The Macroeconomic Impact of Europe's Carbon Taxes

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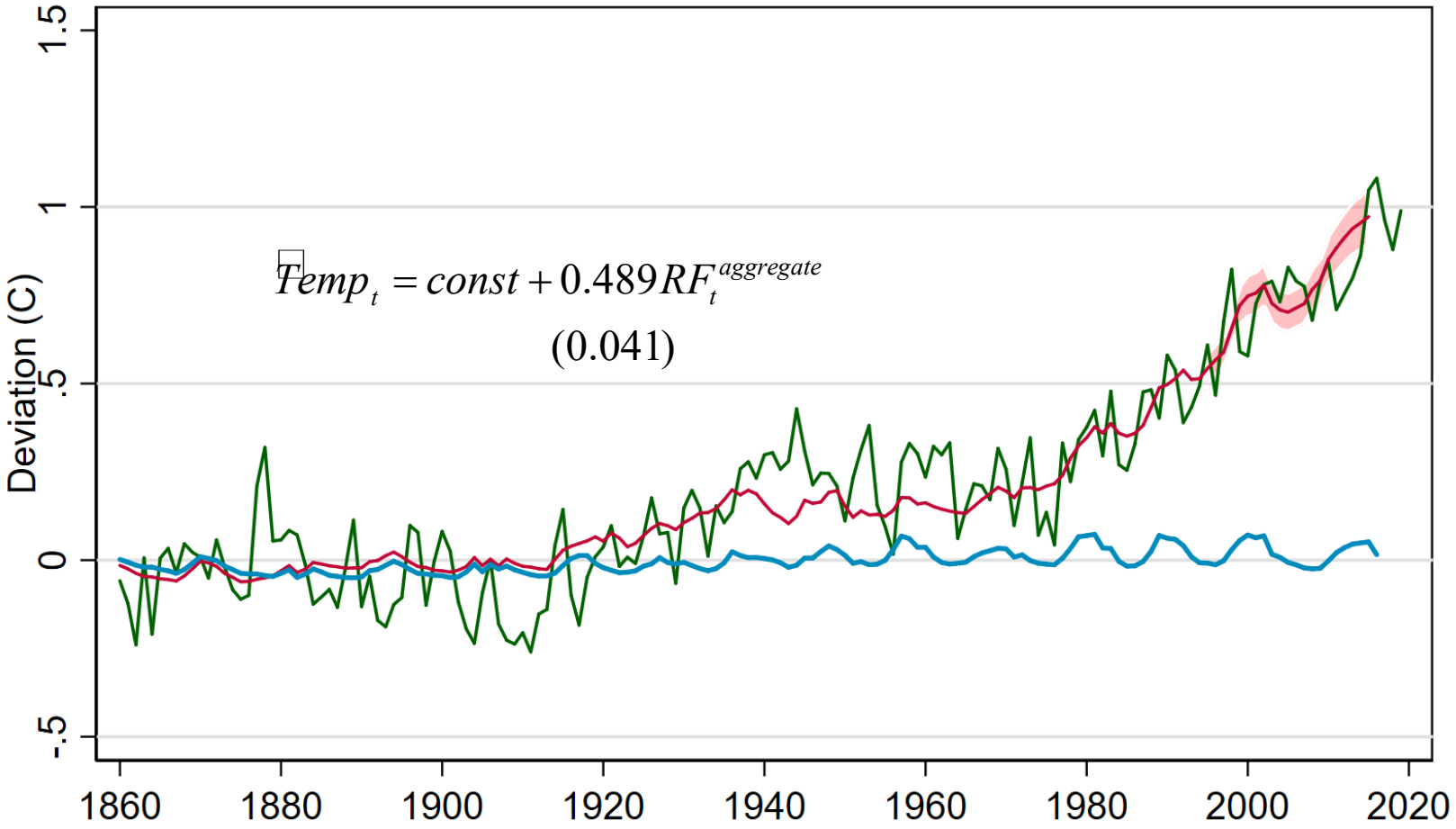
Virtual Seminar on Climate Economics

Federal Reserve Bank of San Francisco

Temperature and Fitted Values based on Radiative Forcings

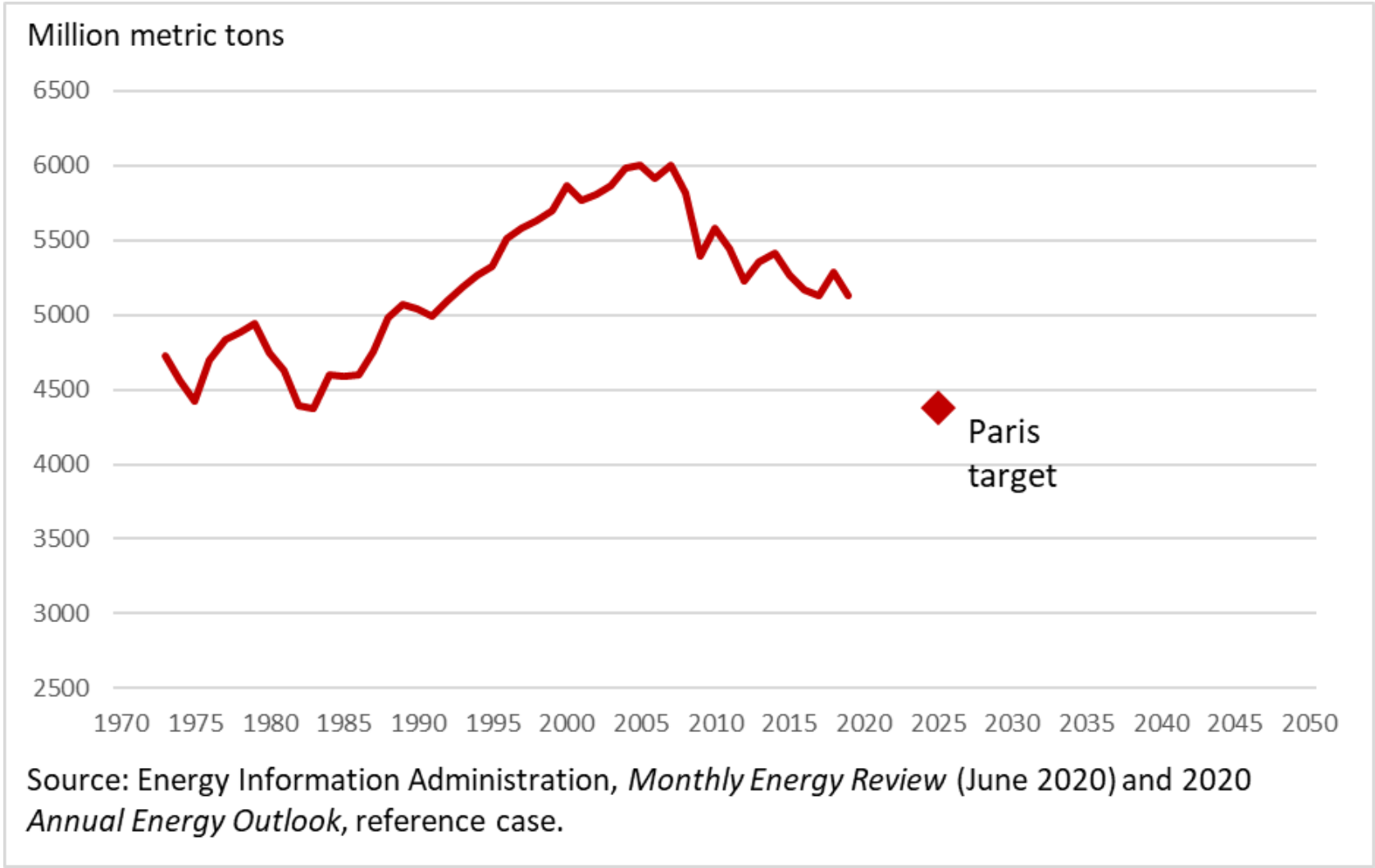
Deviation from 1870-1890 mean



Estimation 1860-1994. Shading is 67% confidence interval conditional on RF.
Predicted value uses DOLS cointegrating vector from Kaufmann, Kaupi, Stock (2006, Table II(2)).

US CO2 emissions

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



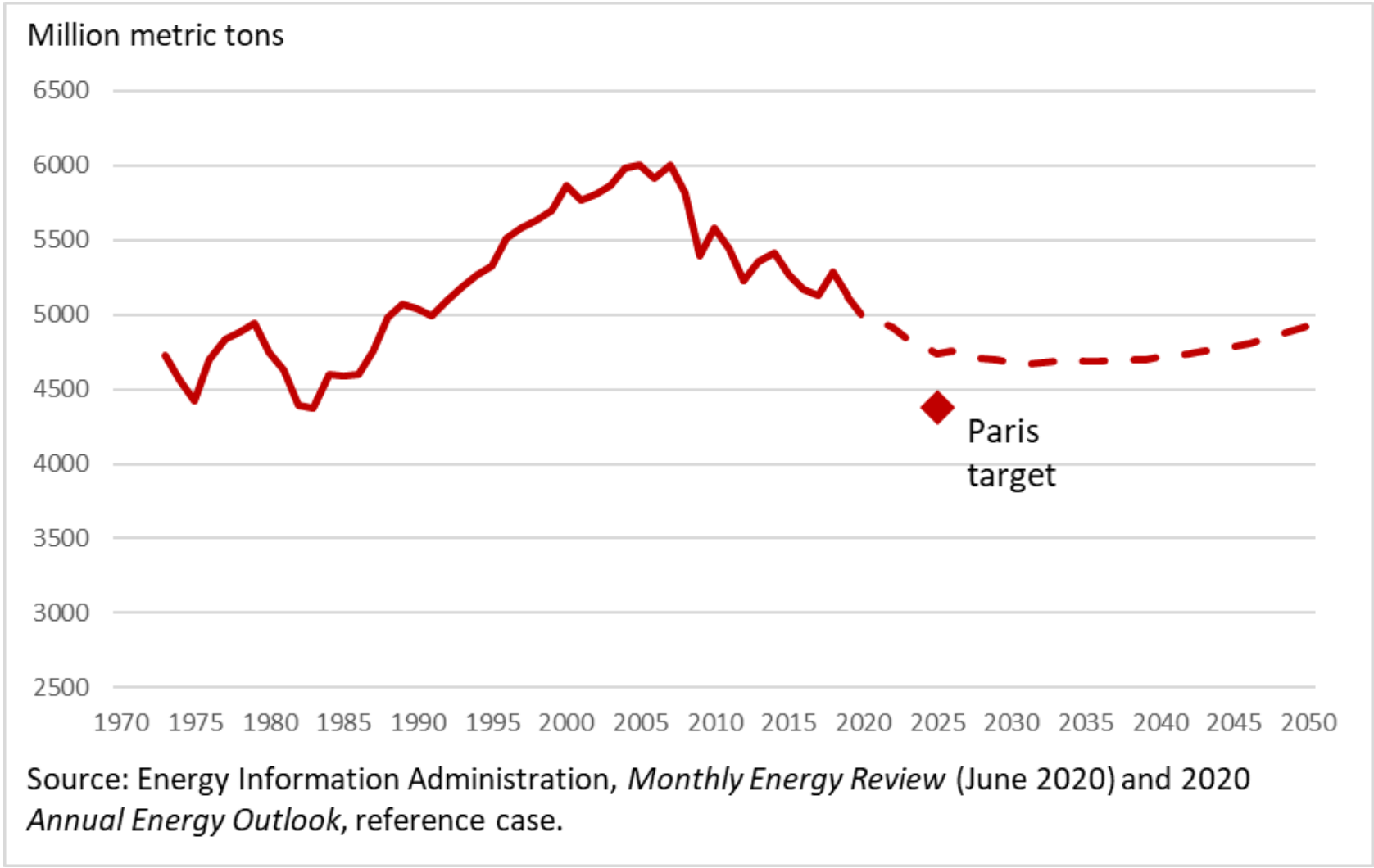
Source: Energy Information Administration, *Monthly Energy Review* (June 2020) and 2020 *Annual Energy Outlook*, reference case.

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

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

But we have a long ways to go:

Source	%, 2019
Gas	38.4
Coal	23.5
Nuclear	19.7
Wind	7.3
Hydro	6.6
Solar	1.8



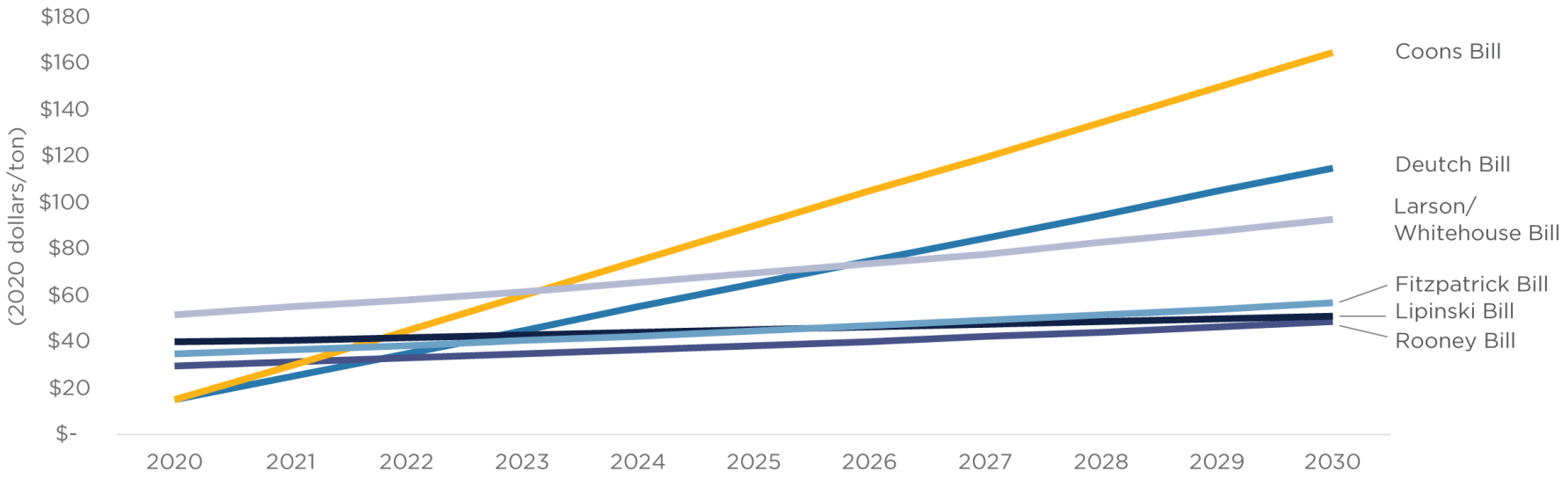
Source: Energy Information Administration, *Monthly Energy Review* (June 2020) and 2020 *Annual Energy Outlook*, reference case.

- **Because of the carbon, investment, and network externalities, markets won't reduce emissions (enough) on their own**
- **One of the main policy tools, loved by economists, is a carbon tax…**

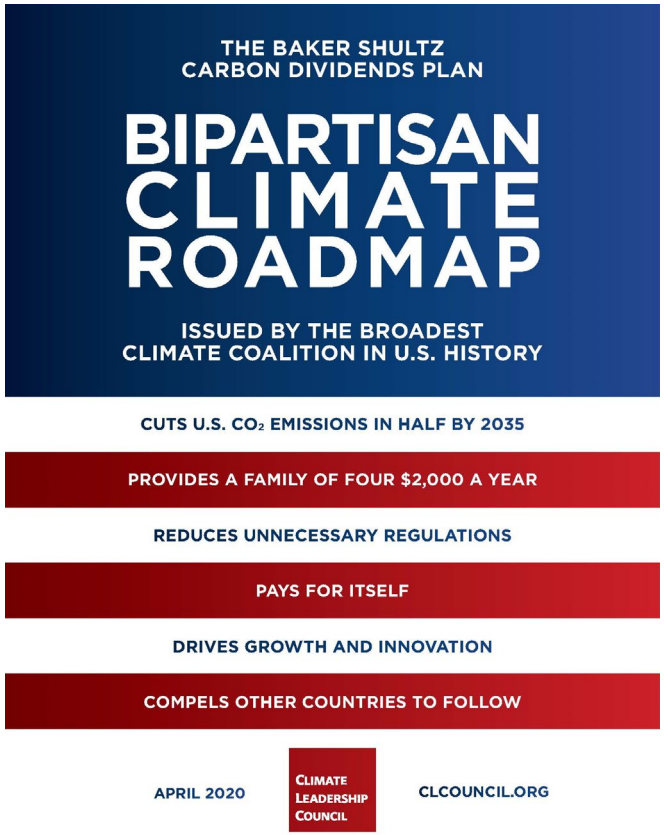
Carbon taxes: Background

Tax schedules for carbon tax bills in the current Congress

Figure 1: Carbon Tax Rates for Federal Carbon Tax Proposals (2020 dollars/ton)



Source: CGEP Analysis



Carbon taxes: Background

REMARKS

Statement by President Trump on the Paris Climate Accord

ENERGY & ENVIRONMENT | Issued on: June 1, 2017

★ ★ ★

…

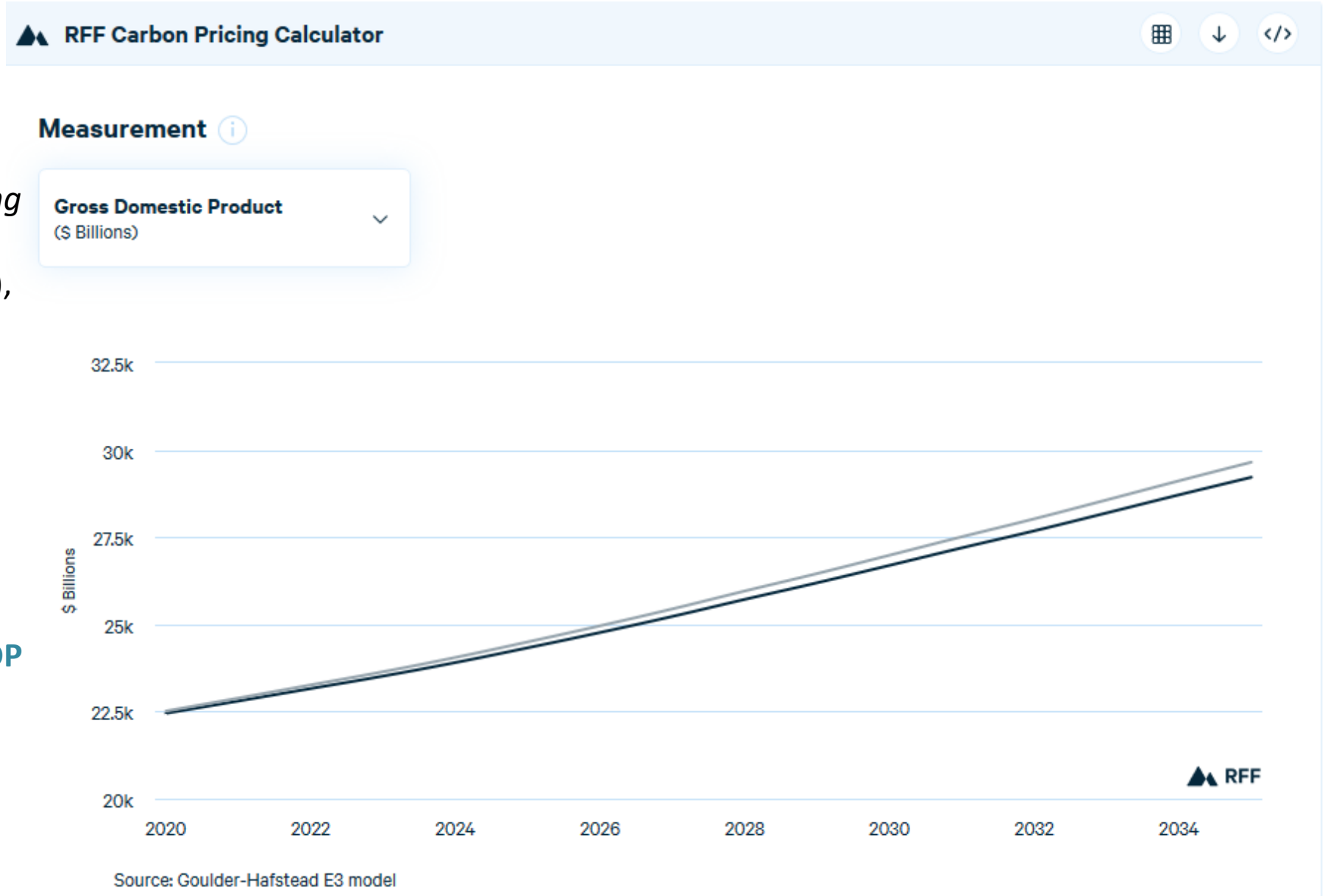
Compliance with the terms of the Paris Accord and the onerous energy restrictions it has placed on the United States could cost America as much as 2.7 million lost jobs by 2025 according to the National Economic Research Associates….

According to this same study, by 2040, compliance with the commitments put into place by the previous administration would cut production for the following sectors: paper down 12 percent; cement down 23 percent; iron and steel down 38 percent; coal — and I happen to love the coal miners — down 86 percent; natural gas down 31 percent. The cost to the economy at this time would be close to $3 trillion in lost GDP and 6.5 million industrial jobs, while households would have $7,000 less income and, in many cases, much worse than that.

