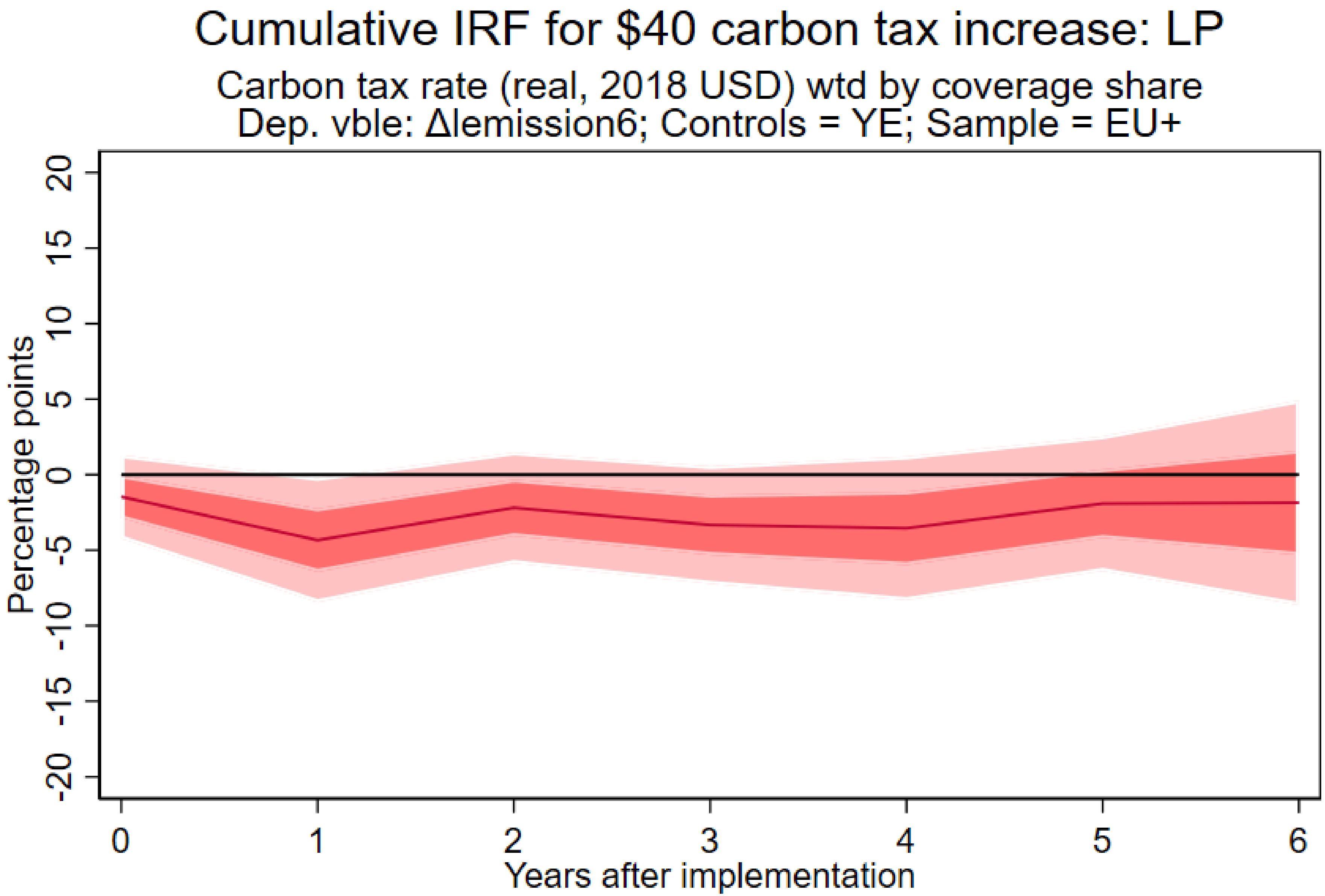
Results: Emissions log level

Sample: **EU+**

Method: **LP**
Restricted
Cumulative IRF

This cumulative IRF is the estimated effect of the tax increase on the *level* of log(emissions), imposing the "parallel path" assumption

Emissions series:
Emissions from fuel consumption



67% and 95% confidence bands. Includes 4 lags of all regressors.

Results: Additional questions + sensitivity analysis

1. Are the results driven by:

   - Scandinavia?
     - **No: results for SCA-only, or EUxSCA, are similar to overall results, just noisier**

   - Countries that have low taxes?
     - **No: very similar results if you use only countries with tax of at least $10/ton share-weighted ($40/ton x 30% coverage = $12/ton share-weighted)**

   - Carbon tax data decisions?
     - **No. Essentially no difference in results if we use the Dolphin et al. (2019) carbon tax rates, see the paper**