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.; [RFF Carbon Pricing Calculator]

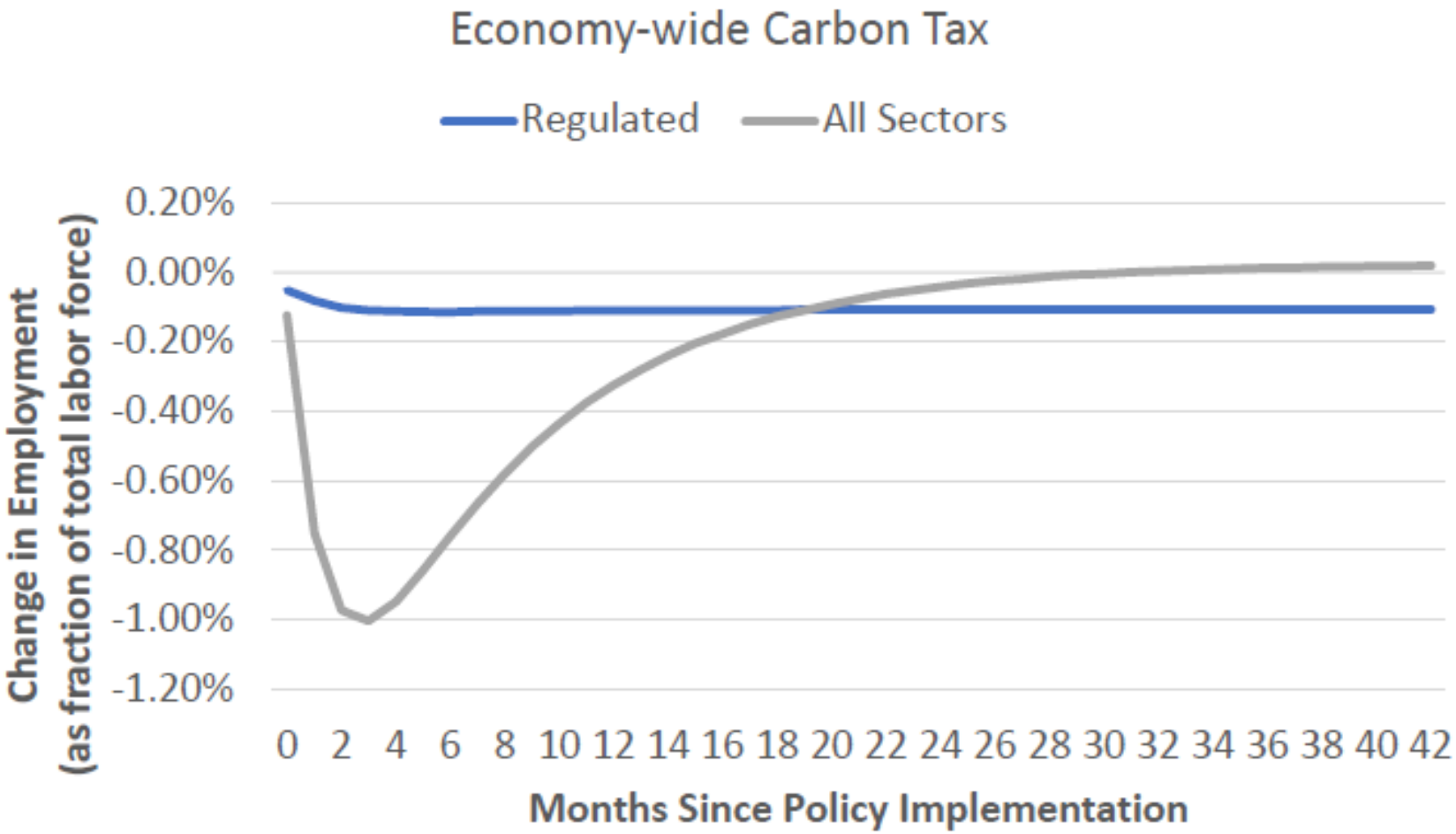
- **Parallel shift down**
- **Importance of revenue recycling method**
- **Example:**
  Tax of $40/ton @5%/year GDP loss in 2035 =
  -1.5% (tax & dividend)
  -1.2% (payroll tax cut)



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

Impacts of a carbon tax

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

Survey: Metcalf (*BPEA*, 2019)

Impacts of a carbon tax: Empirical evidence

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

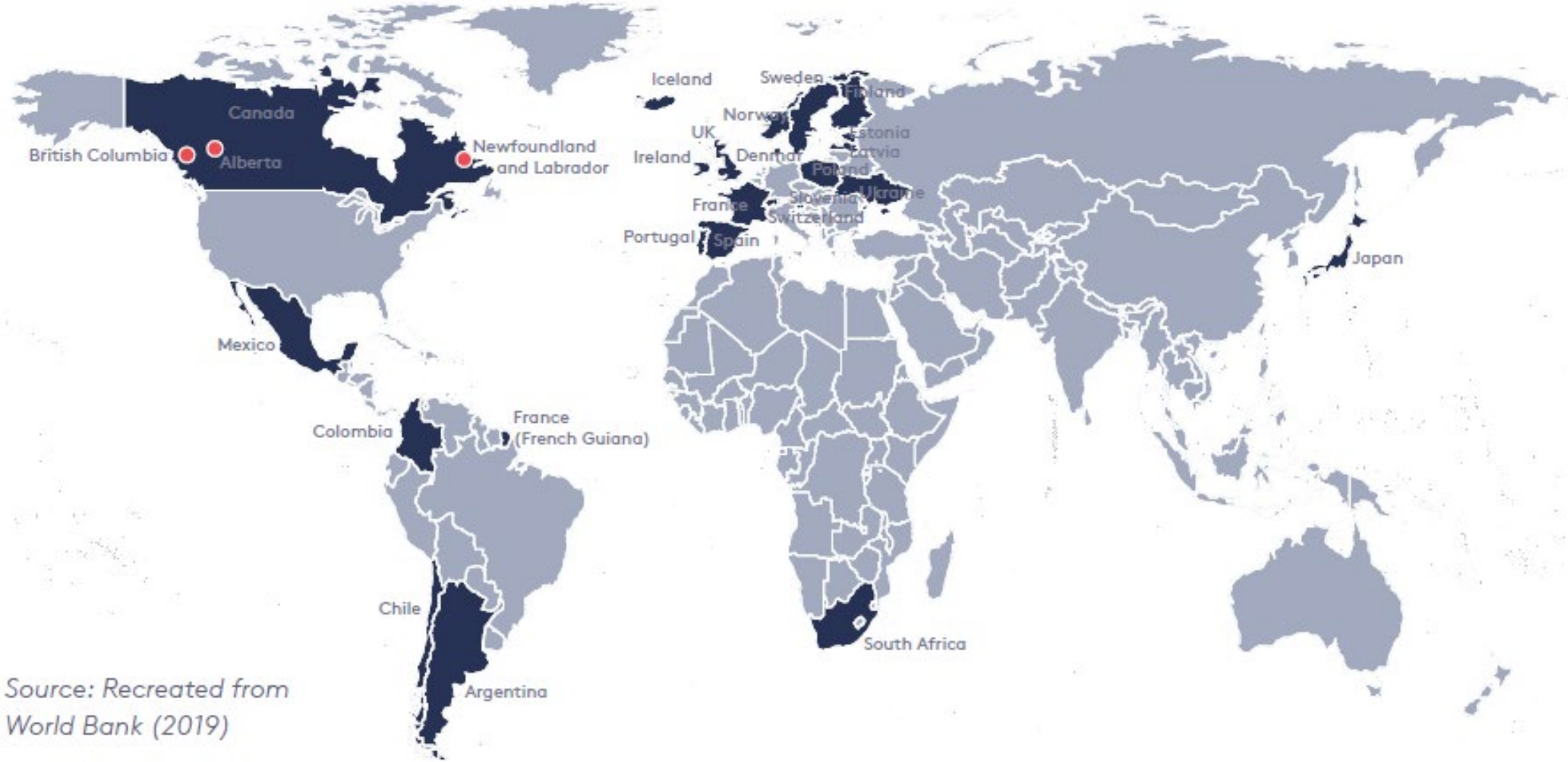
Lin and Li (2011) – Scandinavia + Netherlands
Rivers and Schaufele (2012) – BC transportation emissions
Murray and Rivers (2015) – review of older literature on BC carbon tax
Haites et. al. (2018) – carbon pricing generally, effectiveness and political economy
Dolphin, Pollitt, and Newberry (2019) – 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

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

Figure 1. Regional, national and subnational carbon taxes around the world, July 2019



Source: Grantham Research Institute on Climate Change and the Environment (August 2019)

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,
  - emissions in road transport, commercial & institutional, and household sectors
  - Alternatively, emissions from fuel consumption

Data description

Carbon taxes in 2018

Source: World Bank

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

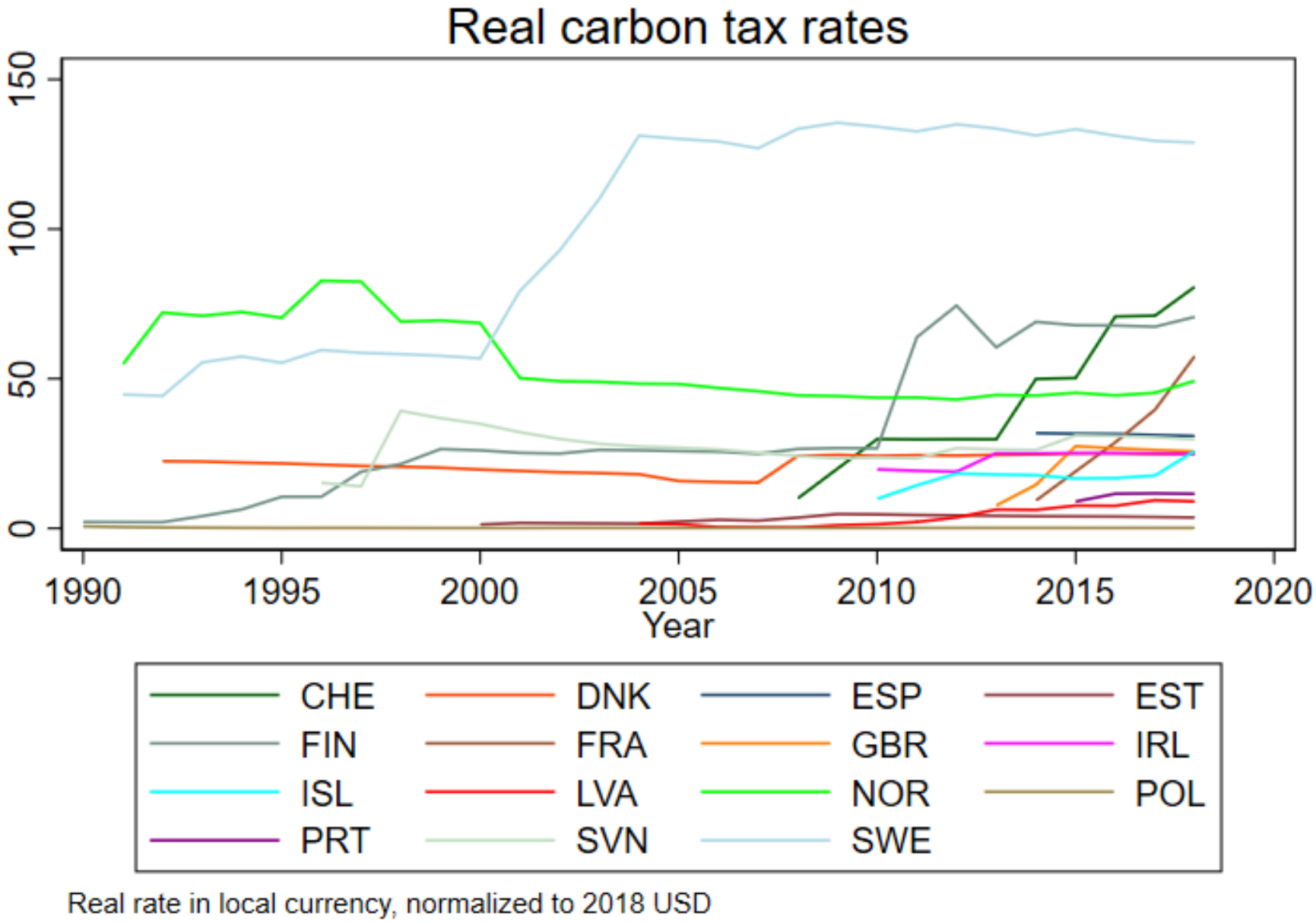
Data description

Carbon tax history for the 15 countries with carbon taxes

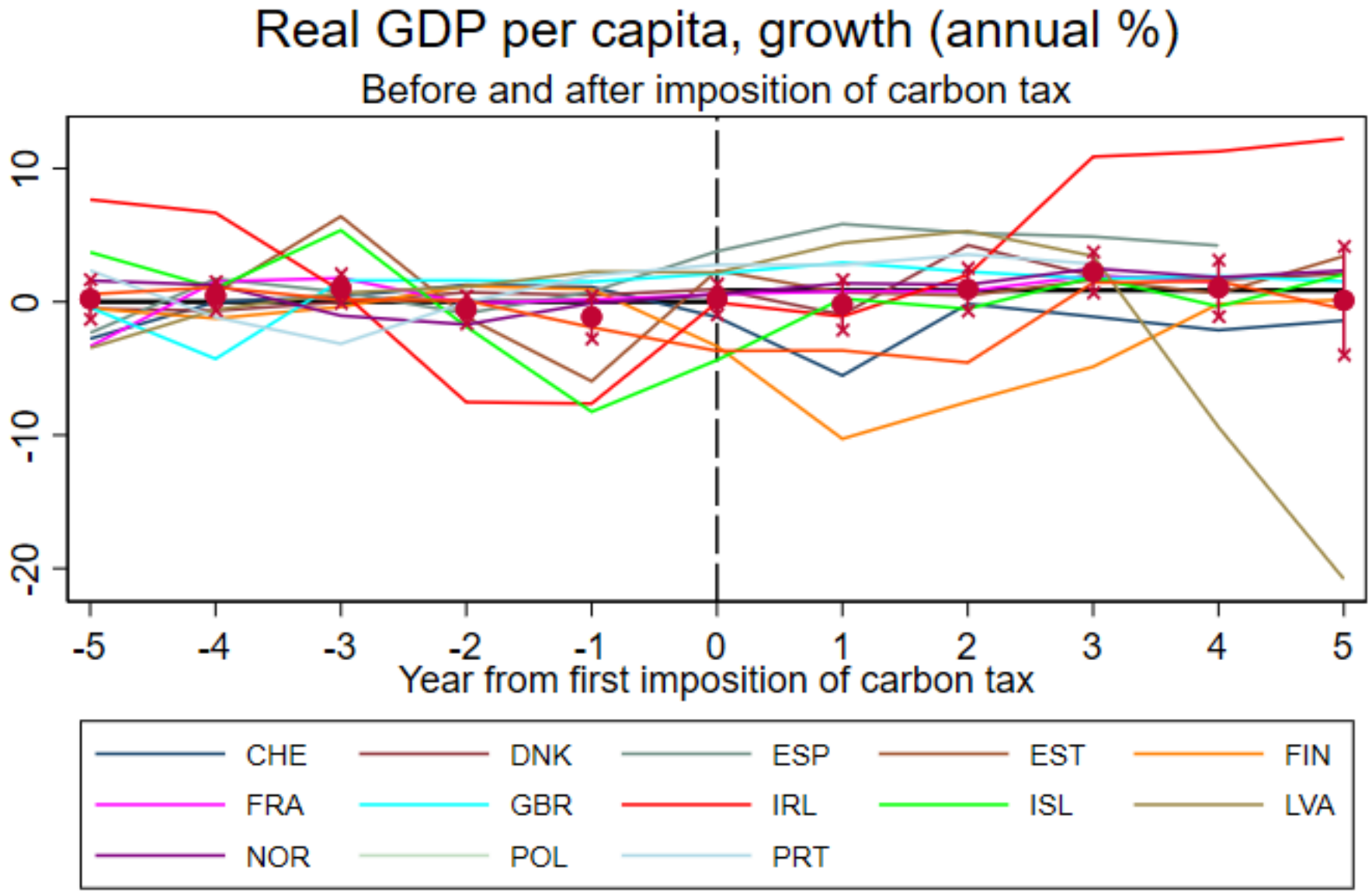
Data source: World Bank (carbon price data in press)

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

GDP growth: World Bank (except as noted below)



Data description



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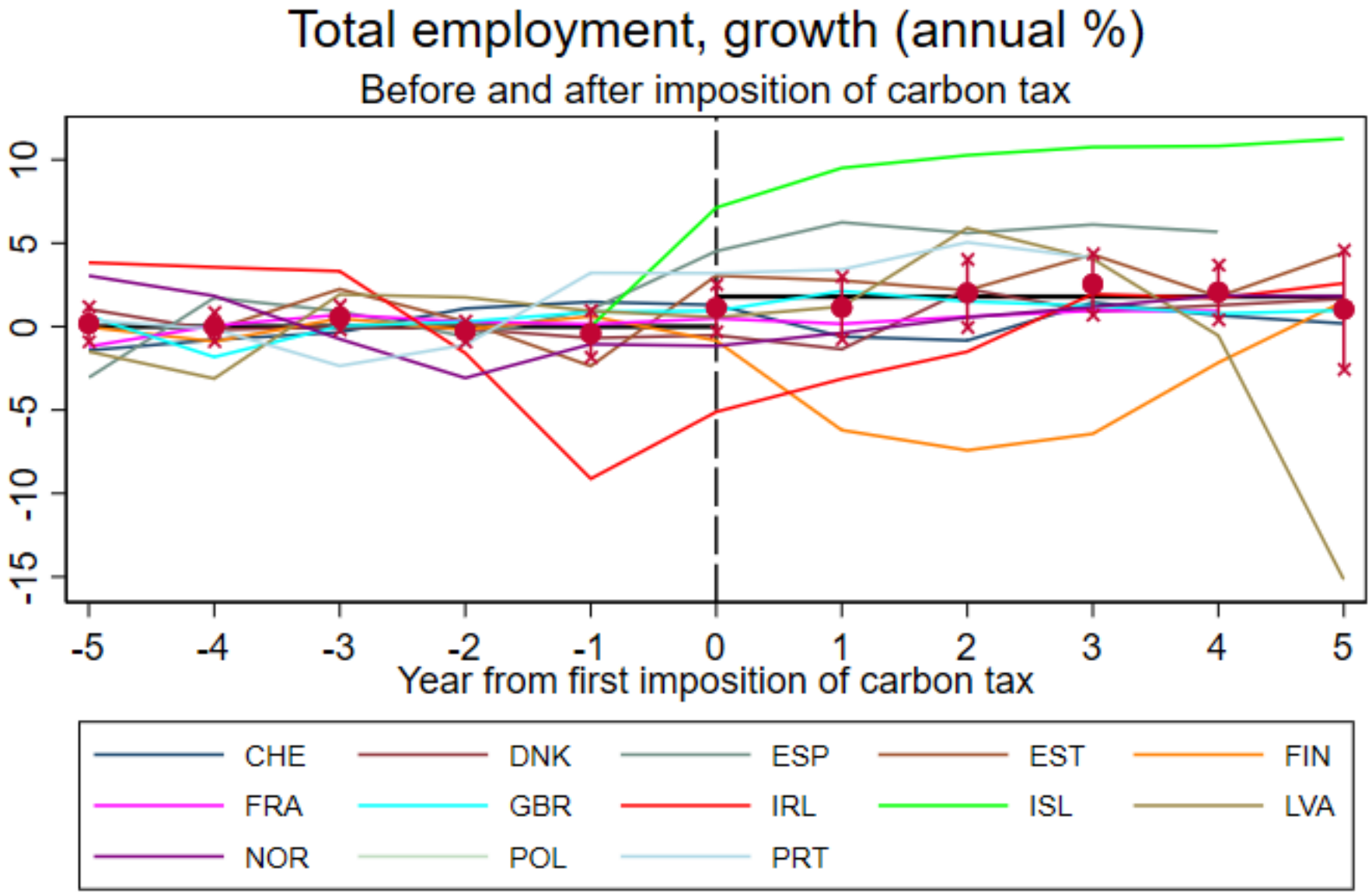
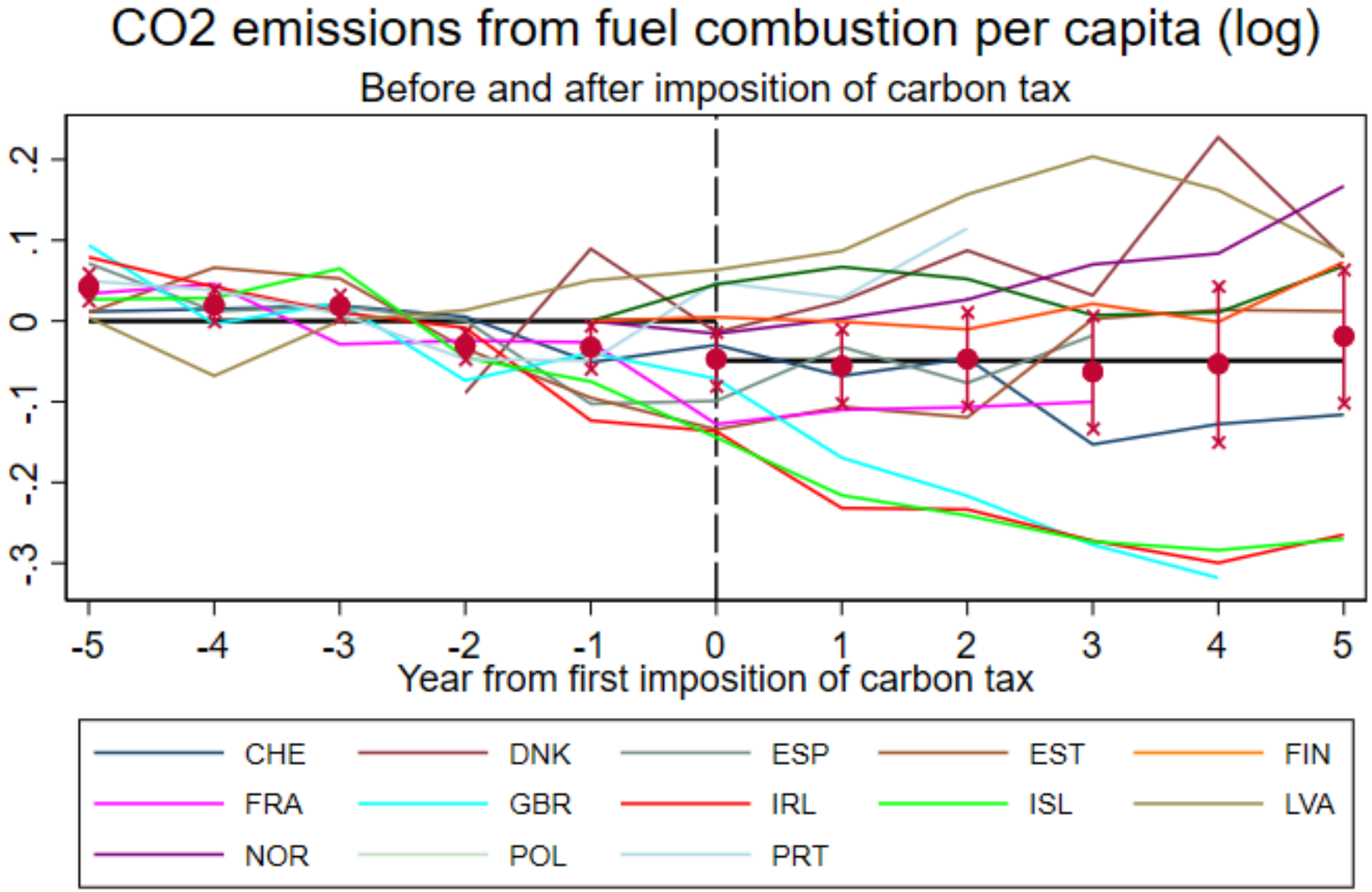


Deviated from country's pre-tax mean. Horizontal lines are pre/post means.
Dots and bars denote mean and 90% confidence interval by year.

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.

Methods: Regressions and identifying assumptions

- Estimand: cumulative dynamic causal effect of change in tax rate on real variables
- Three methods, two exogeneity conditions (identifying assumptions)

Distributed lag (panel)

$$\Delta \ln(GDP_t) = \beta_{yx}(\mathrm{L})\tau_t + \gamma(\mathrm{L})W_t + u_t$$

Exogeneity condition:

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

Local projections (panel)

Exogeneity condition:

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

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

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

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)

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 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 carbon tax change 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

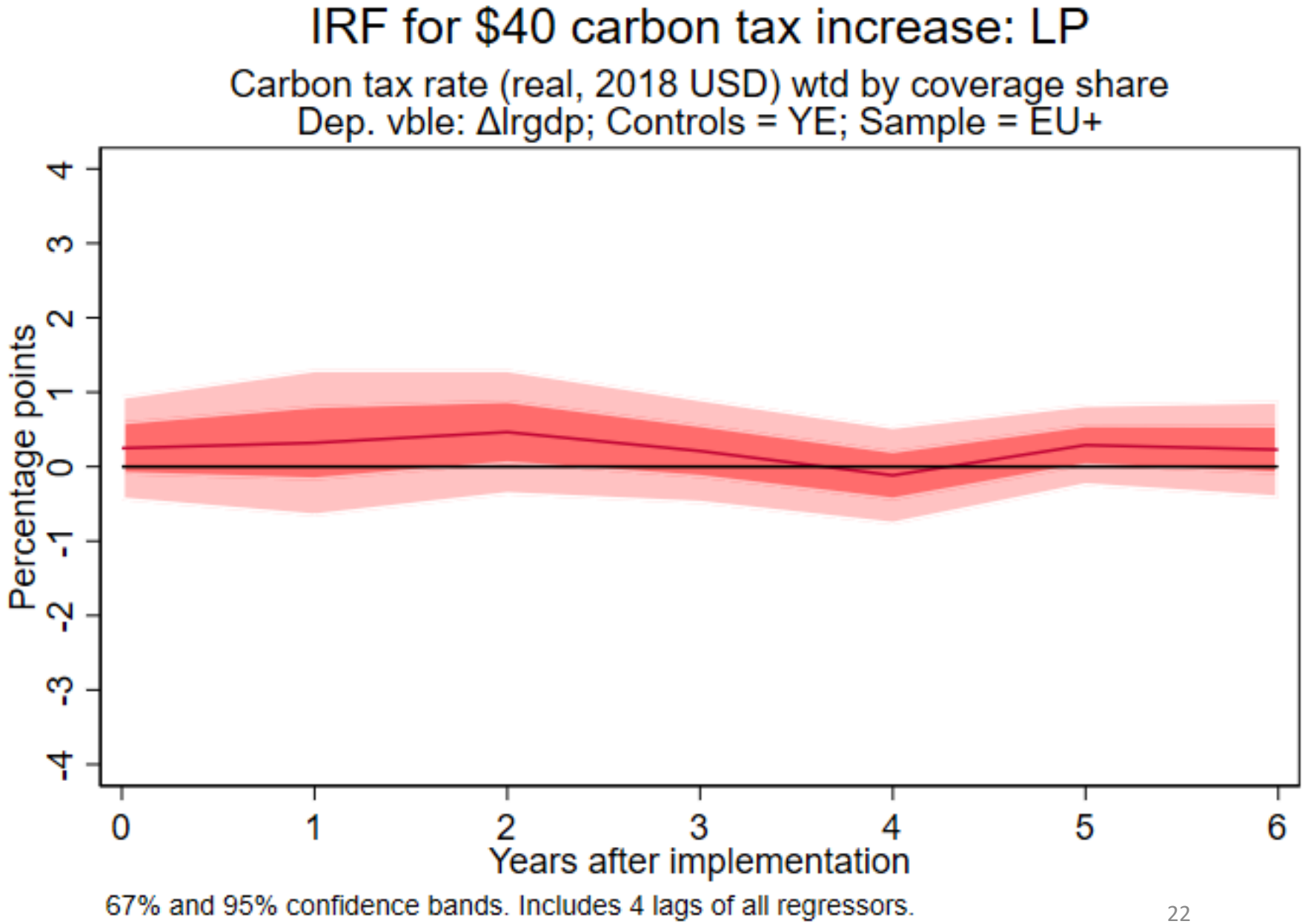
➢ Fail to reject "parallel paths" restriction

	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**
Unrestricted



Results: GDP growth

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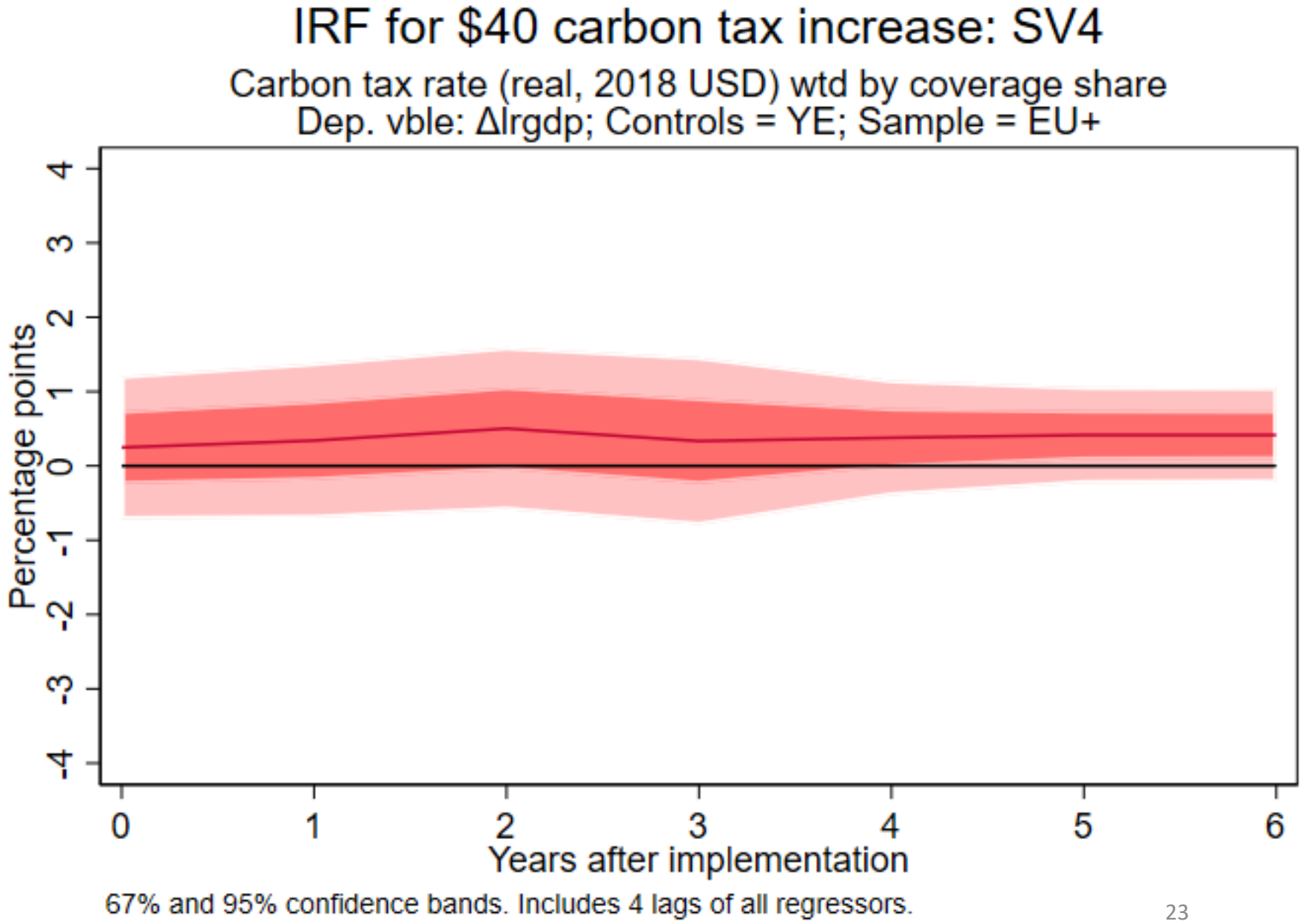
Unrestricted



Results: GDP growth

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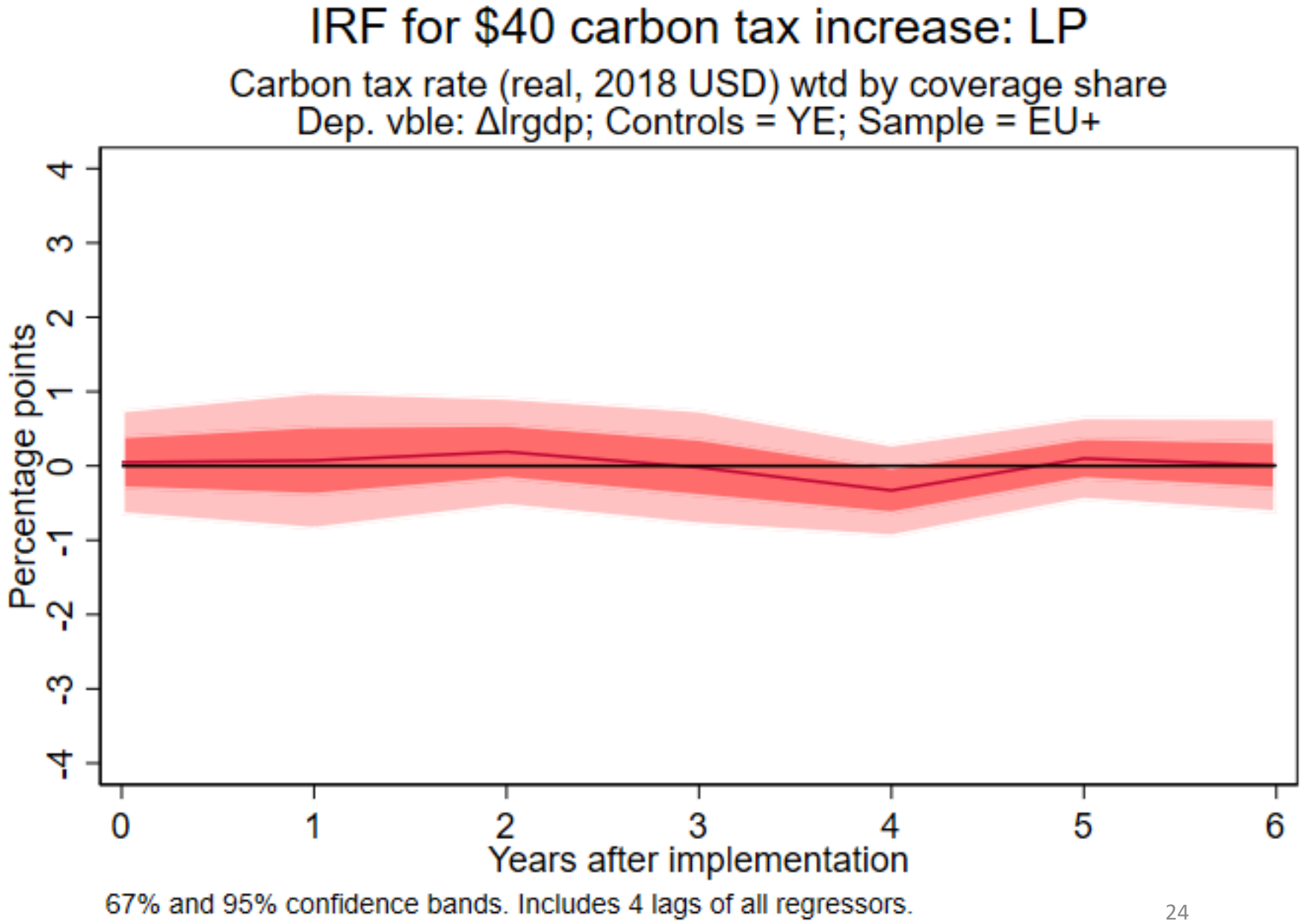

Results: GDP growth

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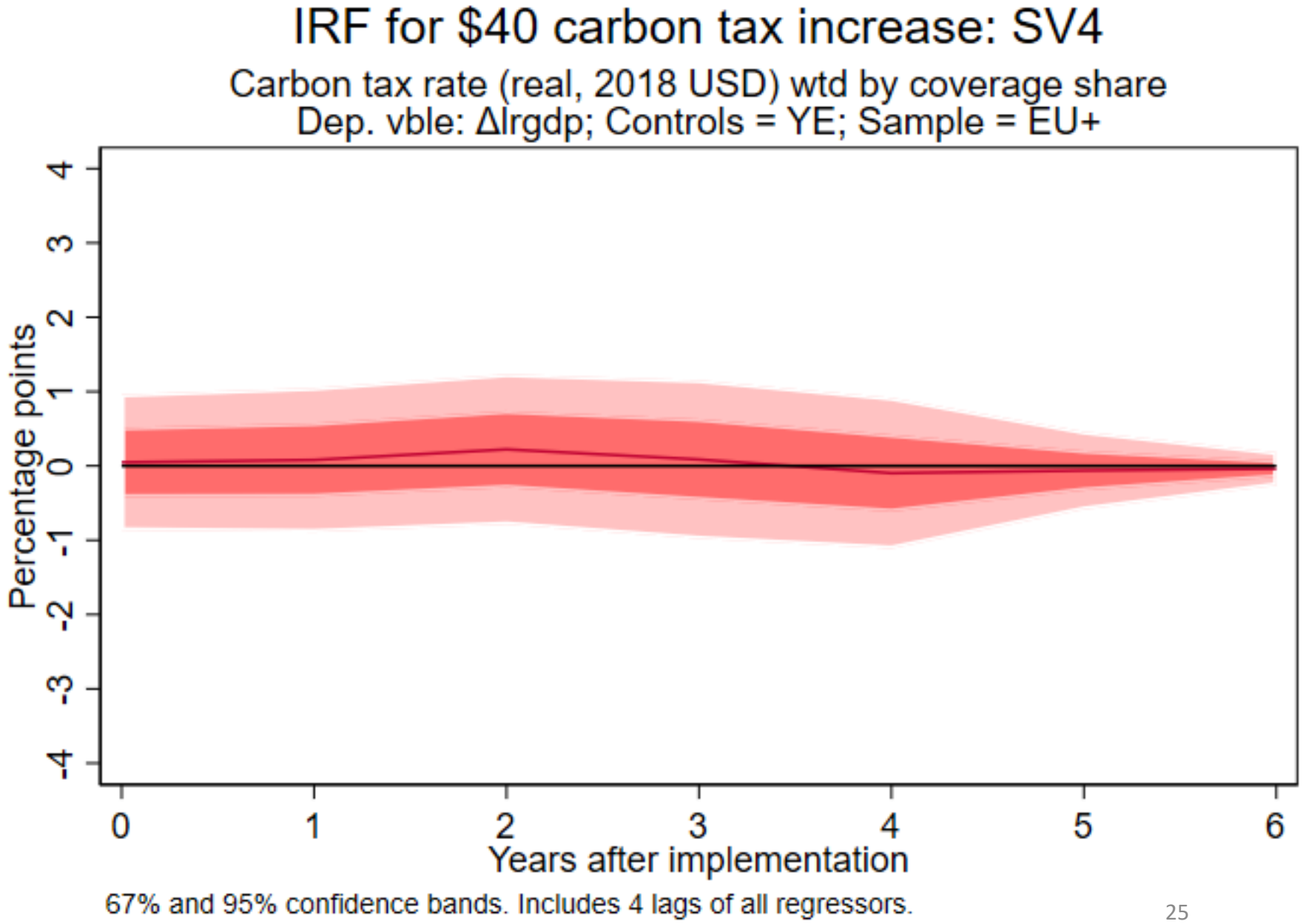