2. Are the positive GDP and employment results a consequence of how the country uses the revenue?

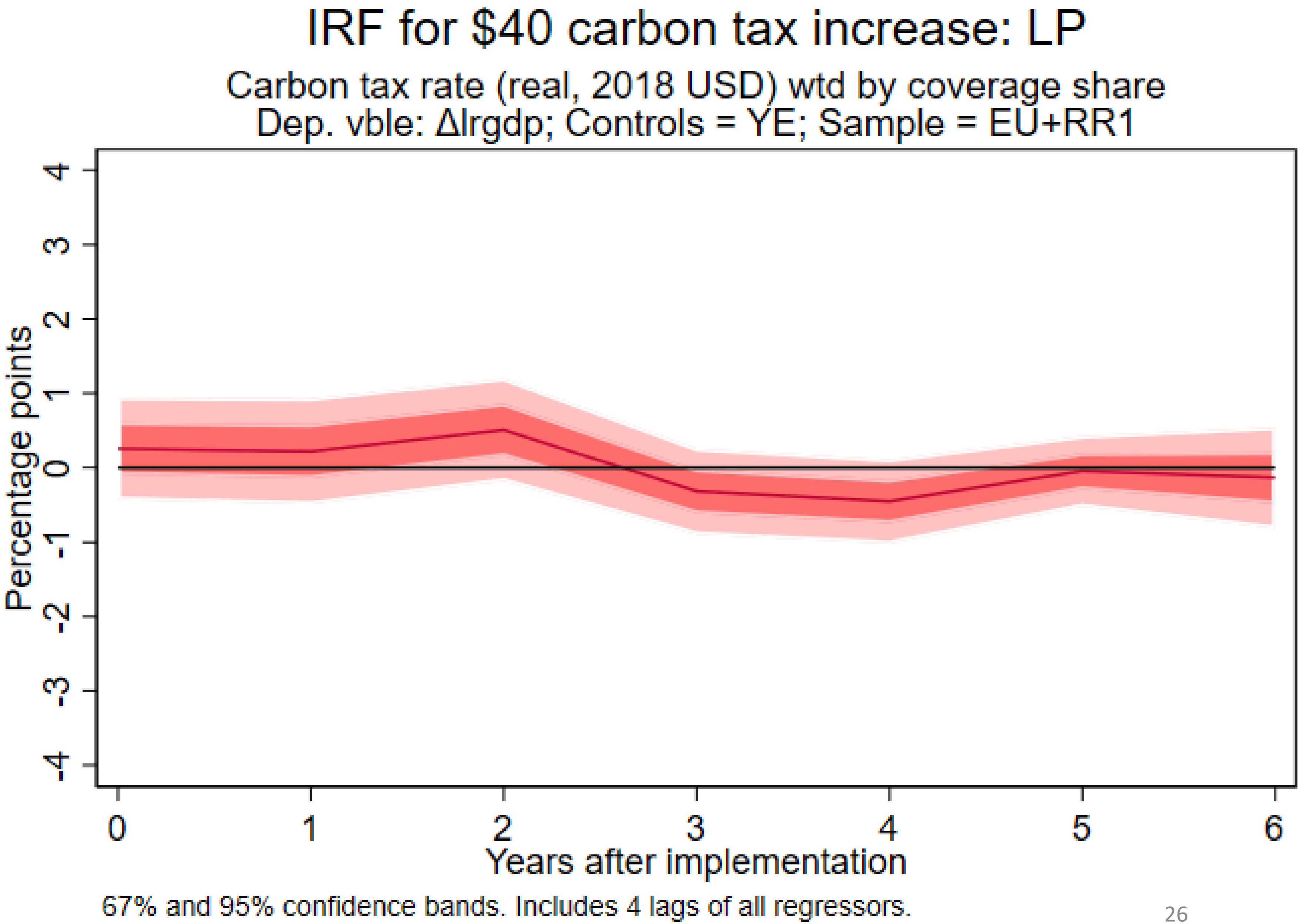
Results: Effect of revenue recycling

Sample: **EU+**
Revenue recycling

Dep vble: **GDP growth**

Method: **LP**
Restricted

Revenue recycling countries
Denmark, Sweden, Norway, Finland, Switzerland, Portugal



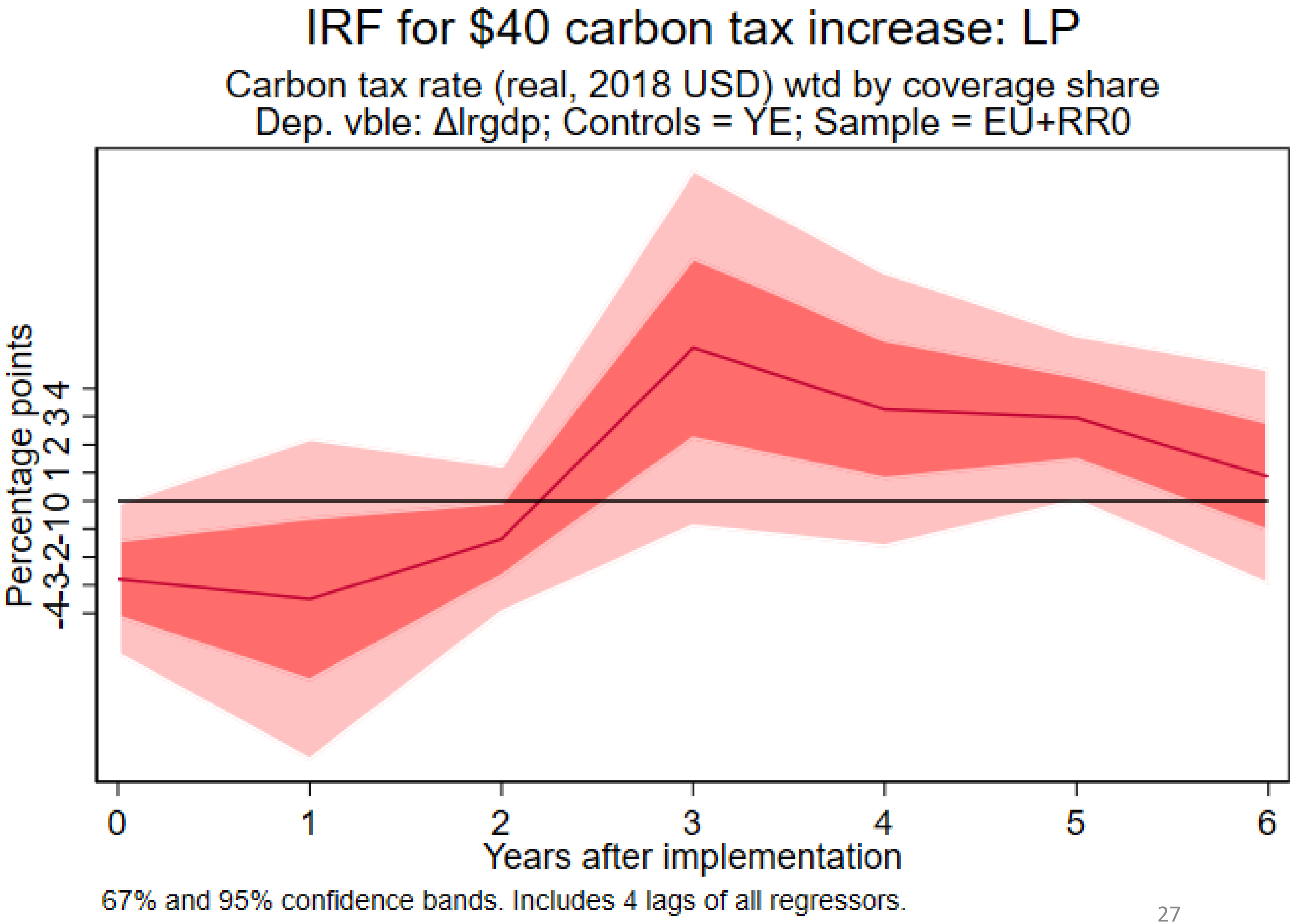
Results: Effect of revenue recycling

Sample: **EU+**
No revenue recycling

Dep vble: **GDP growth**

Method: **LP**
Restricted

<u>Revenue recycling countries</u>
Denmark, Sweden, Norway, Finland, Switzerland, Portugal



Results: Effect of revenue recycling

Sample: **EU+**
Revenue recycling

Dep vble: **Empl. growth**

Method: **LP**
Restricted

Revenue recycling countries
Denmark, Sweden, Norway, Finland
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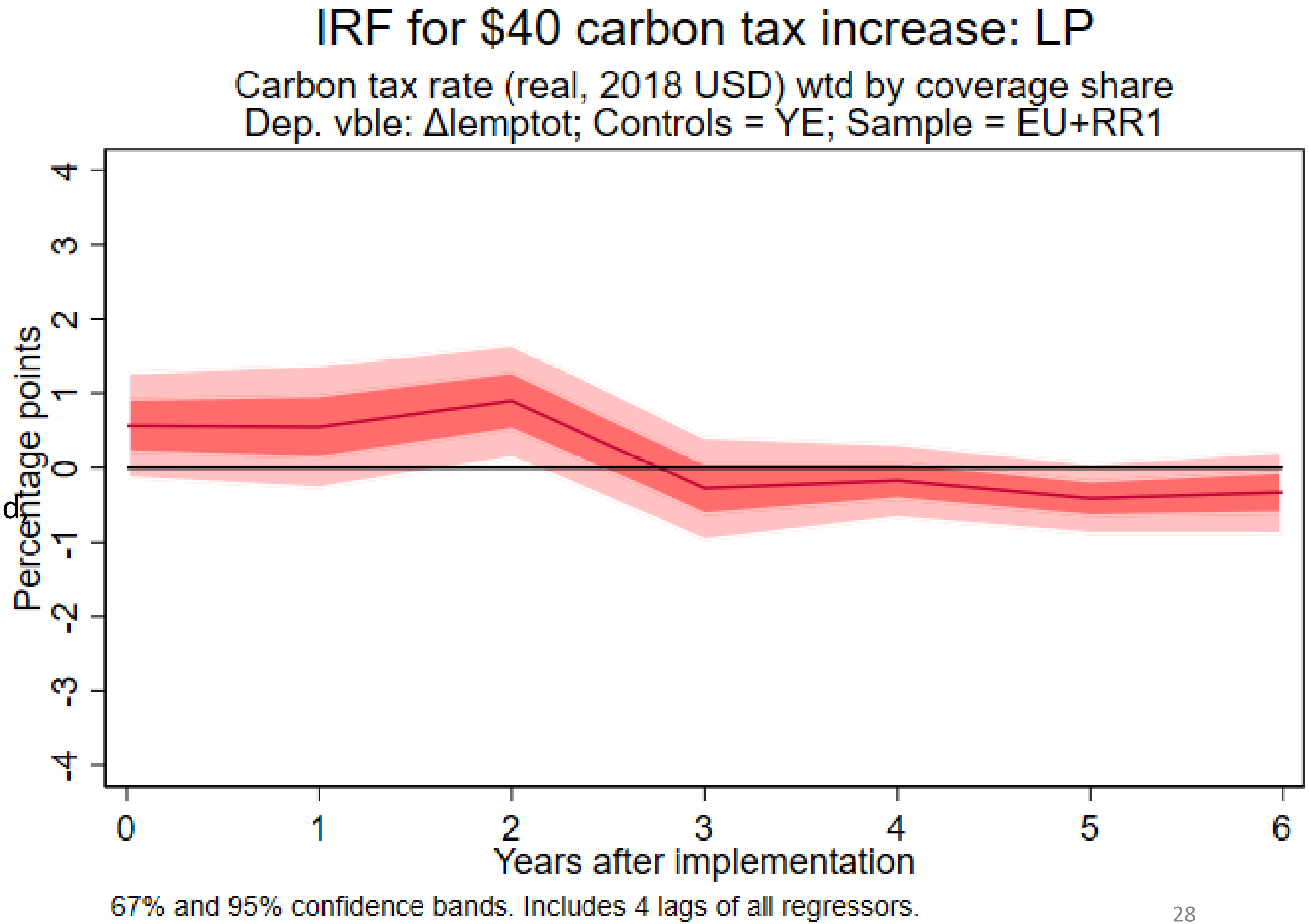