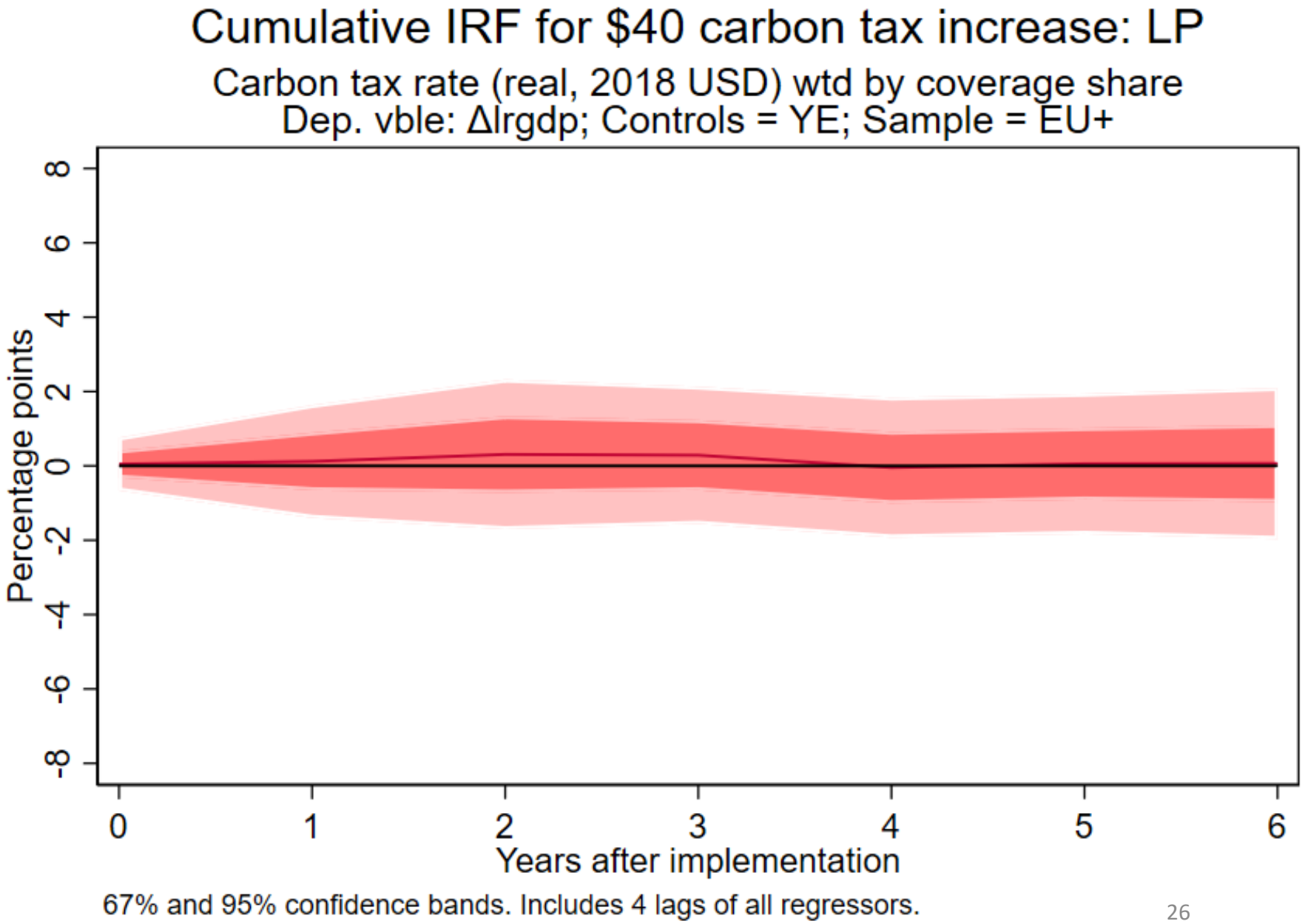
Results: GDP growth

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



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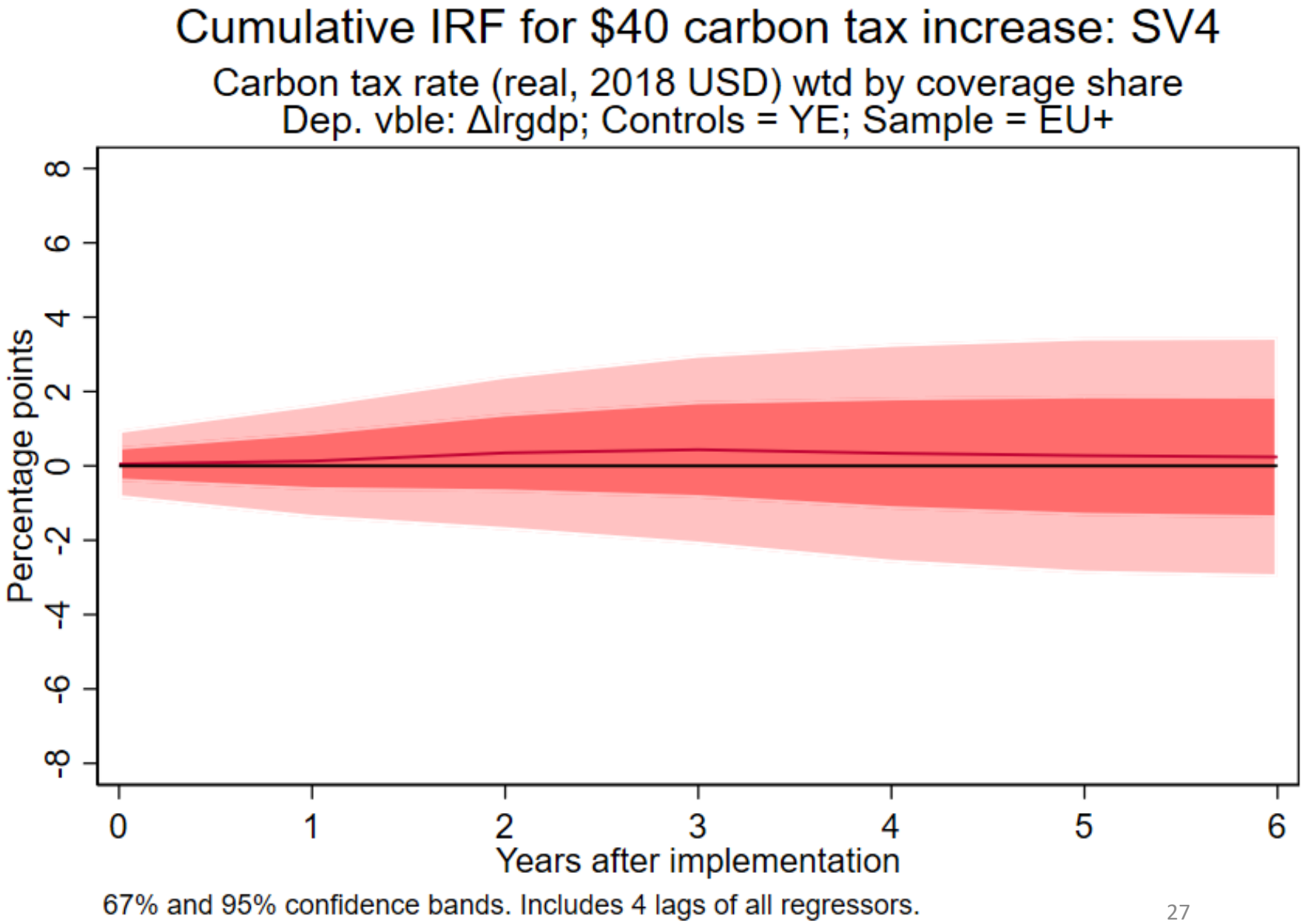
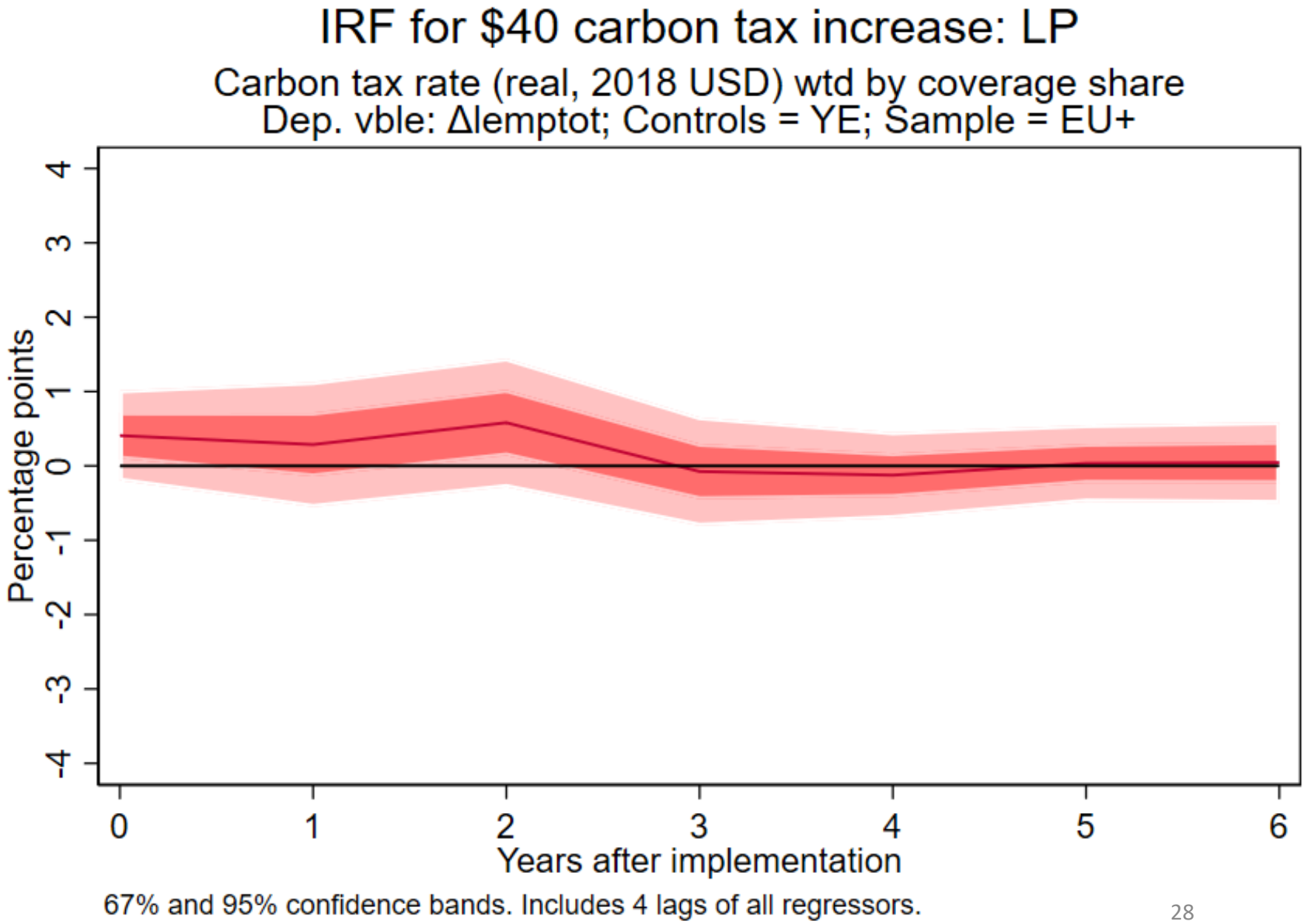


Results: Employment

Sample: **EU+**

Method: **LP**
Unrestricted



Results: Employment

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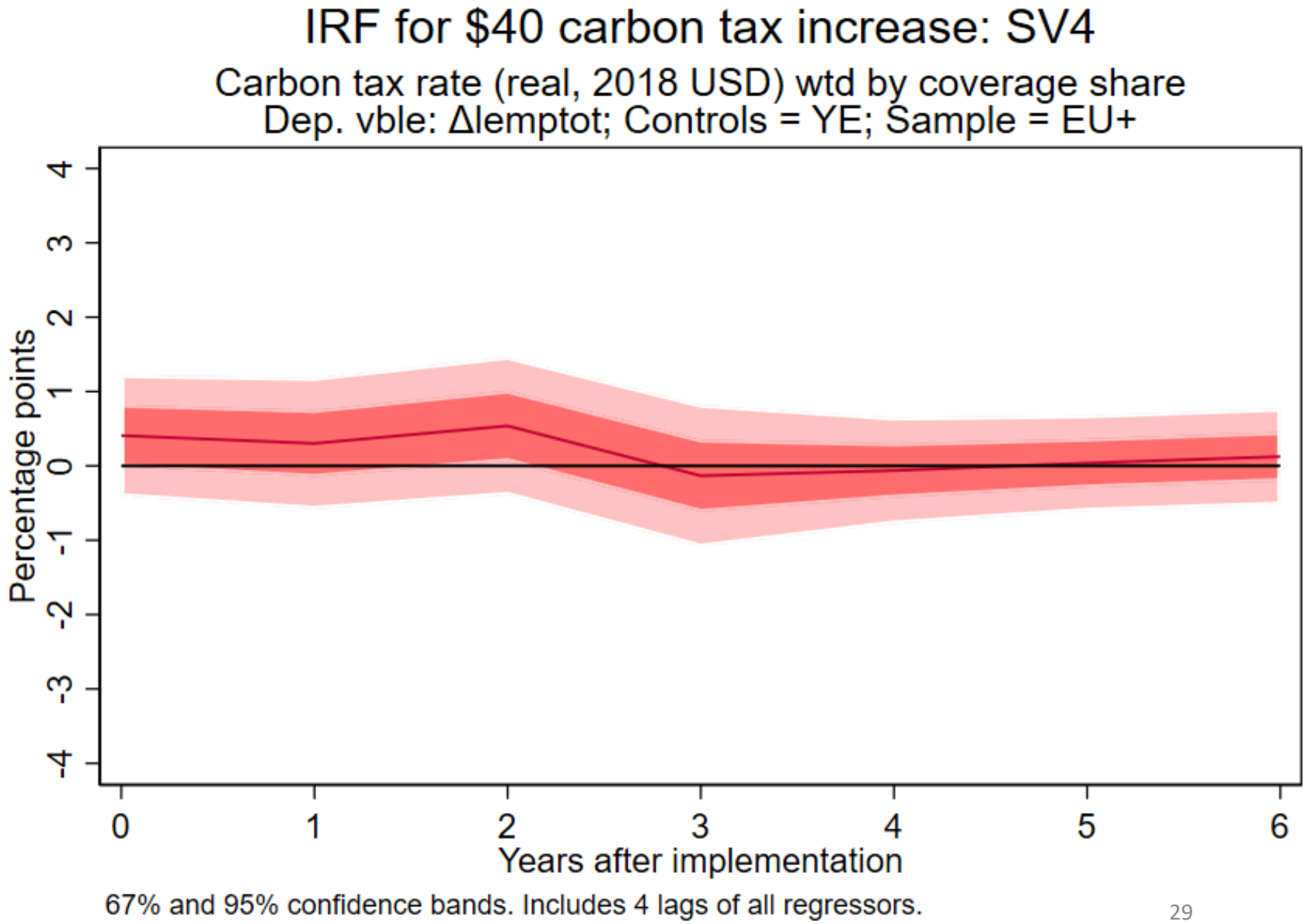
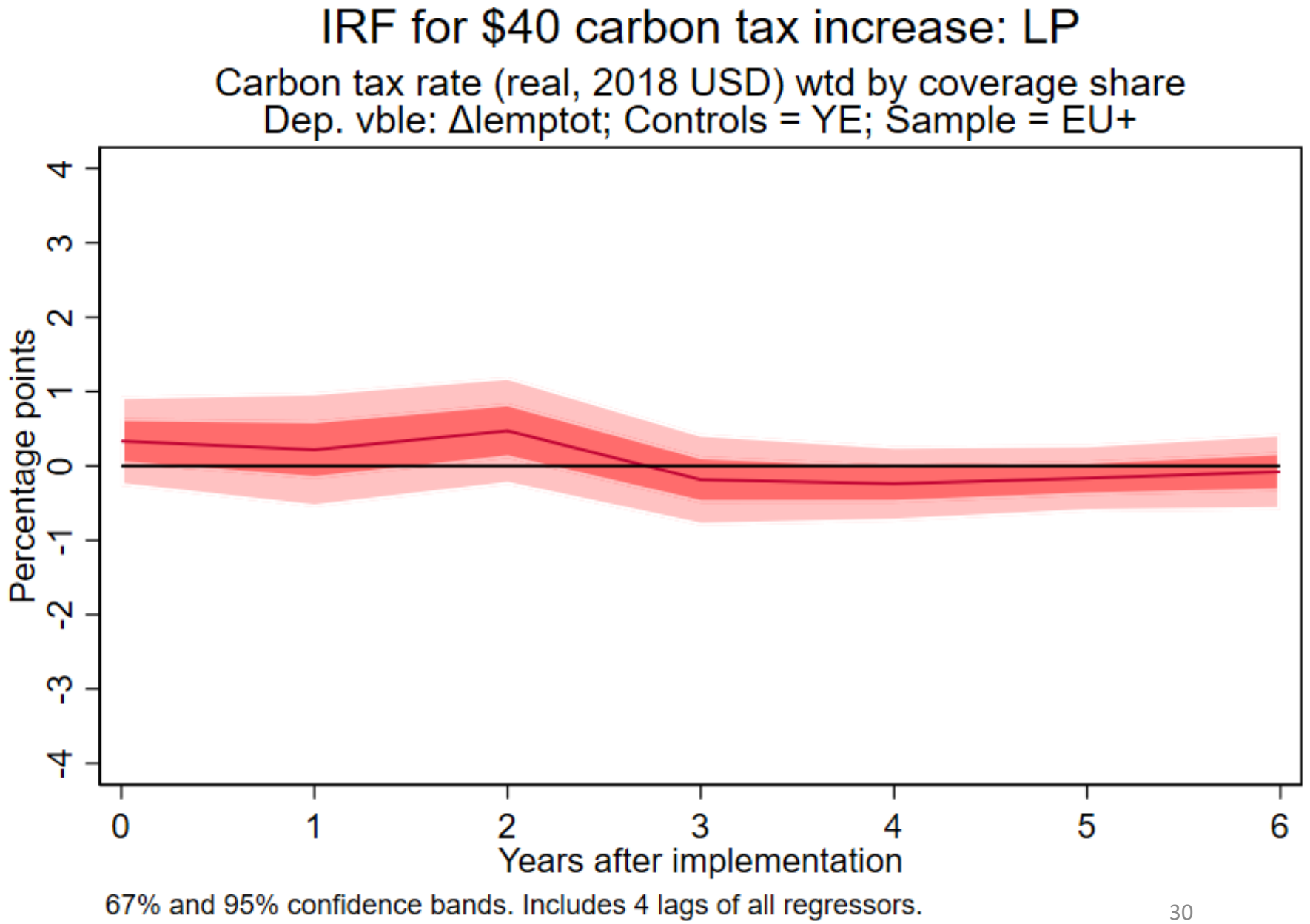