Results: Effect of revenue recycling

Sample: **EU+**
No revenue recycling

Dep vble: **Empl. growth**

Method: **LP**
Restricted

Revenue recycling countries
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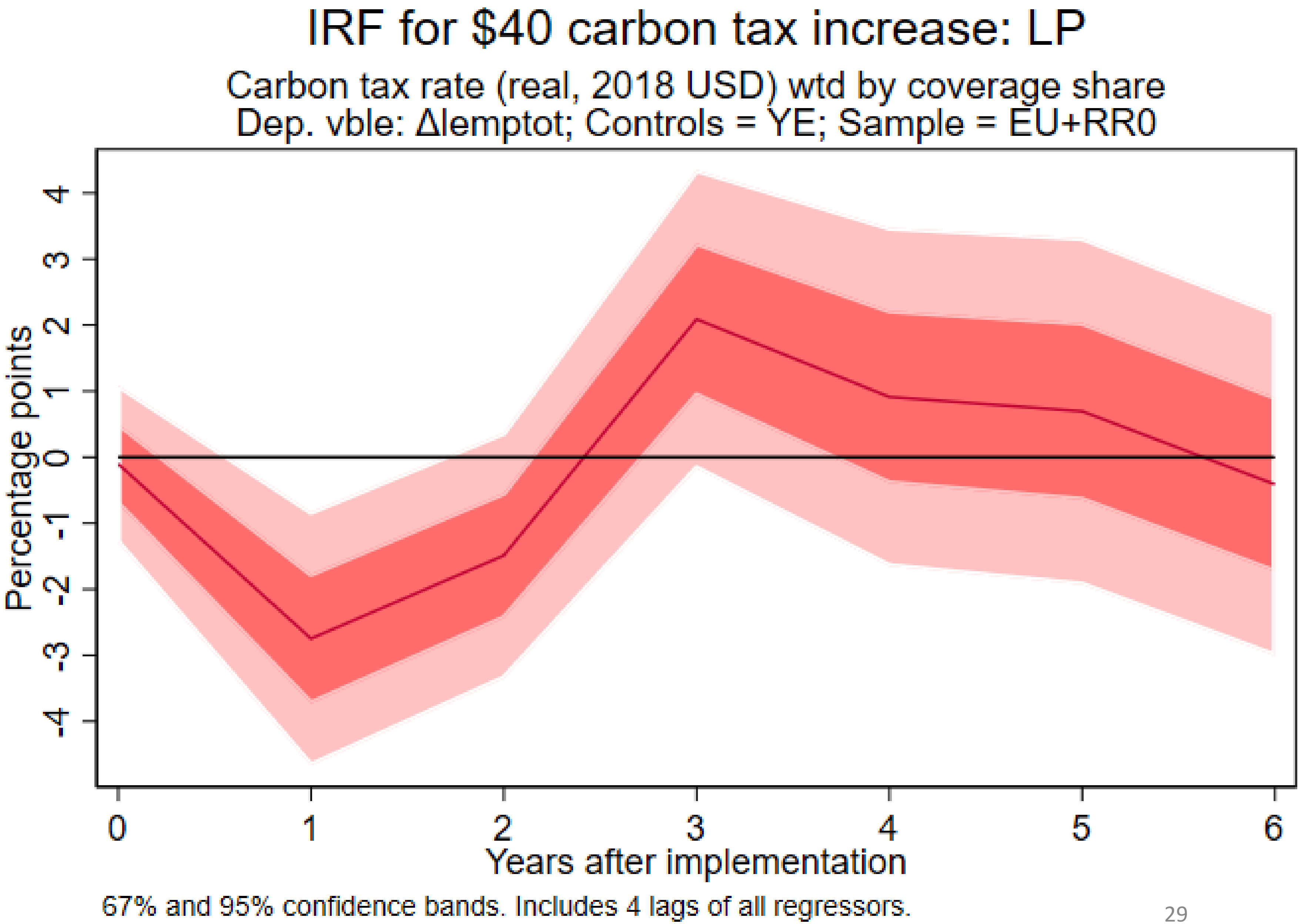
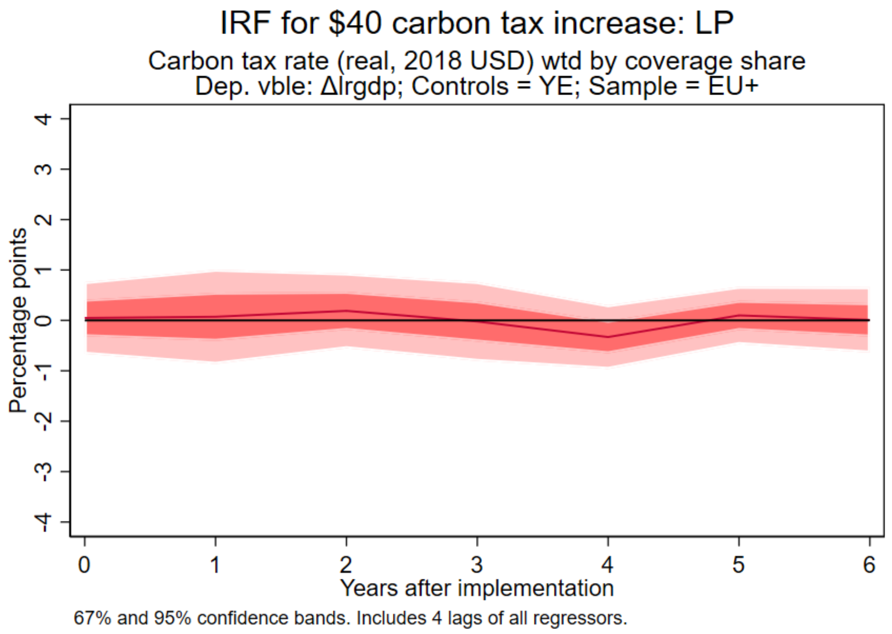


Summary

GDP

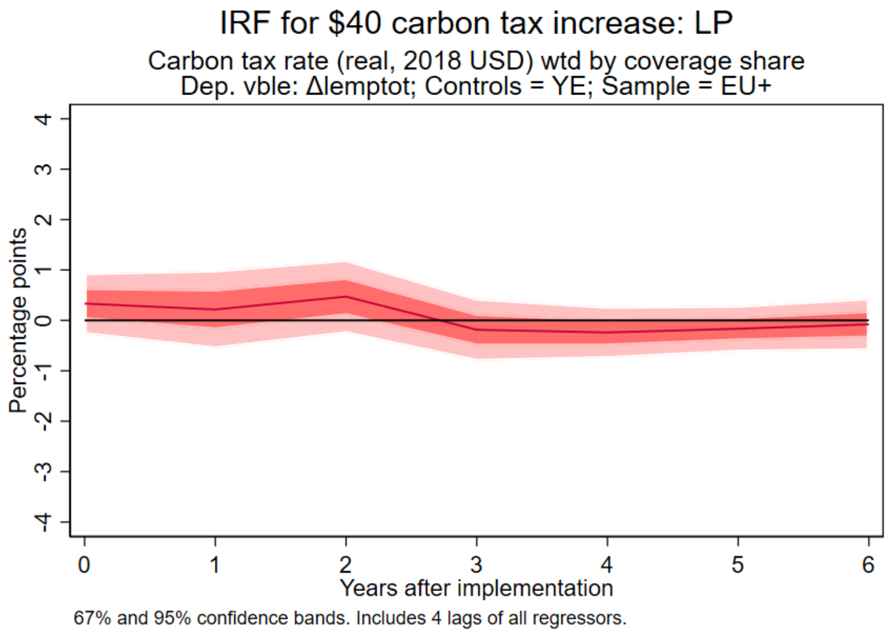
No effect



Employment

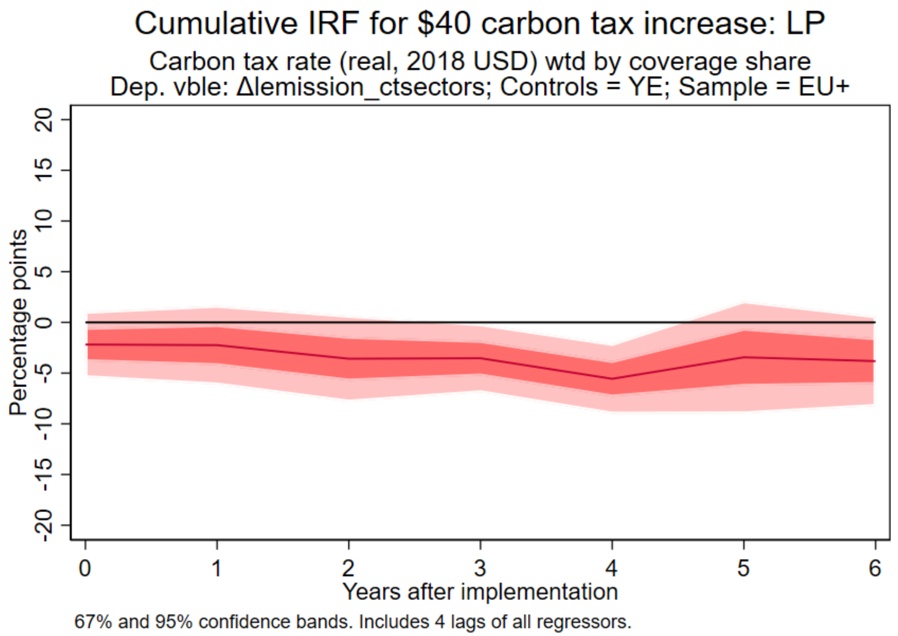
No effect

- *initial positive bump?*

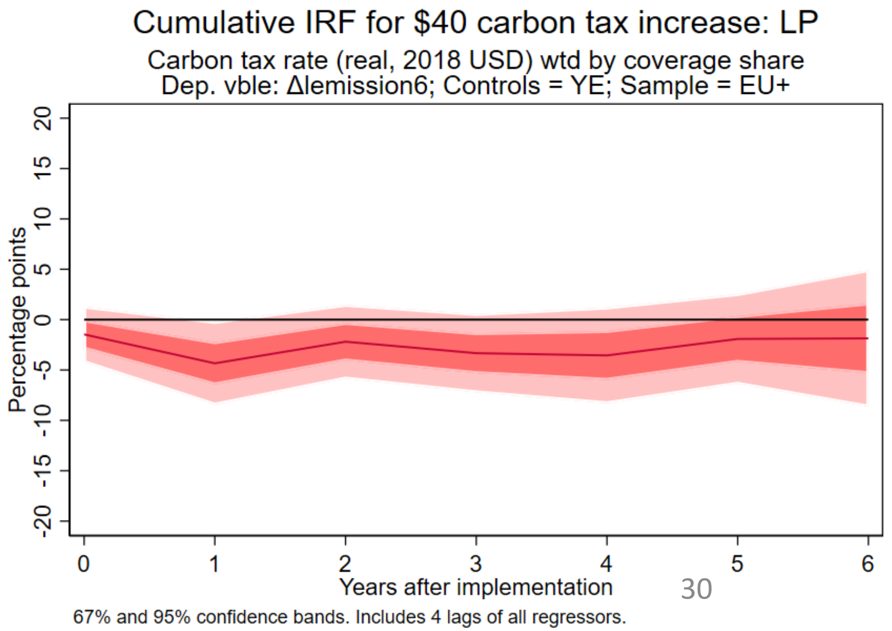


Emissions from covered sectors

4-6% reduction



Emissions from fuel consumption



Discussion

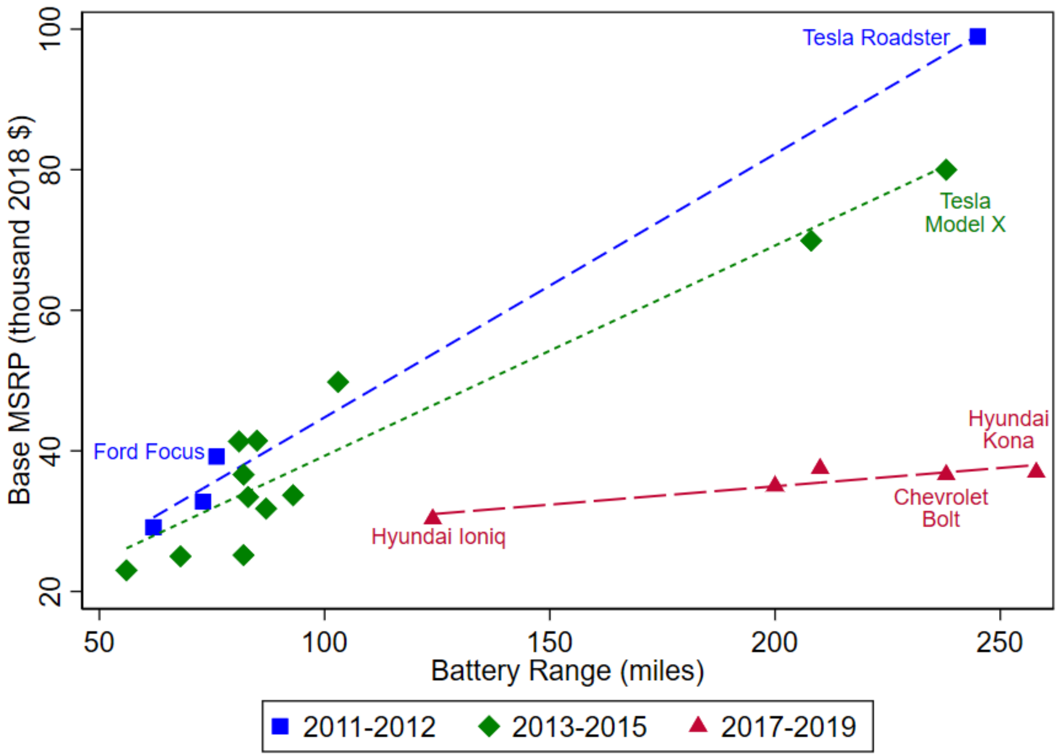
Comparisons, caveats, and comments:

- **Our results are consistent with Rafaty, Dolphin, and Pretis (2020)**
  - OECD, effect of carbon price on emissions, synthetic controls, passage effect
- **What about spillover effects on comparison group (countries that don't increase CT)**
  - *Does the treatment affect the control group*
- **Endogeneity issues:**
  - Changes in tax rate change once imposed?
  - Endogeneity of adoption of tax in the first place
- **Interaction with EU ETS**
- **External validity**
  - The taxes studied don't cover the power sector

Discussion

Bigger picture:

- **In the power sector, a carbon price is now transformative because wind & solar are becoming cheaper and cheaper.**
- **Outside of the power sector, a carbon tax has only a modest short-run effect on emissions**
  - \$40/ton ≈ 40¢/gallon of gasoline
  - Effect over longer run would be more substantial (induced investment in greener technology)
- **The energy transition must be affordable so consumers *choose* clean technologies**
  - ➢ Role for (smart) technology policy