Results: Employment

Sample: **EU+**

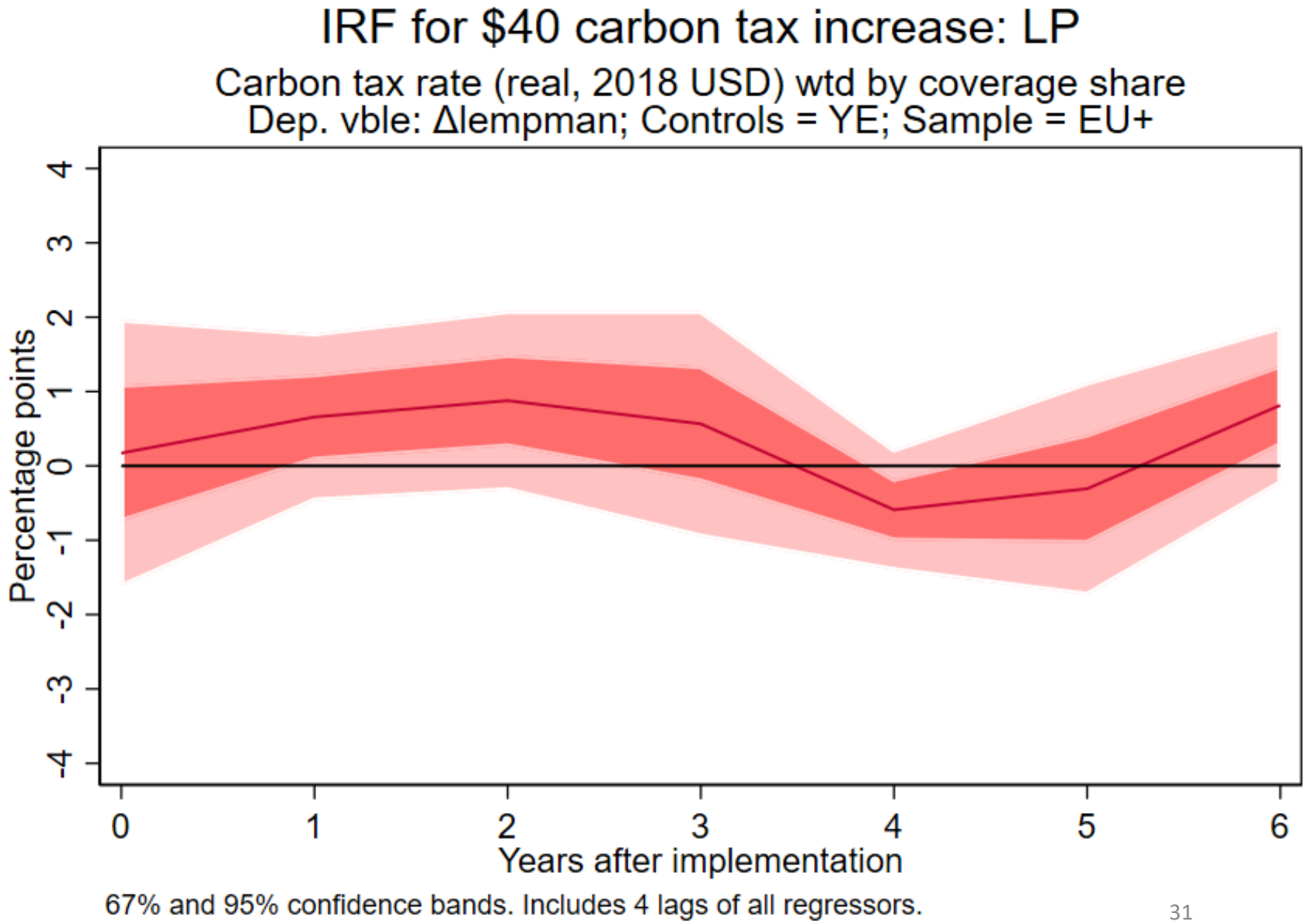
Method: **LP**
Restricted



Results: Manufacturing Employment

Sample: **EU+**

Method: **LP**
Restricted



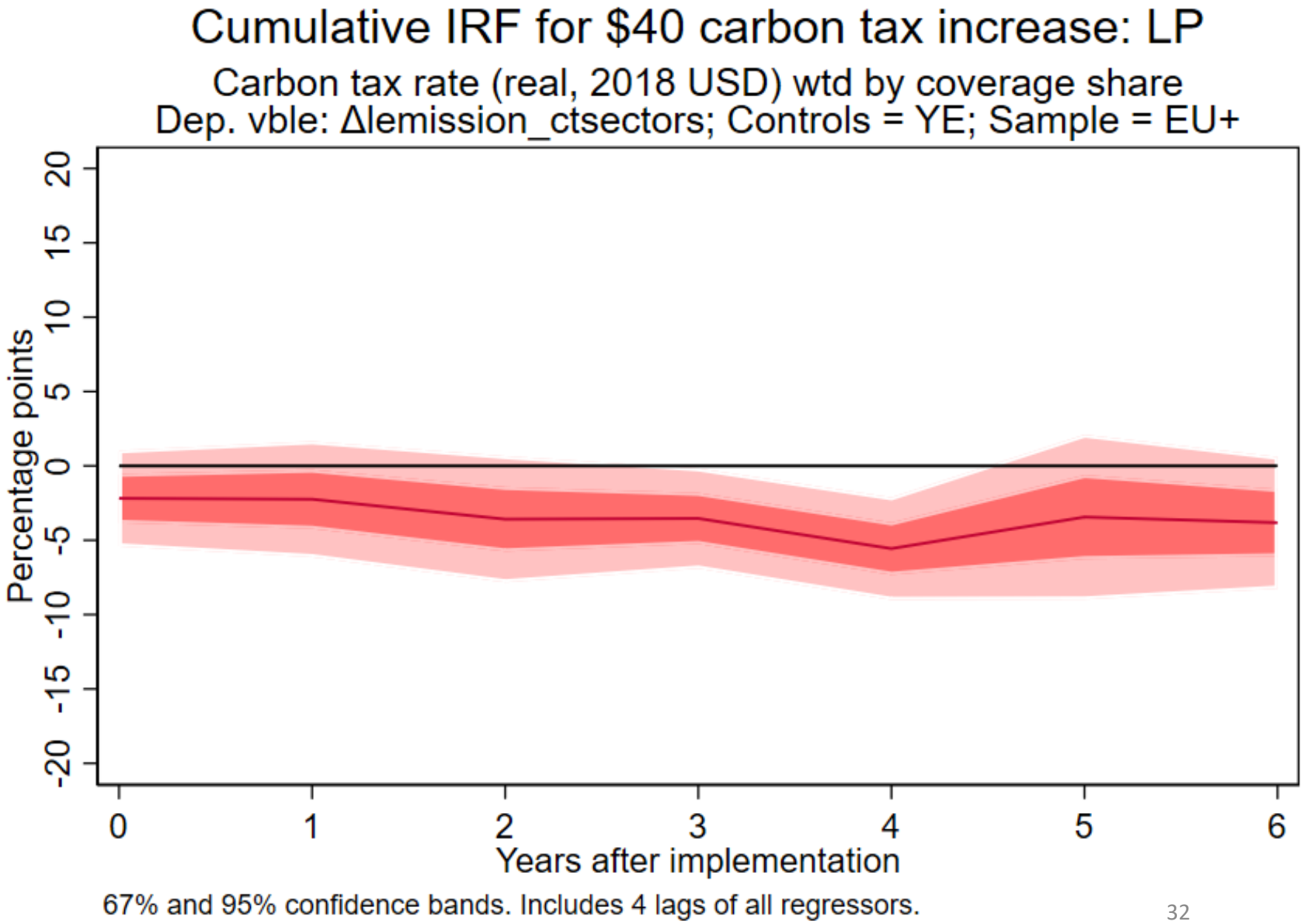
Results: Emissions

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



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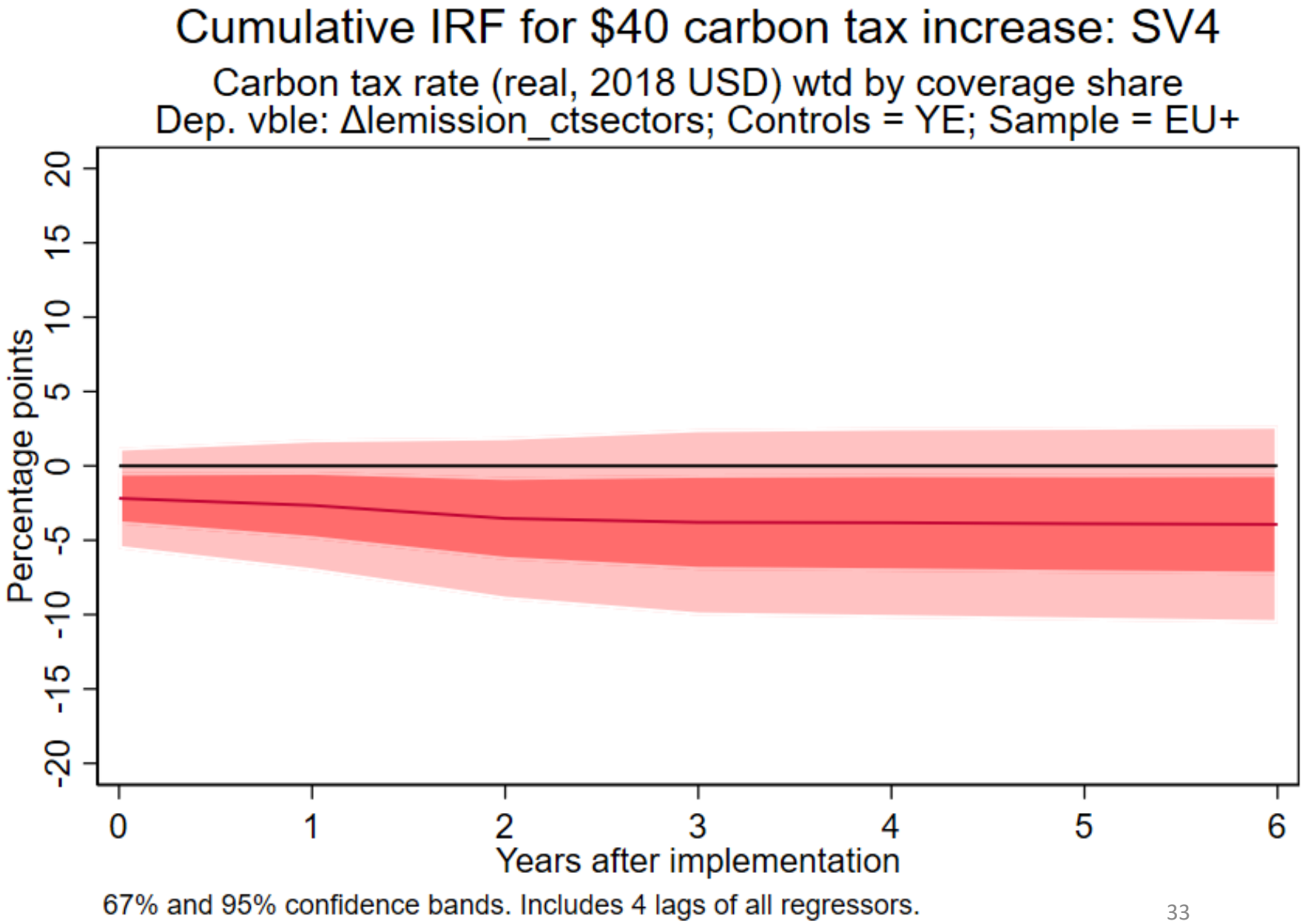

Results: Emissions

Sample: **EU+**

Method: **LP**
Restricted
Cumulative IRF

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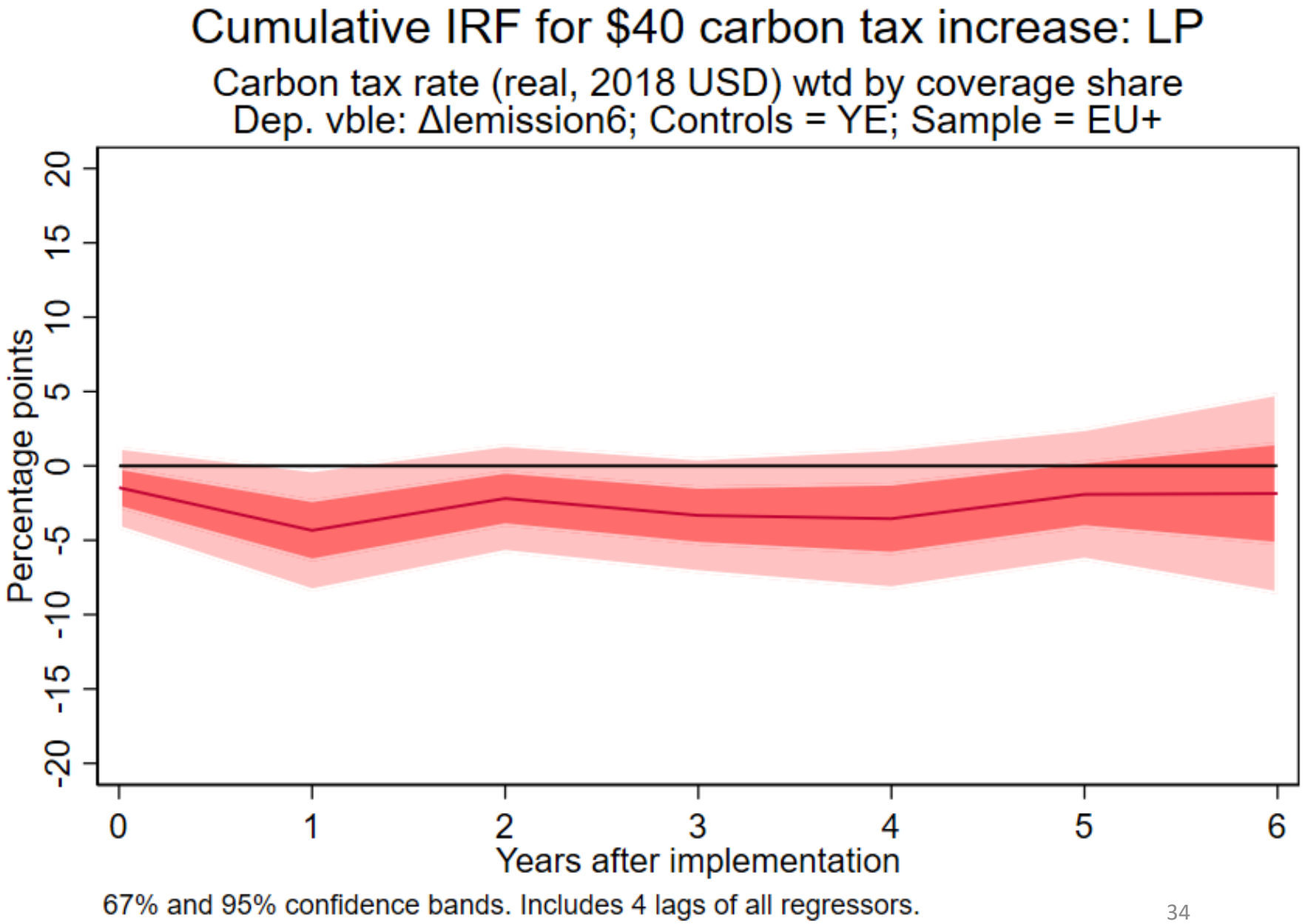
Emissions series:
Emissions from fuel consumption



Results: Additional questions + sensitivity analysis

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

2. 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)**

3. Sensitivity check:
   - Dolphin et al. (2019) tax rate series
     - ➢ **Essentially no difference in results, see the paper**

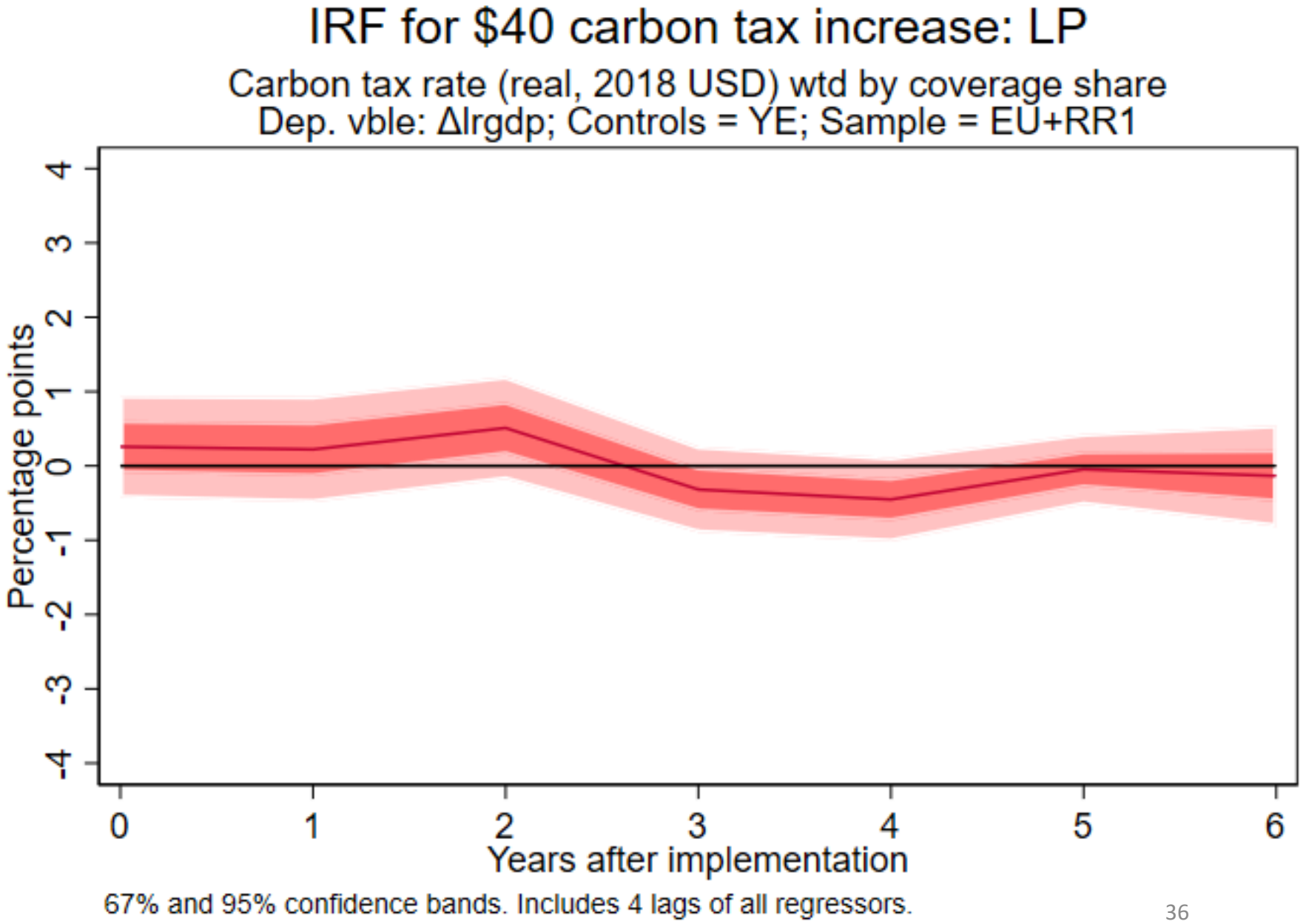
Results: Effect of revenue recycling

Sample: **EU+**
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+**
No revenue recycling

Dep vble: **GDP growth**

Method: **LP**
Restricted

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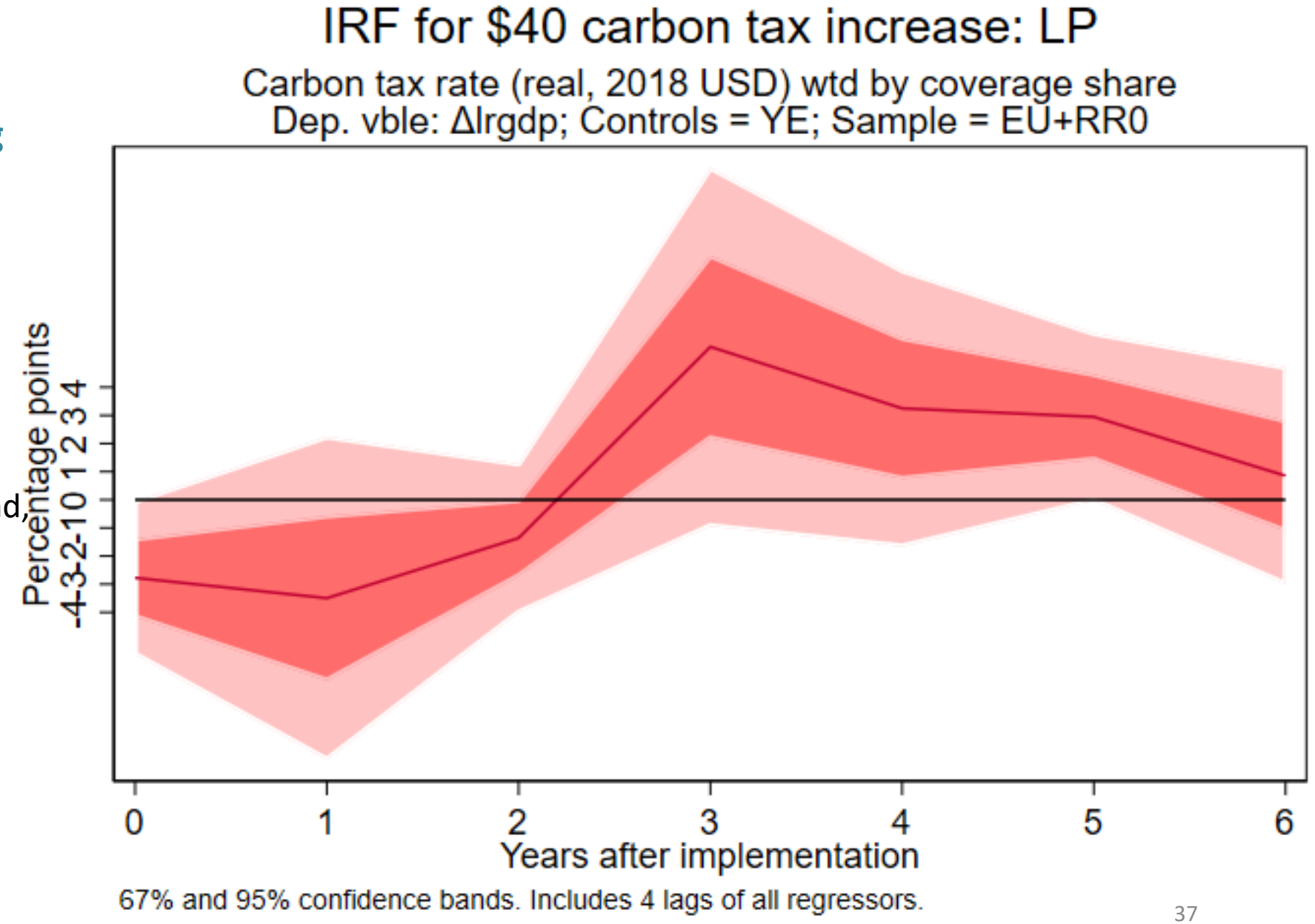

Results: Effect of revenue recycling

Sample: **EU+**
Revenue recycling

Dep vble: **Empl. growth**

Method: **LP**
Restricted

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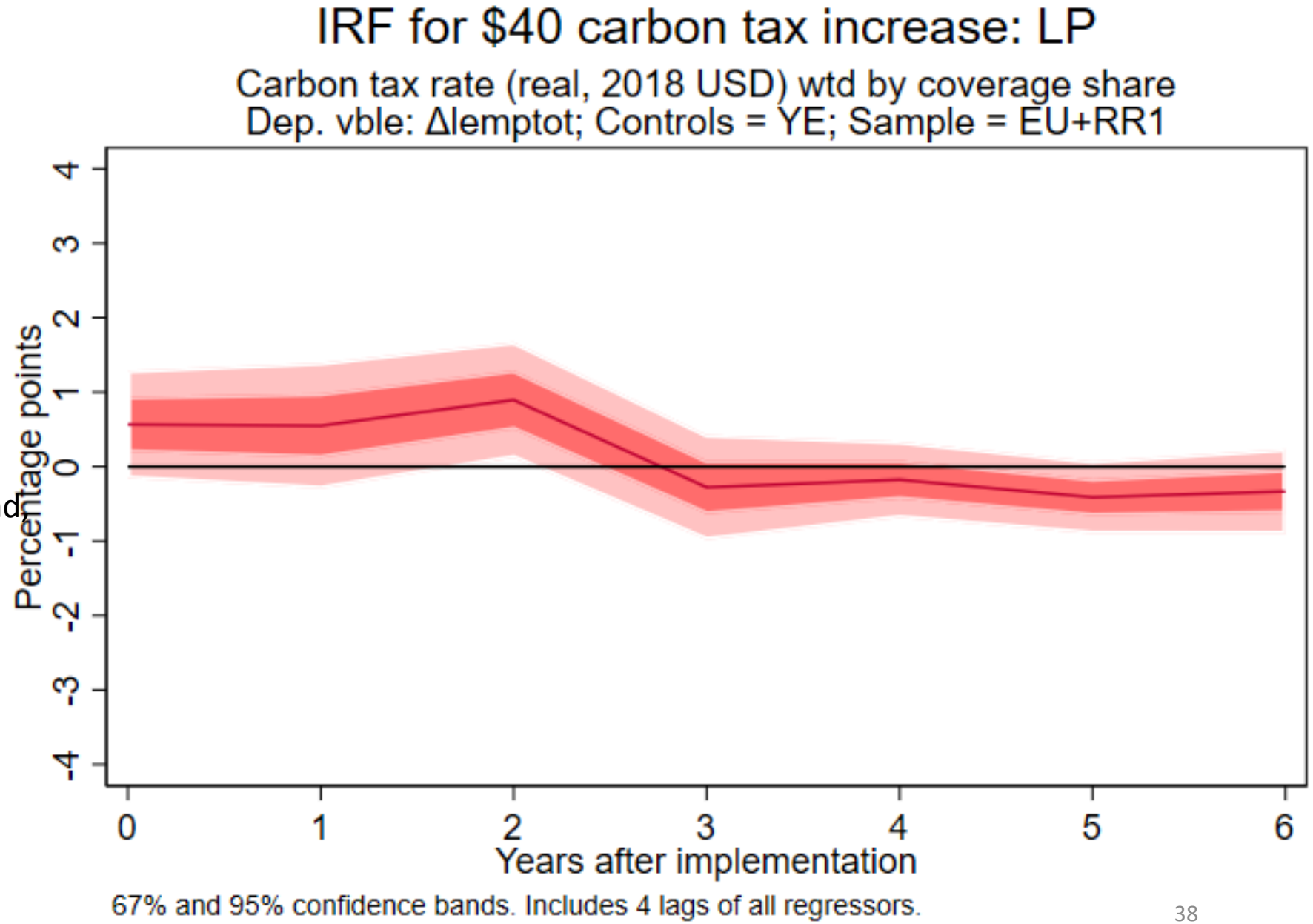