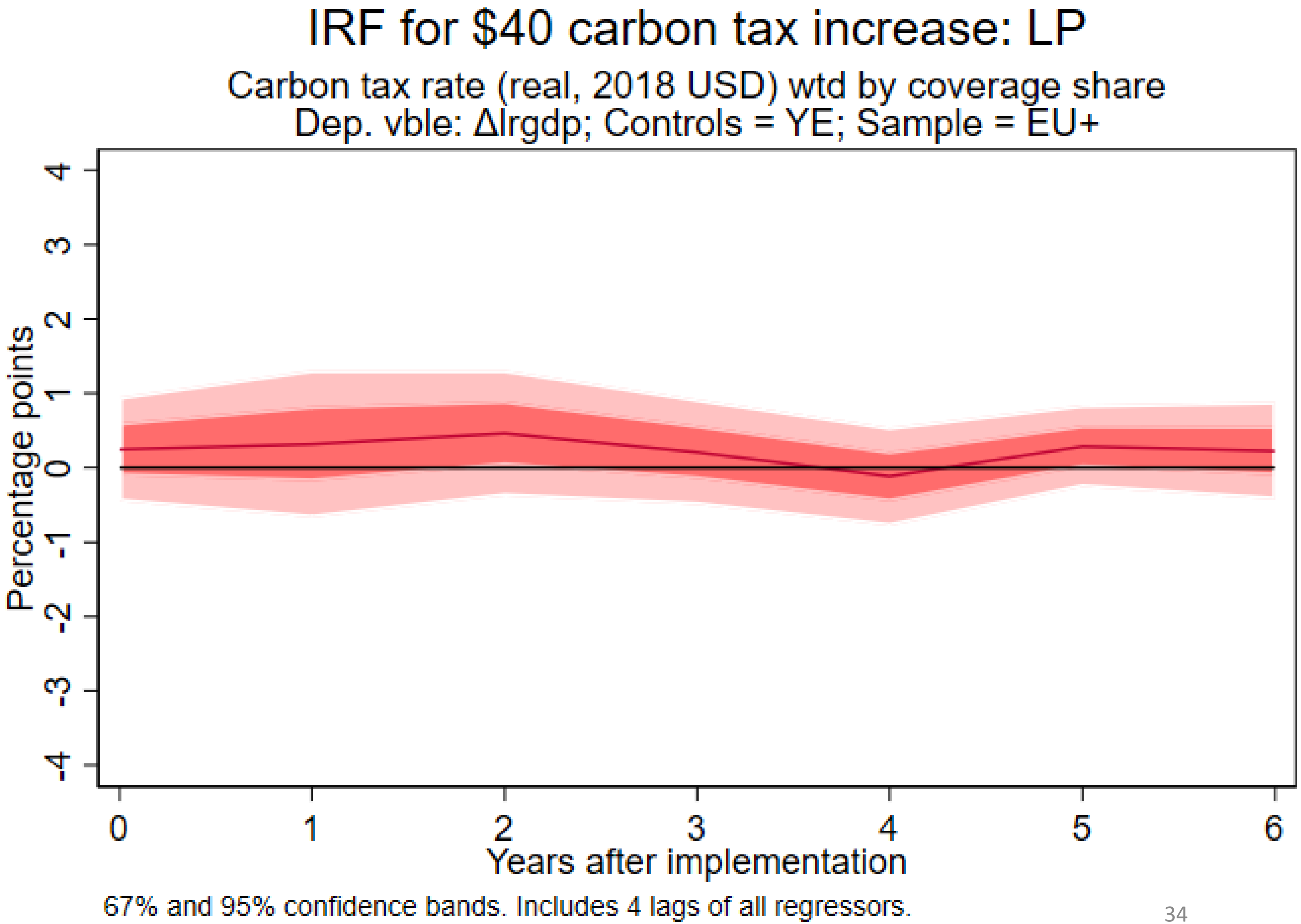


Additional Slides

Results: GDP growth

Sample: **EU+**

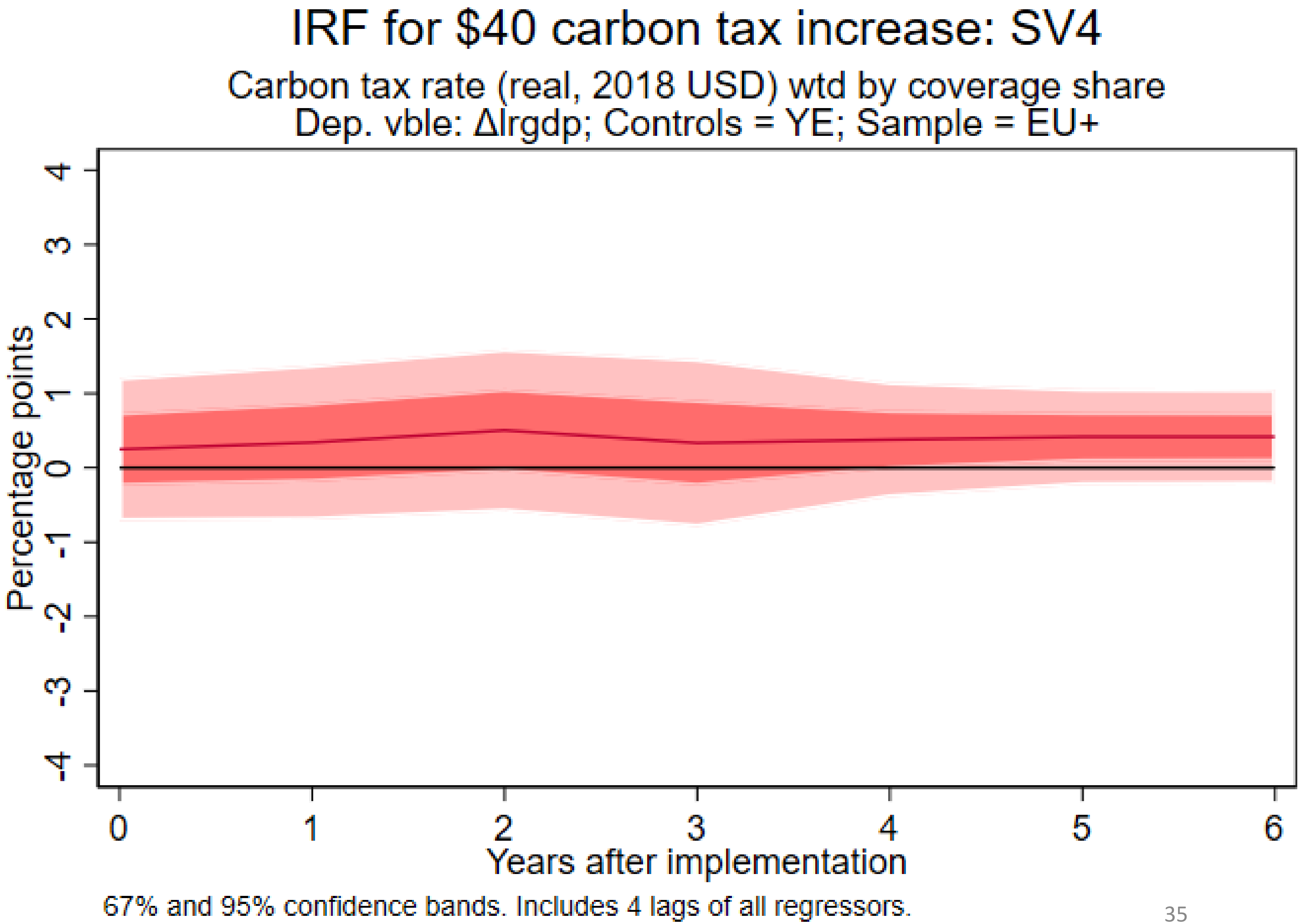
Method: **Linear Projection**
Unrestricted