Results: Effect of revenue recycling

Sample: **EU+**
No revenue recycling

Dep vble: **Empl. growth**

Method: **LP**
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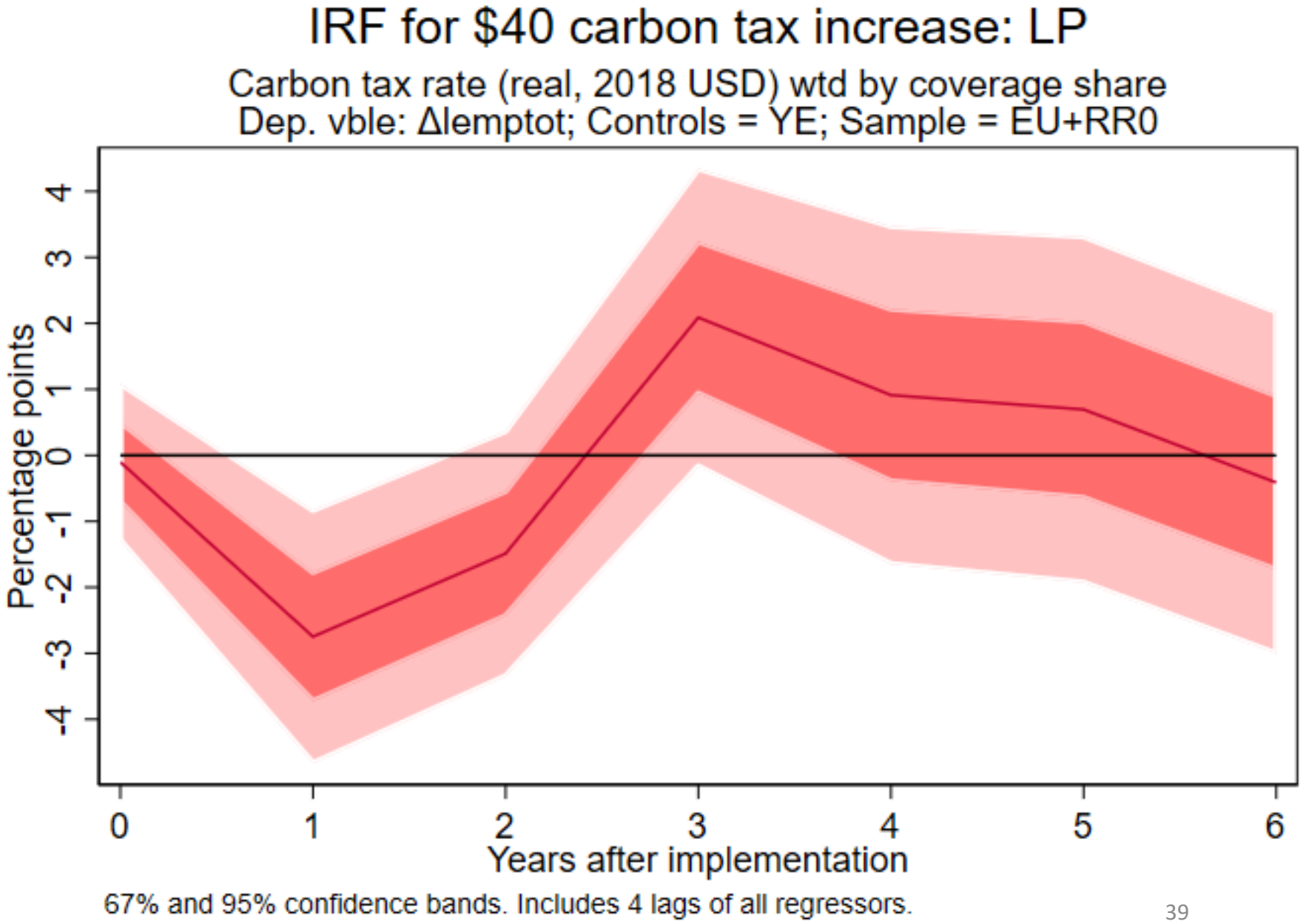
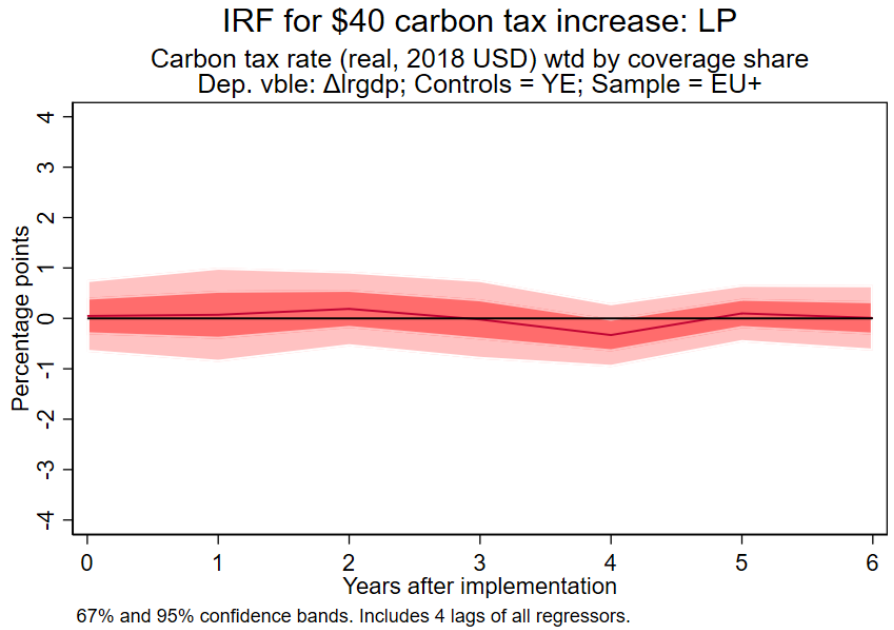
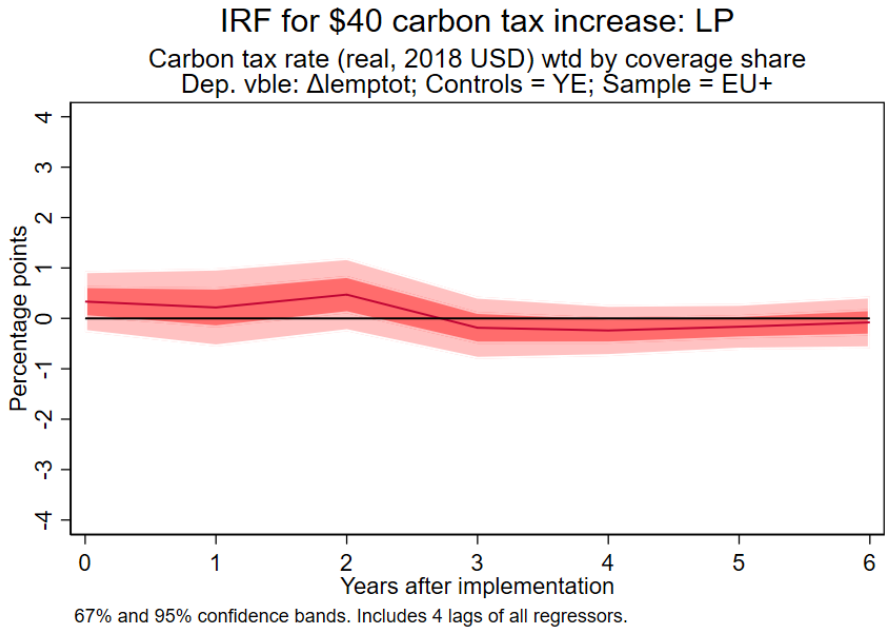


Summary

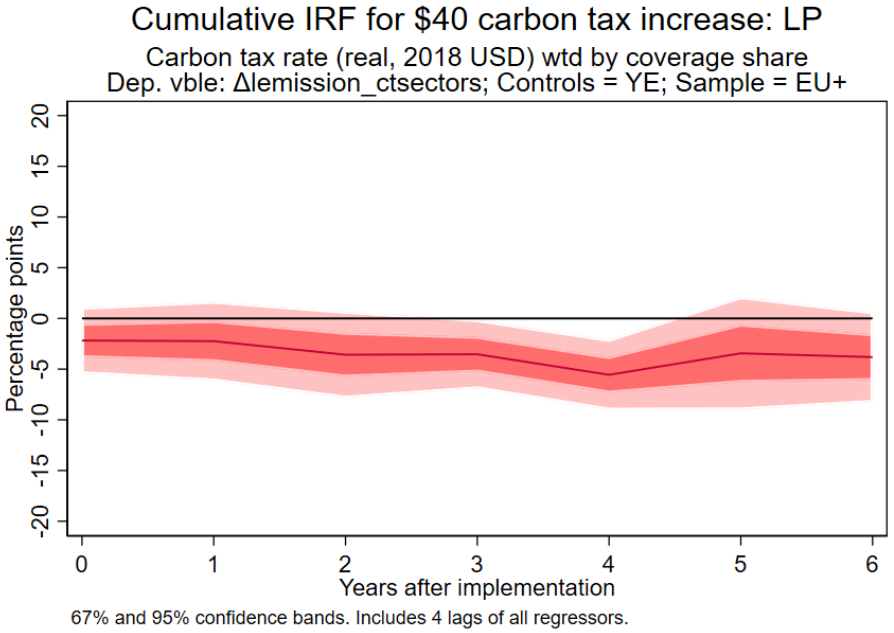
GDP



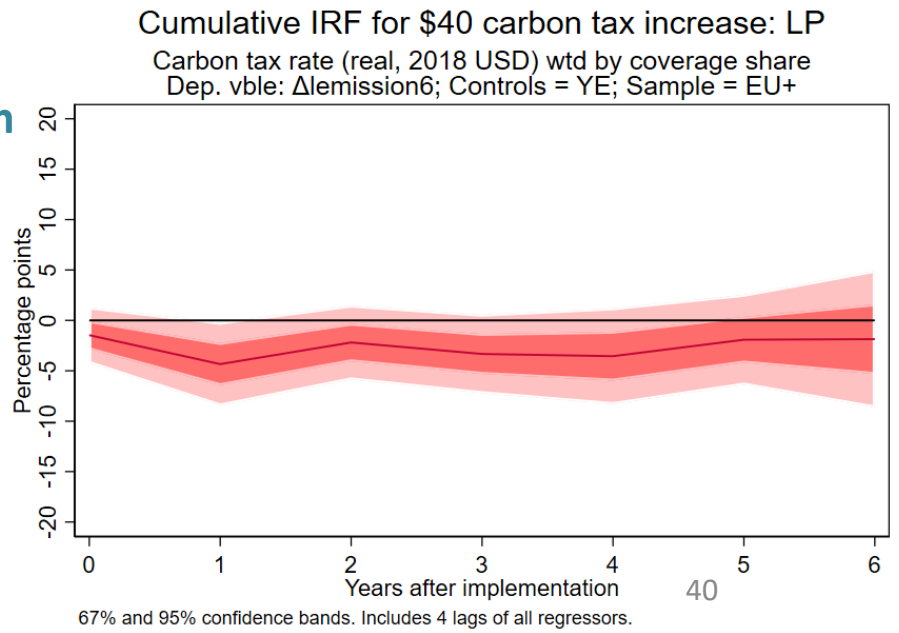
Employment



Emissions from transportation, commercial, & HH sectors



Emissions from fuel consumption



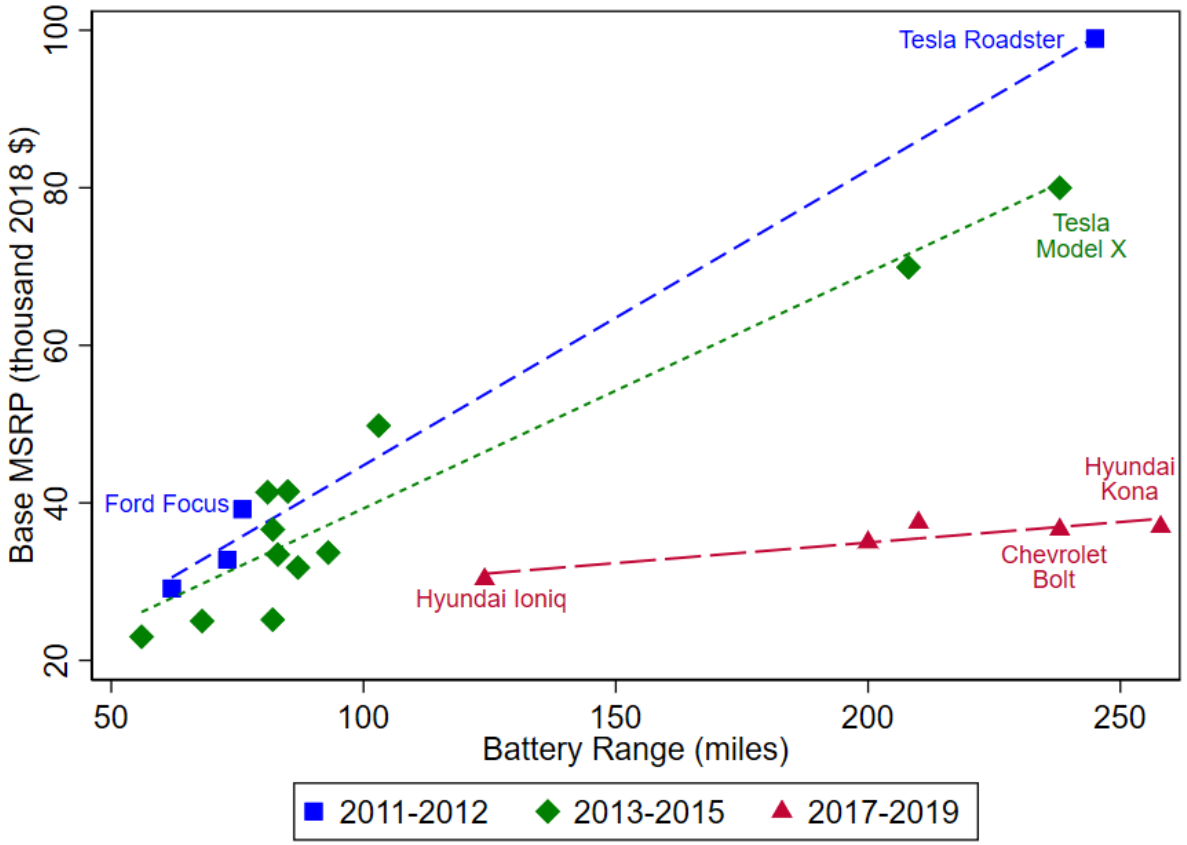
Discussion

Caveats/comments on this paper:

- **Spillover effects on comparison group (countries that don't increase CT)**
  - (treatment affects 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**

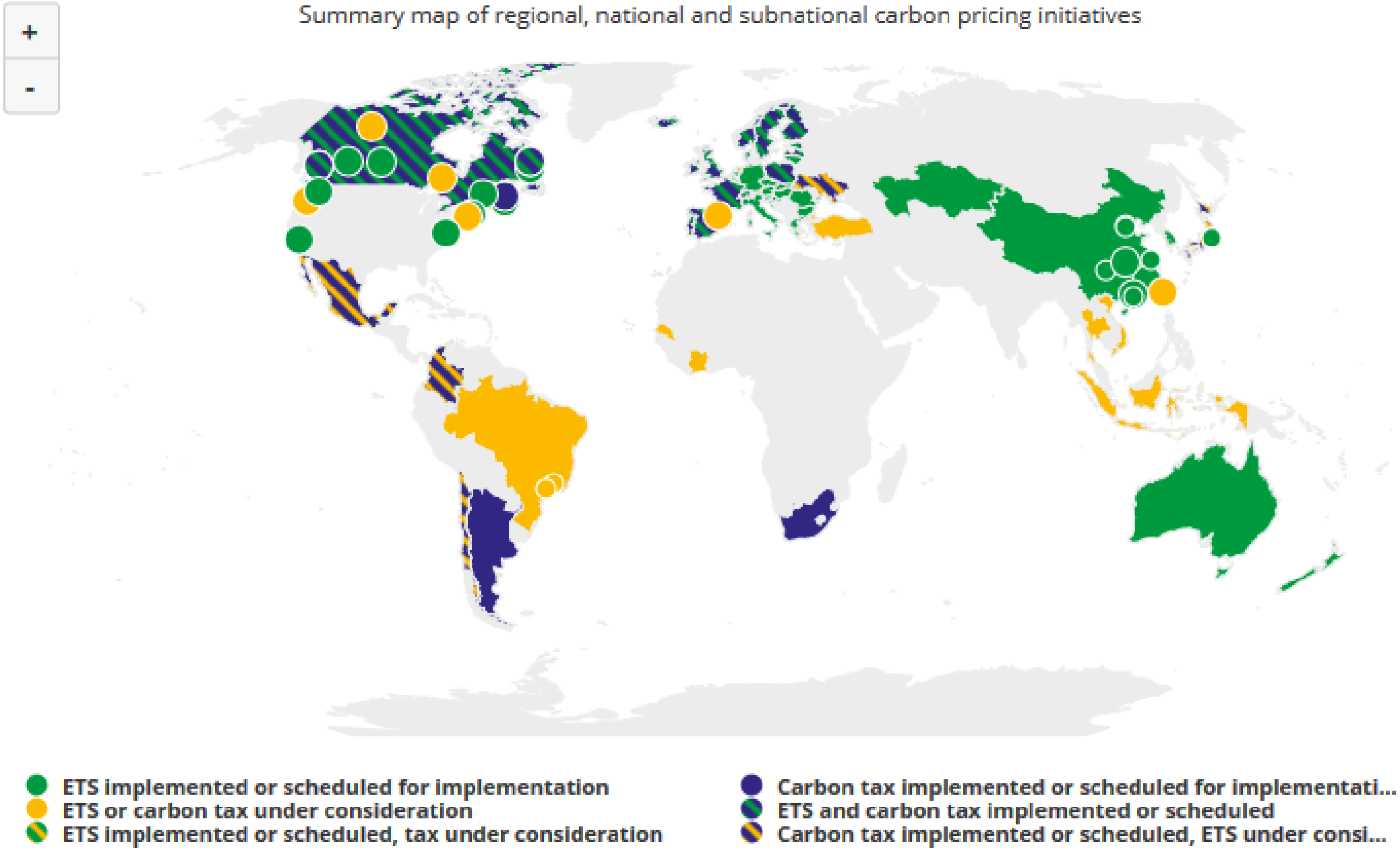
Bigger picture:

- **Outside of the power sector, a carbon tax has little effect on emissions**
  - $40/ton ≈ 40¢/gallon of gasoline
- **The energy transition must be affordable so consumers *choose* clean technologies**
  - ➢ Critical role for (smart) technology policy



Additional Slides

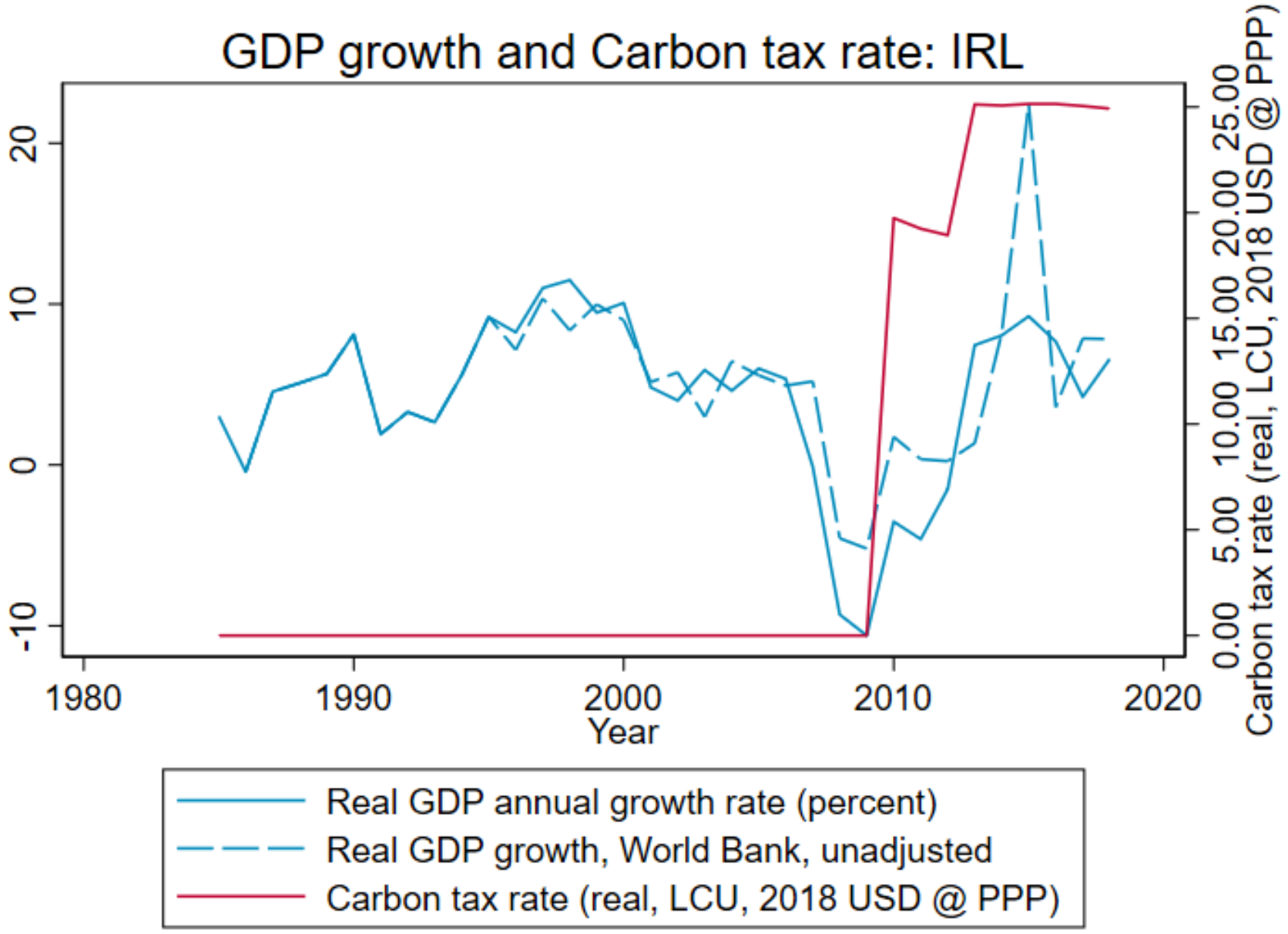
More details on carbon pricing schemes internationally



Data odds and ends

Ireland:

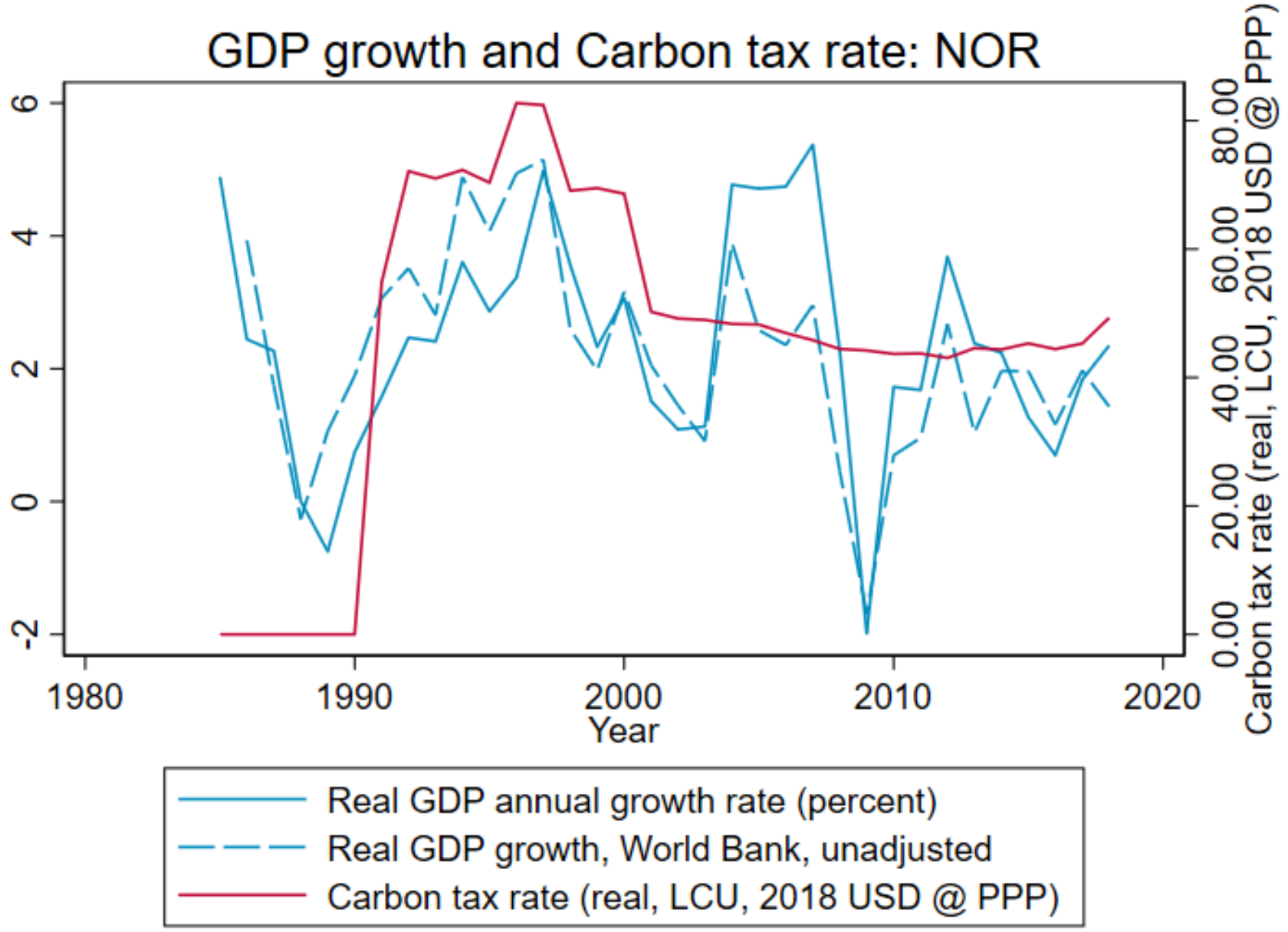
Replace World Bank GDP data with adjusted Irish statistical agency data



Data odds and ends

Norway:

Use “Onshore GDP” from Statistics Norway



Data odds and ends

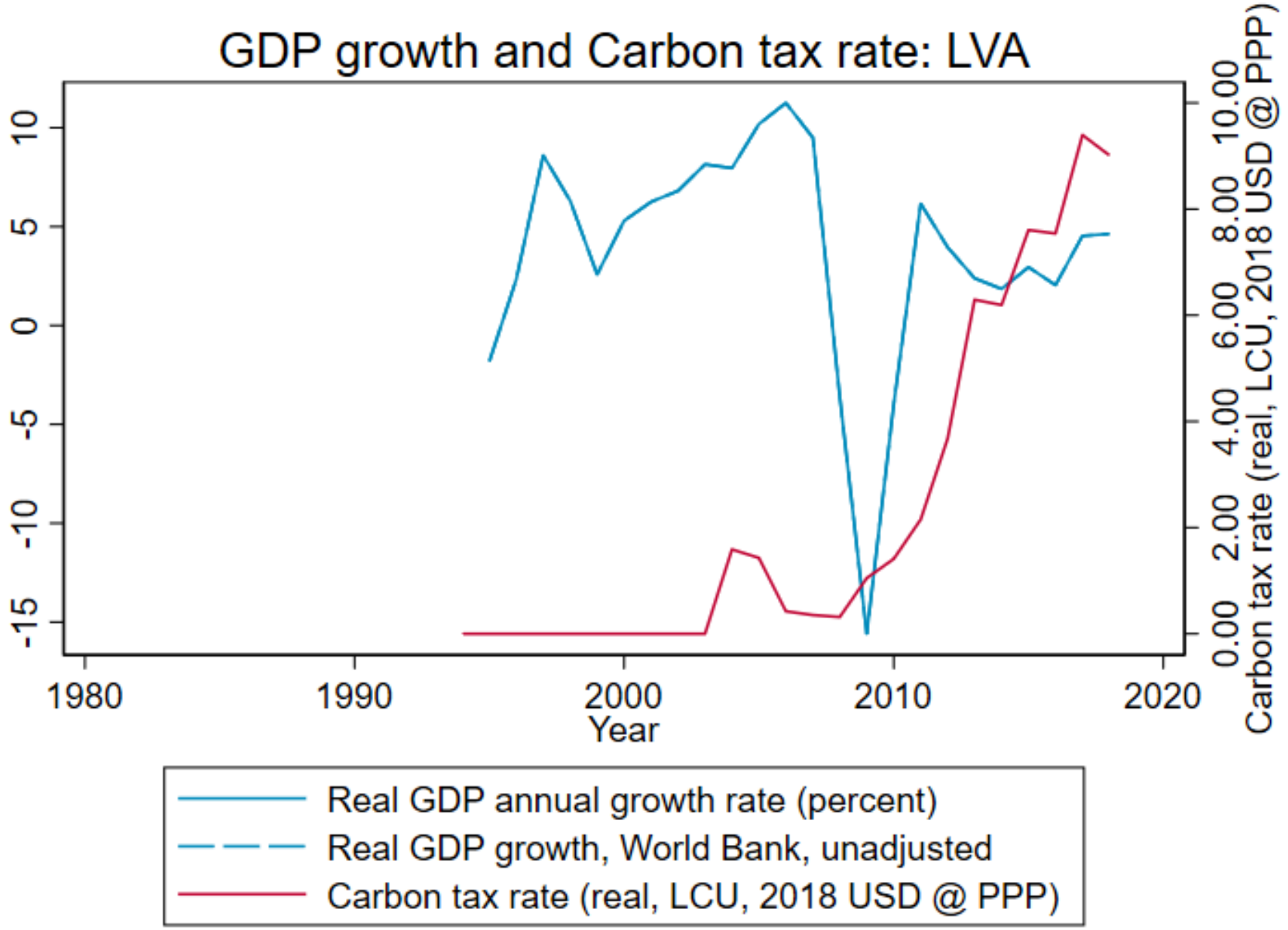
Latvia:

No adjustments

Latvia joined the EU In 2004 and adopted the Euro in 2014.

<u>Reference</u>

Åslund and Dombrovskis (PIIE, 2011)

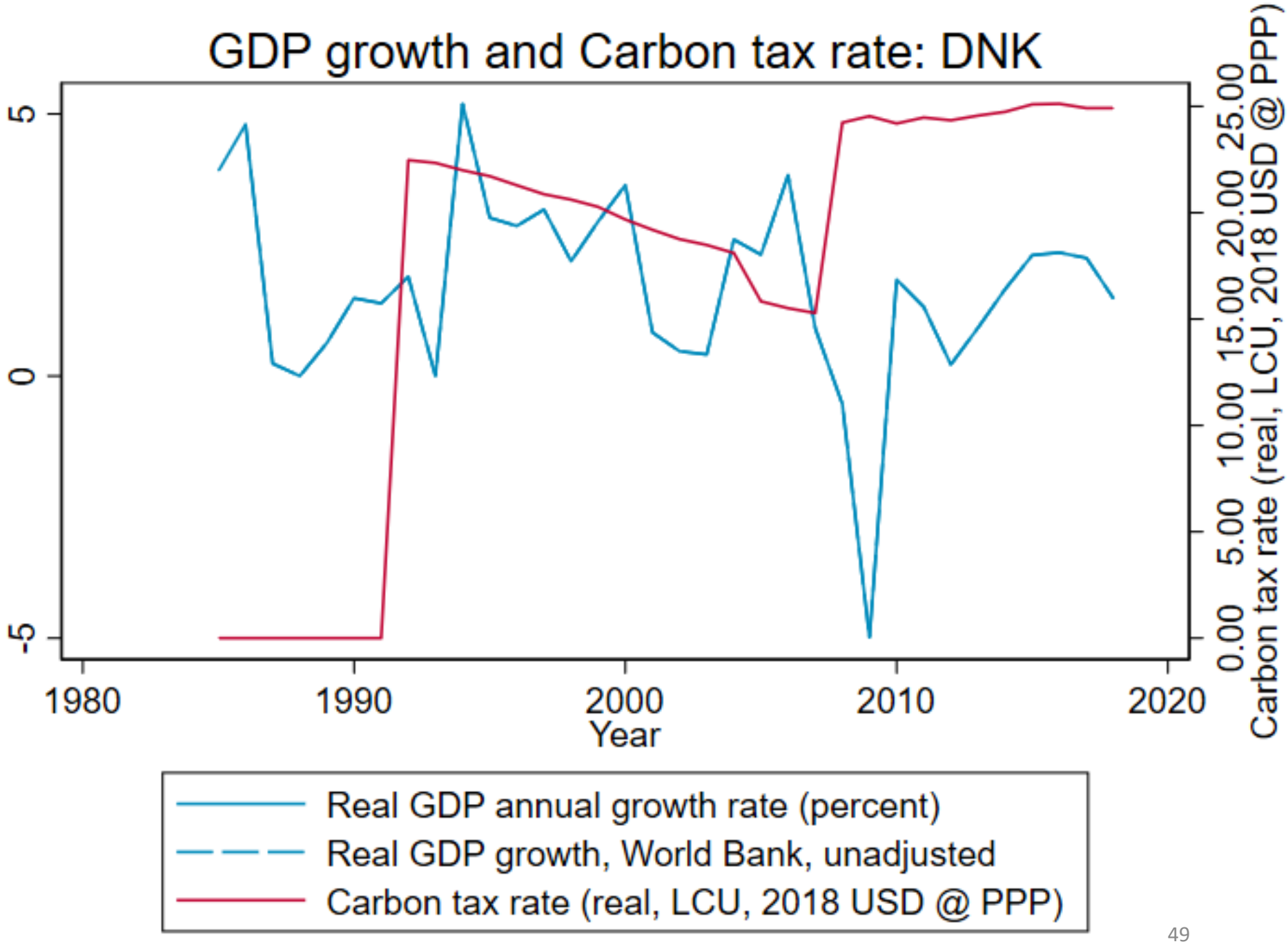


Focus on Scandinavia

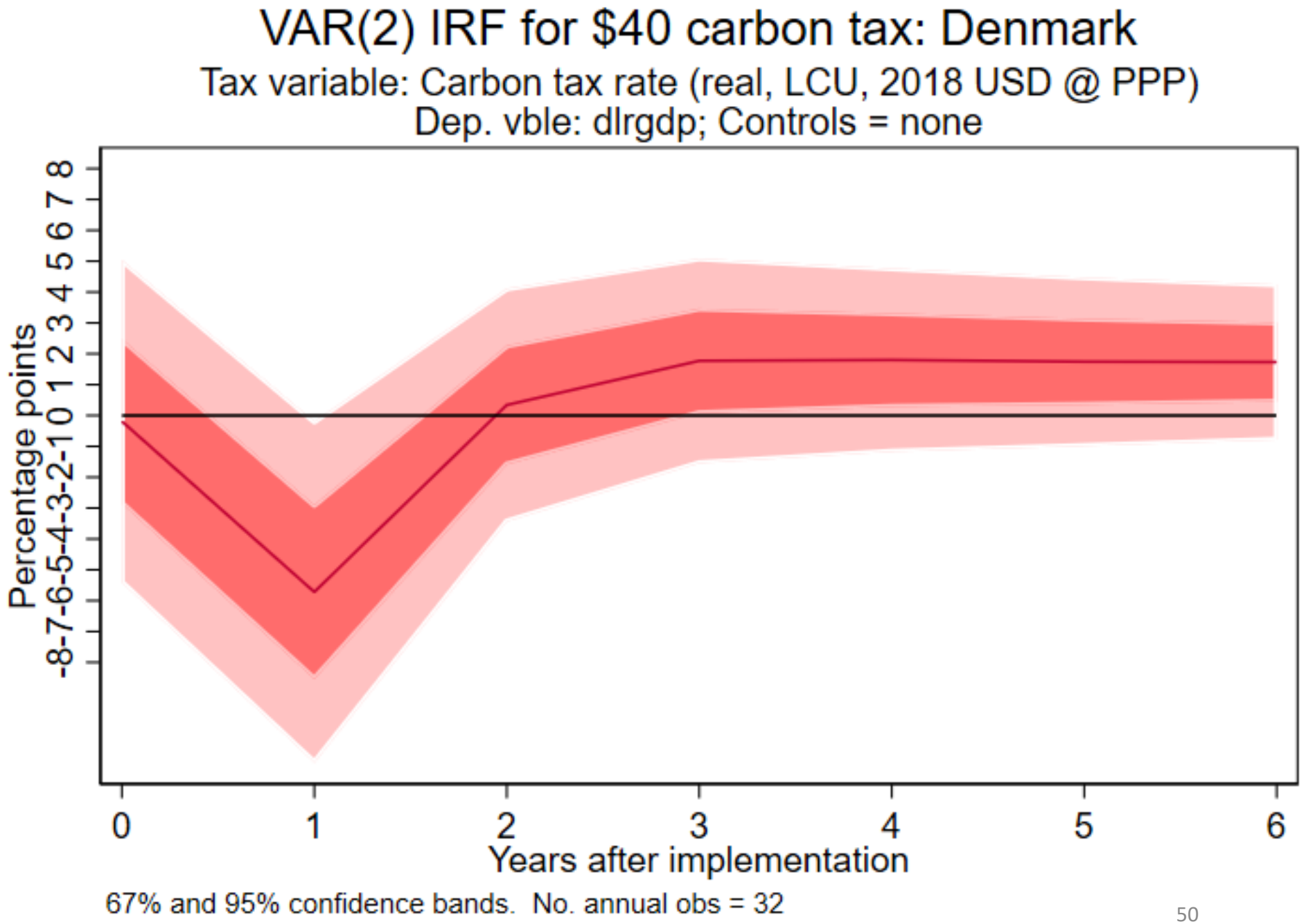
Data source: World Bank (carbon price data in press)

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

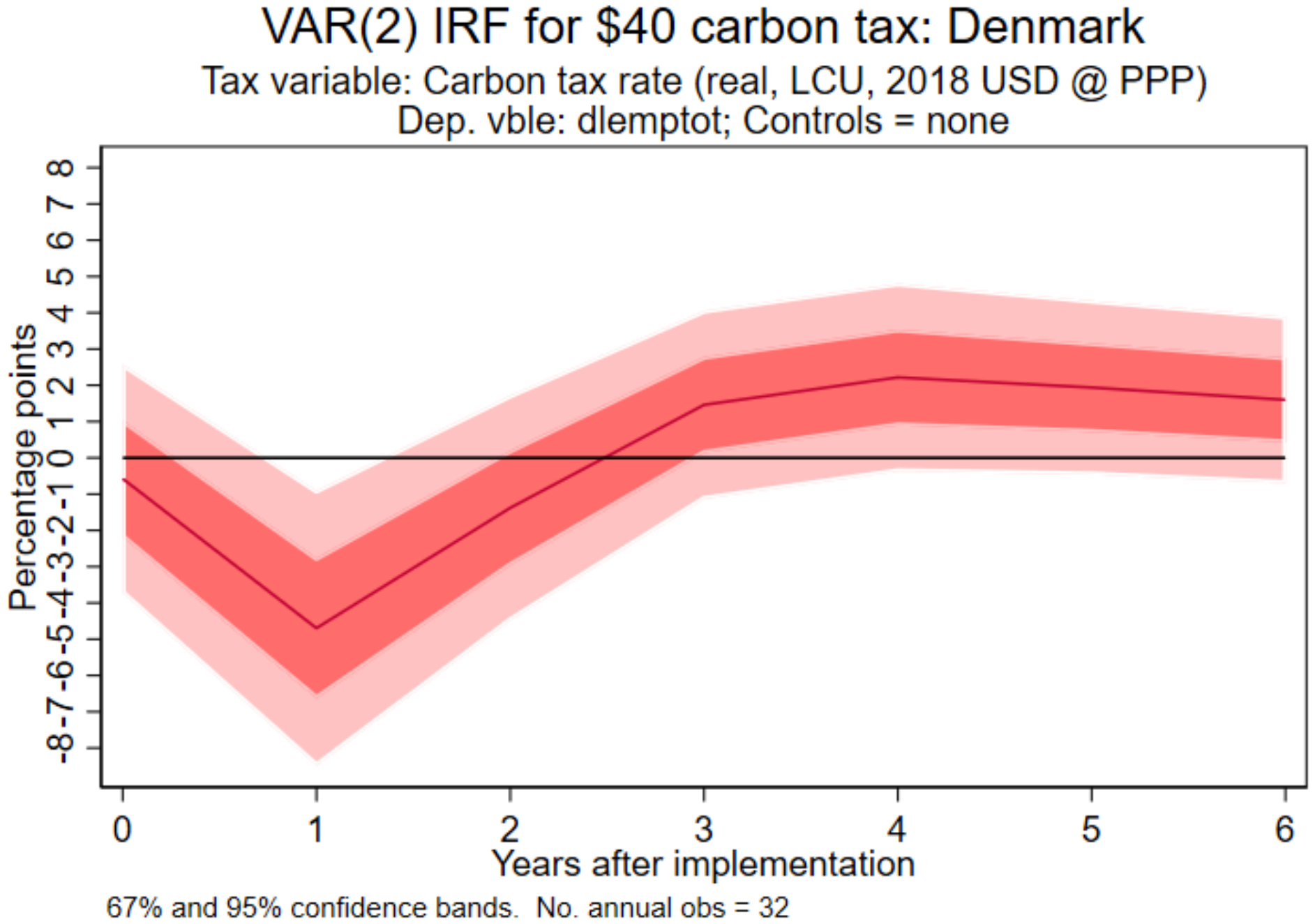
Denmark


GDP growth and Carbon tax rate: DNK
5
0
-5
1980
1990
2000
2010
2020
Year
0.00
5.00
10.00
15.00
20.00
25.00
Carbon tax rate (real, LCU, 2018 USD @ PPP)
Real GDP annual growth rate (percent)
Real GDP growth, World Bank, unadjusted
Carbon tax rate (real, LCU, 2018 USD @ PPP)