Results: GDP growth

Sample: **EU+**

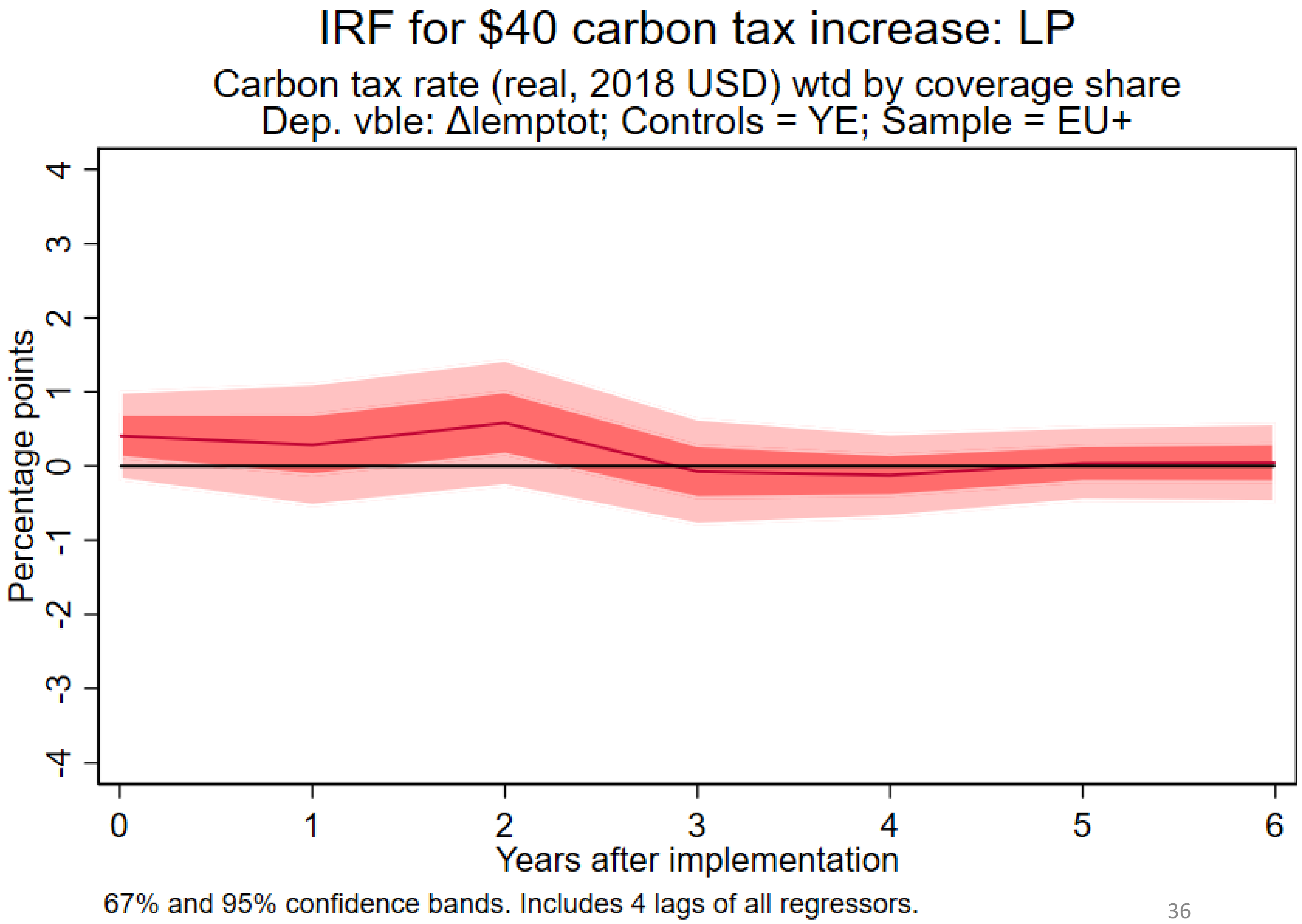
Method: **SVAR**
Unrestricted



Results: Employment

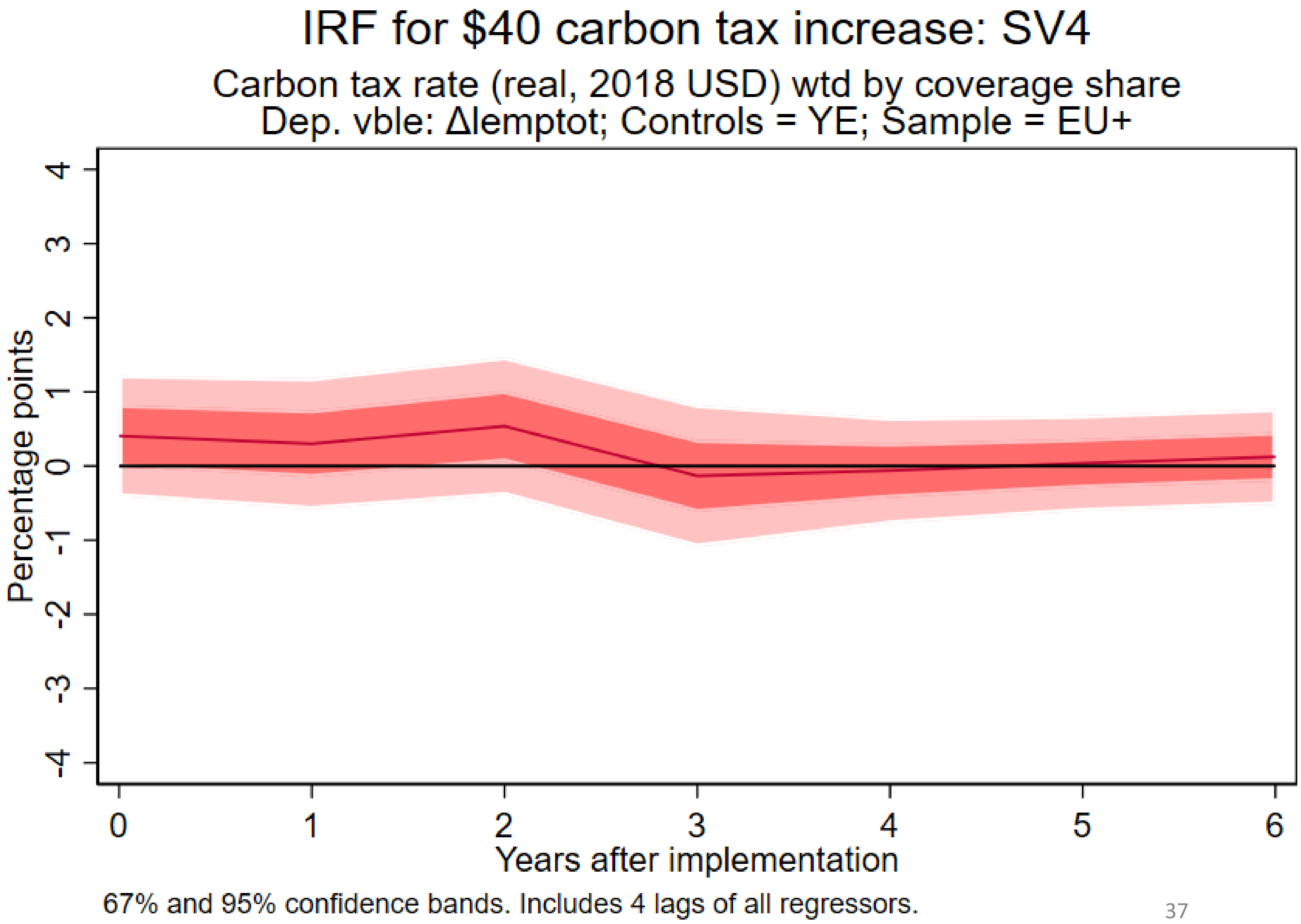
Sample: **EU+**

Method: **LP**
Unrestricted



Sample: **EU+**

Method: **SVAR Unrestricted**



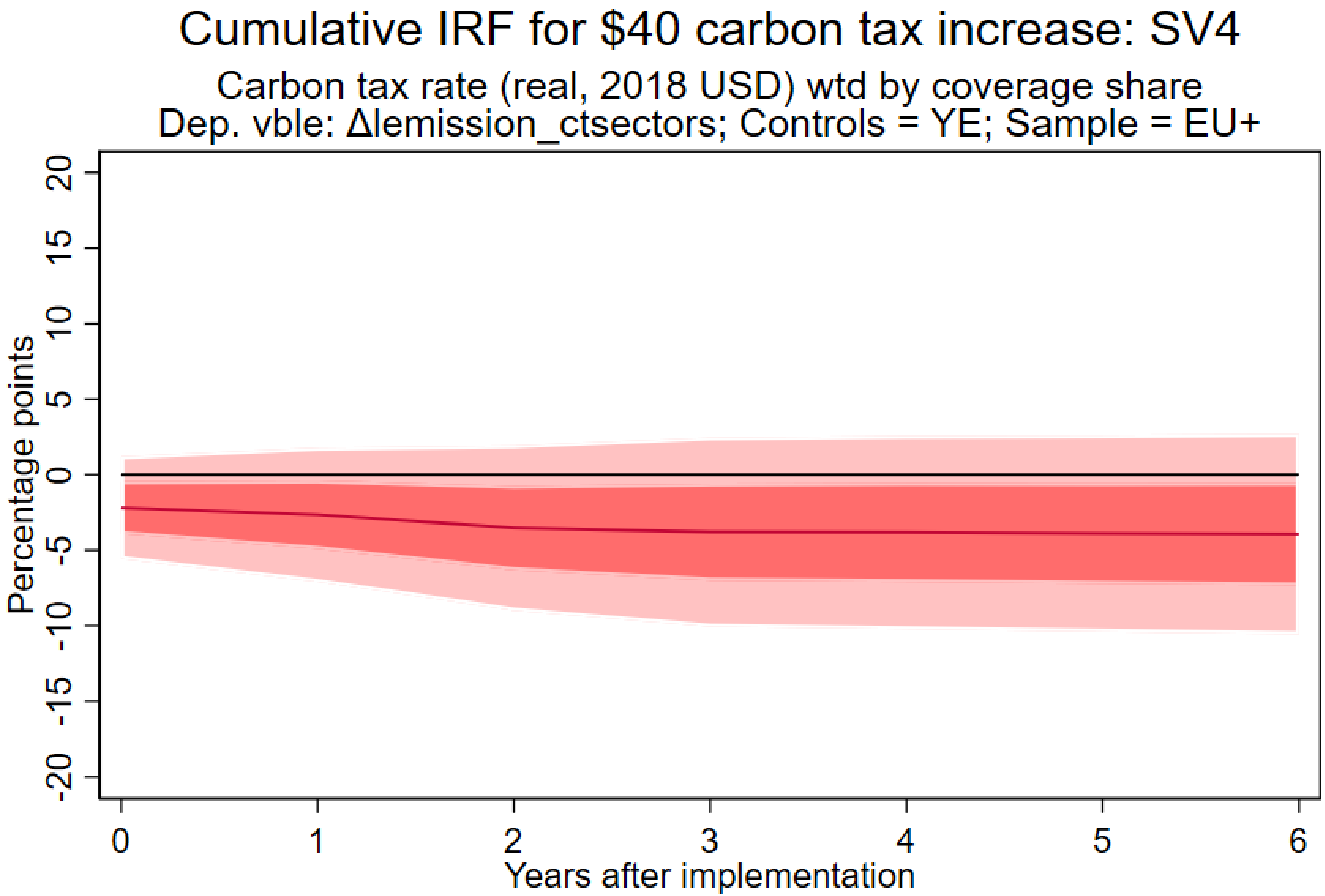
Results: Emissions

Sample: **EU+**

Method: **SVAR**
Restricted
Cumulative IRF

This cumulative IRF is the estimated effect of the tax increase on the *level* of log(emissions), imposing the "parallel path" assumption

Emissions series:
Emissions in sectors exposed to the carbon tax



67% and 95% confidence bands. Includes 4 lags of all regressors.

More details on carbon pricing schemes internationally