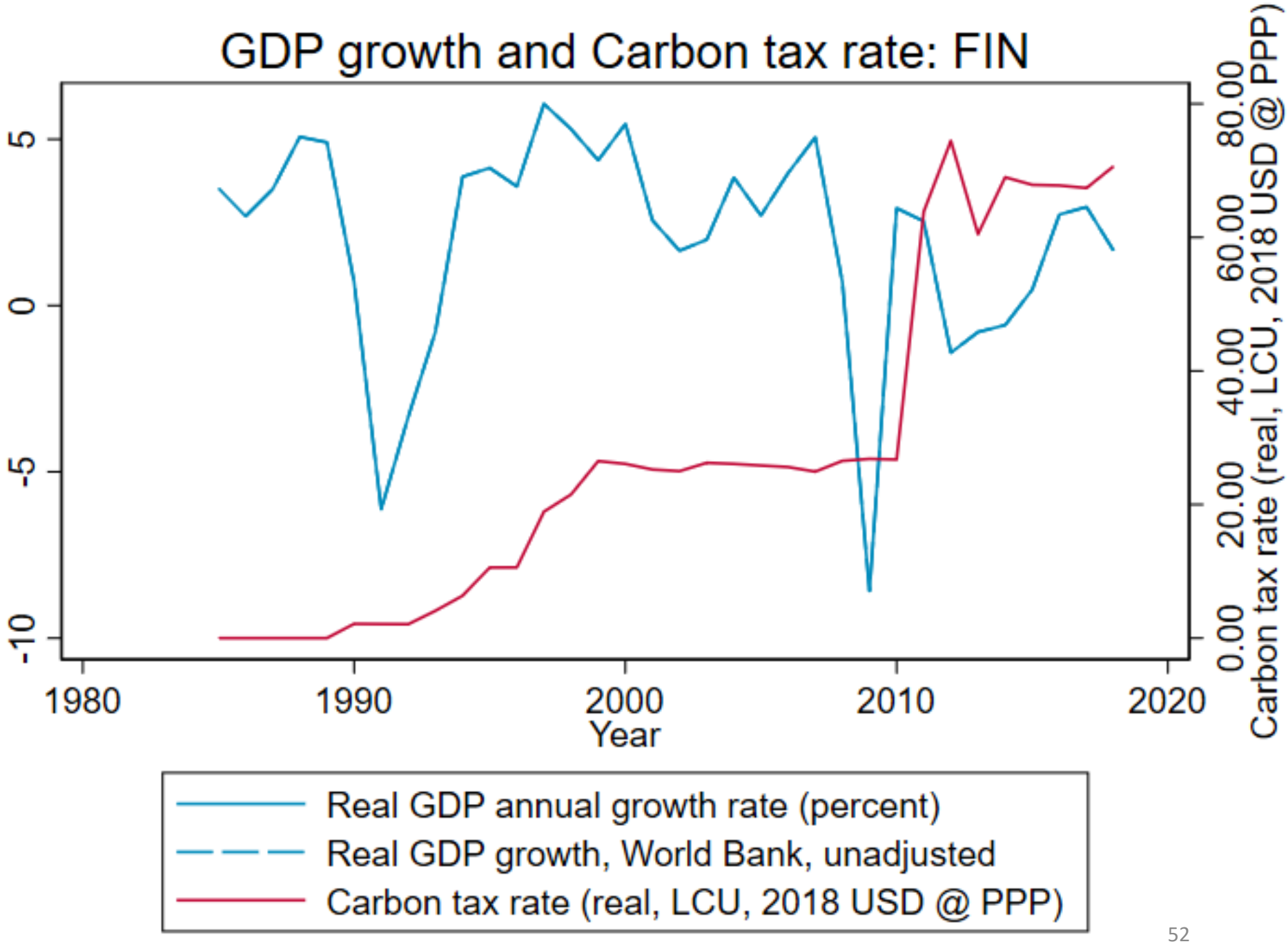
VAR IRF: Denmark



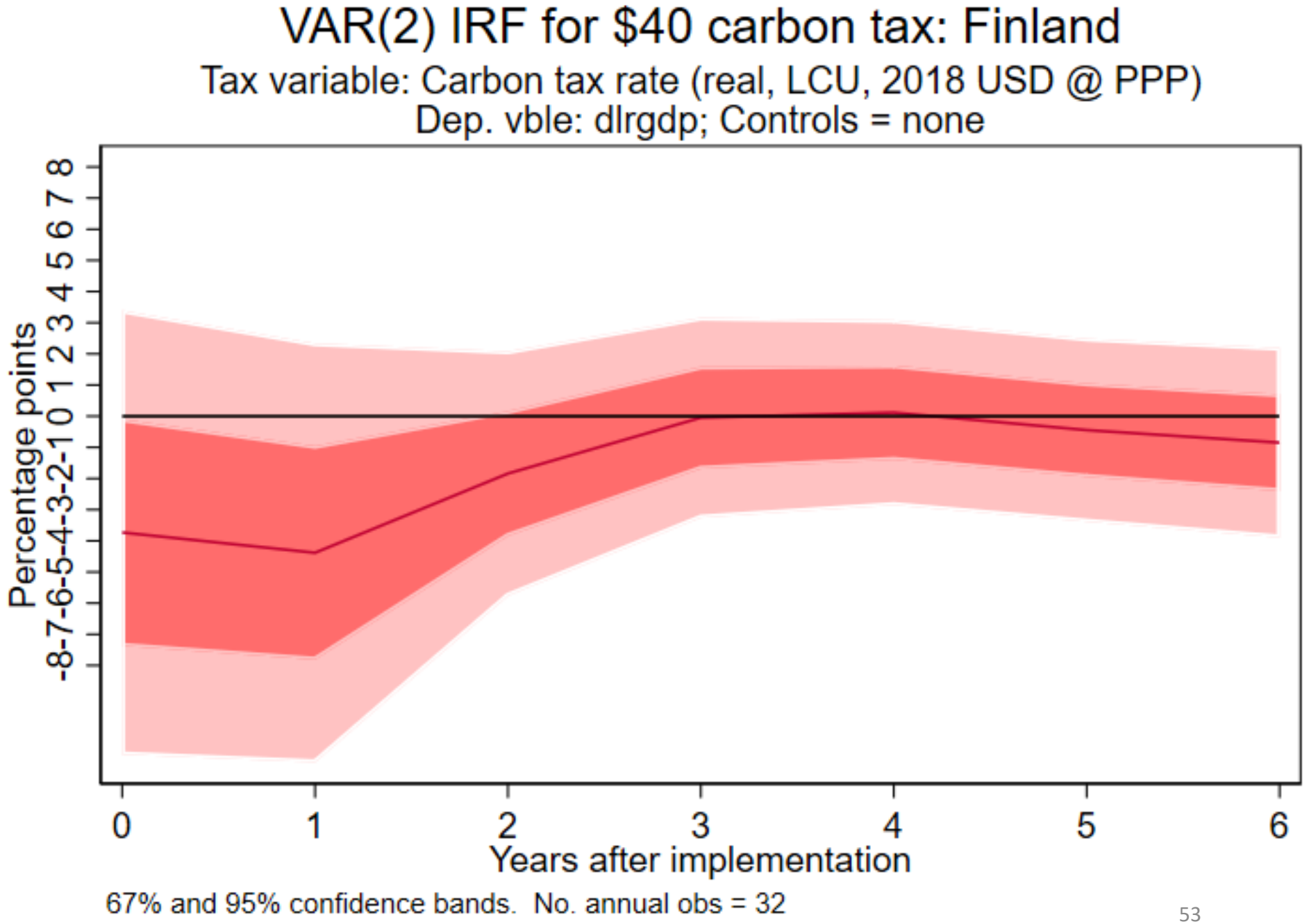
VAR IRF: Denmark



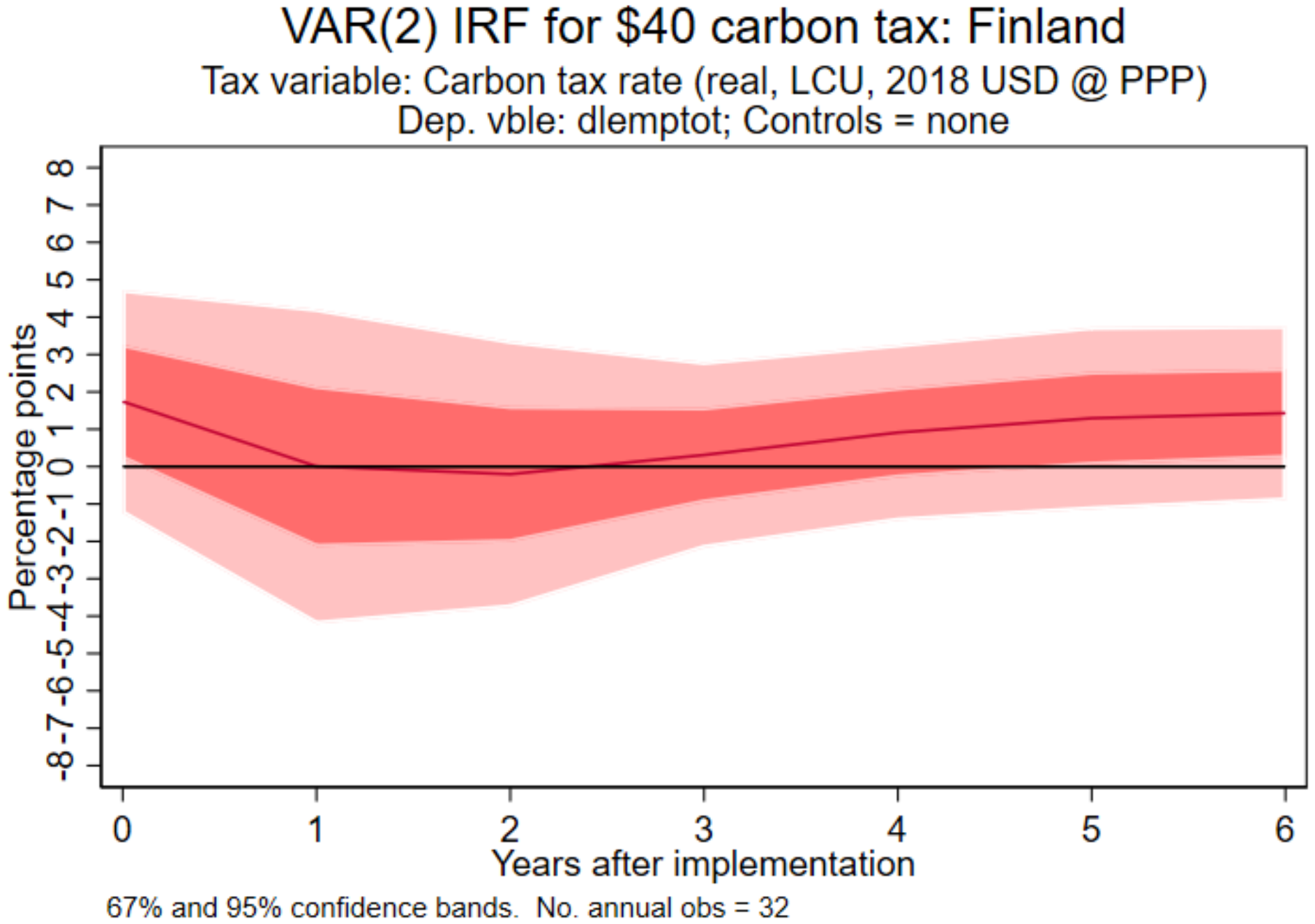
Finland


GDP growth and Carbon tax rate: FIN
5
0
-5
-10
1980
1990
2000
2010
2020
Year
0.00
20.00
40.00
60.00
80.00
Carbon tax rate (real, LCU, 2018 USD @ PPP)
Real GDP annual growth rate (percent)
Real GDP growth, World Bank, unadjusted
Carbon tax rate (real, LCU, 2018 USD @ PPP)

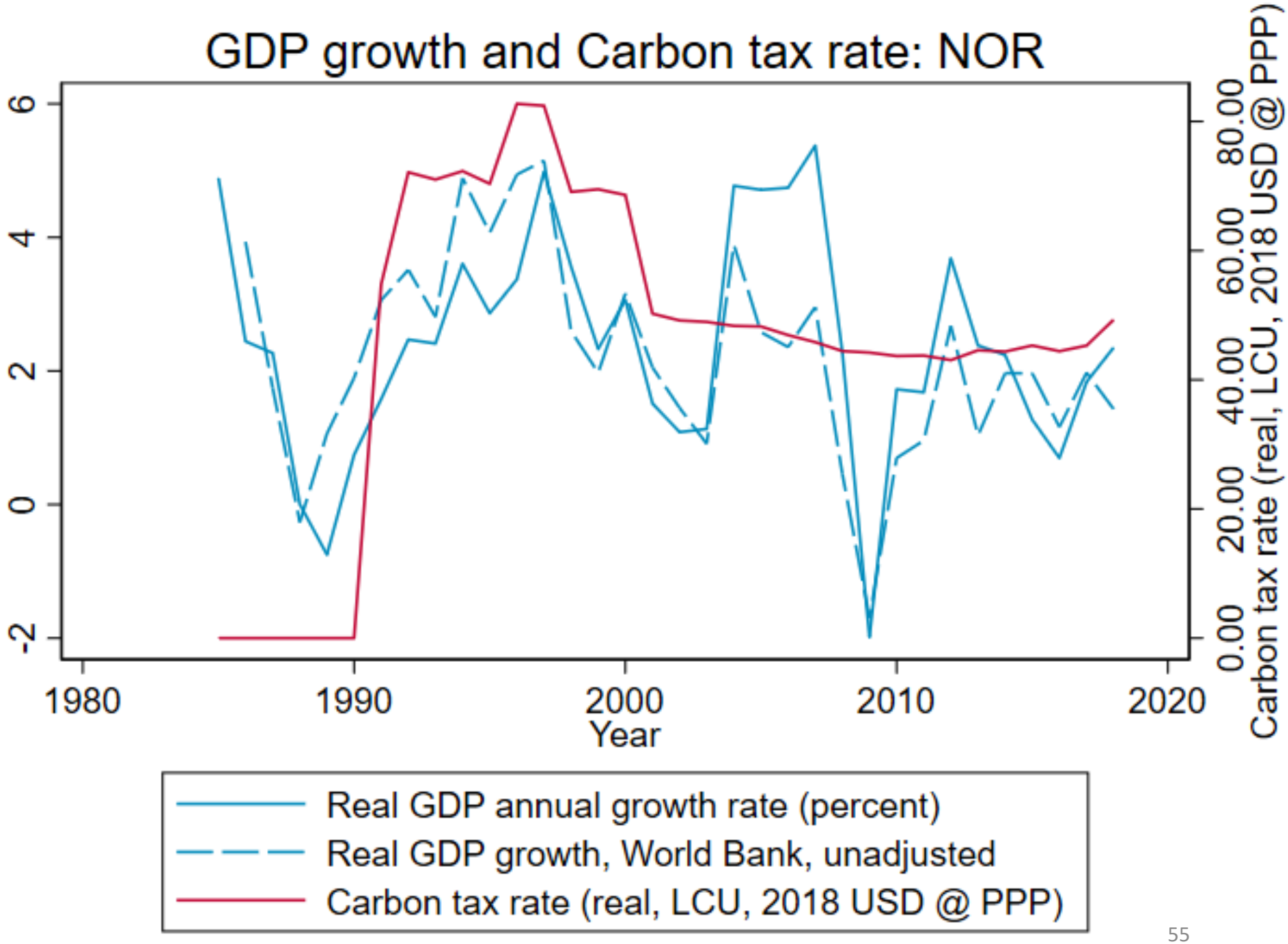
VAR IRF: Finland



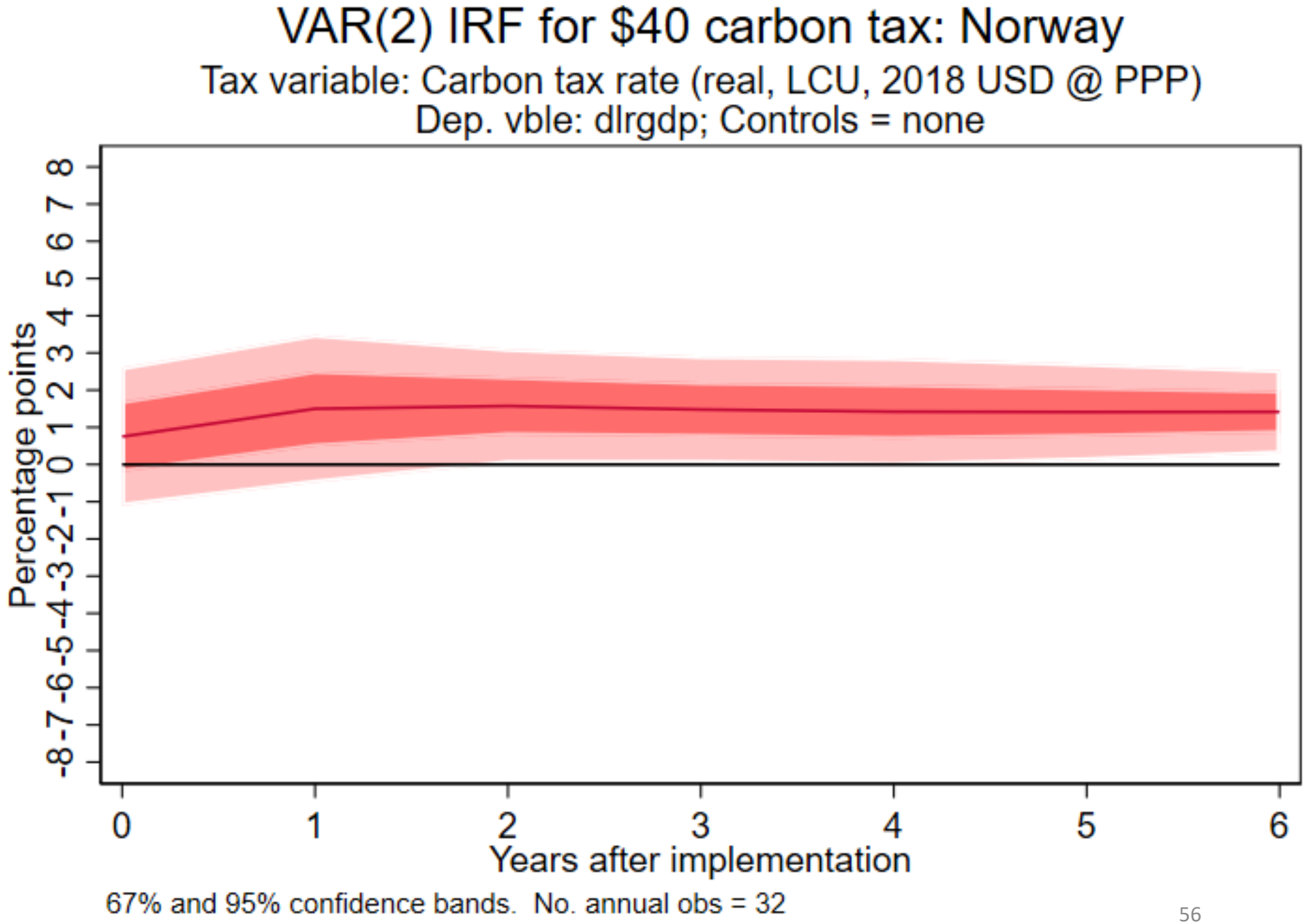
VAR IRF: Finland



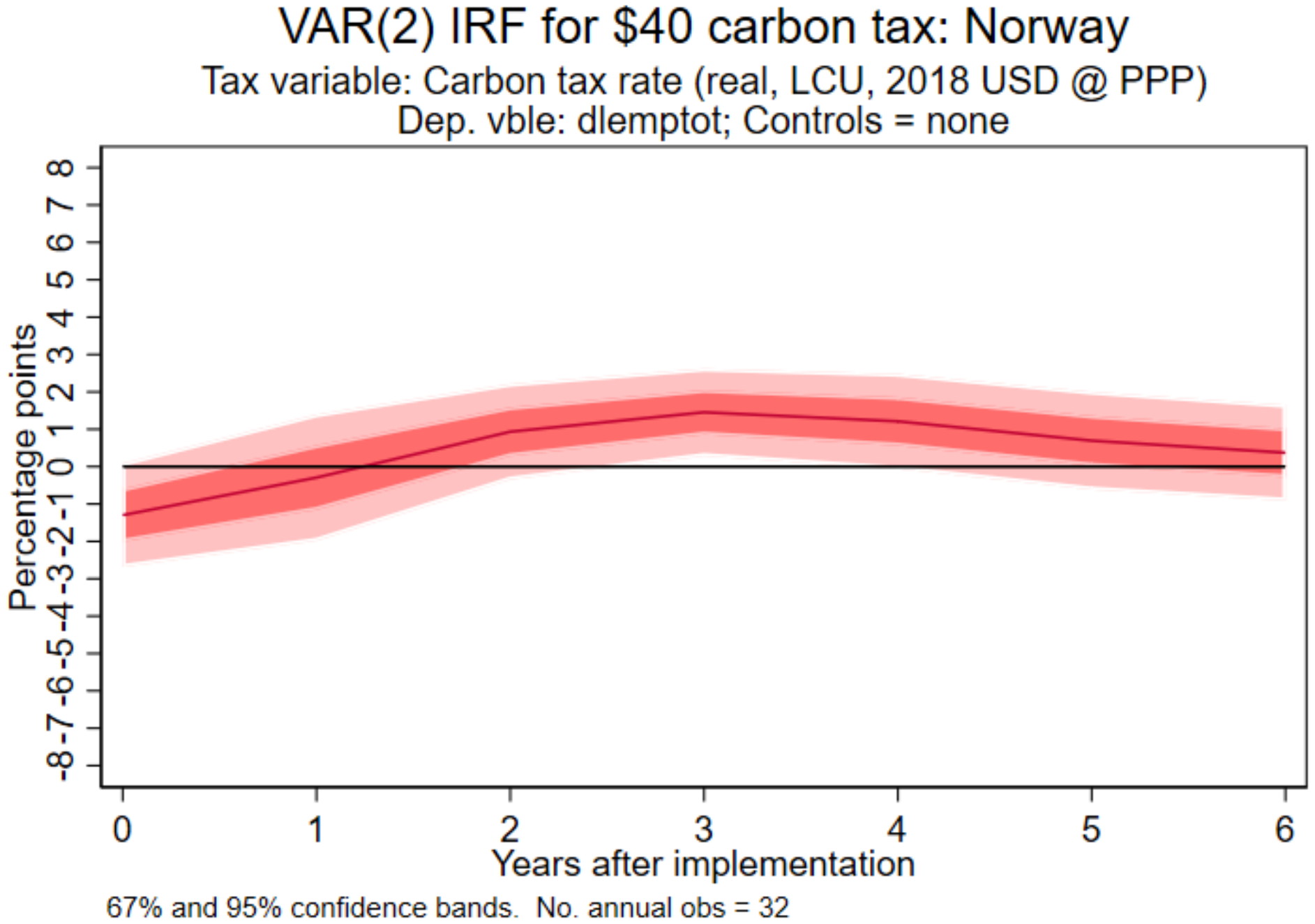
Norway


GDP growth and Carbon tax rate: NOR
6
4
2
0
-2
1980
1990
2000
2010
2020
Year
0.00
20.00
40.00
60.00
80.00
Carbon tax rate (real, LCU, 2018 USD @ PPP)
Real GDP annual growth rate (percent)
Real GDP growth, World Bank, unadjusted
Carbon tax rate (real, LCU, 2018 USD @ PPP)

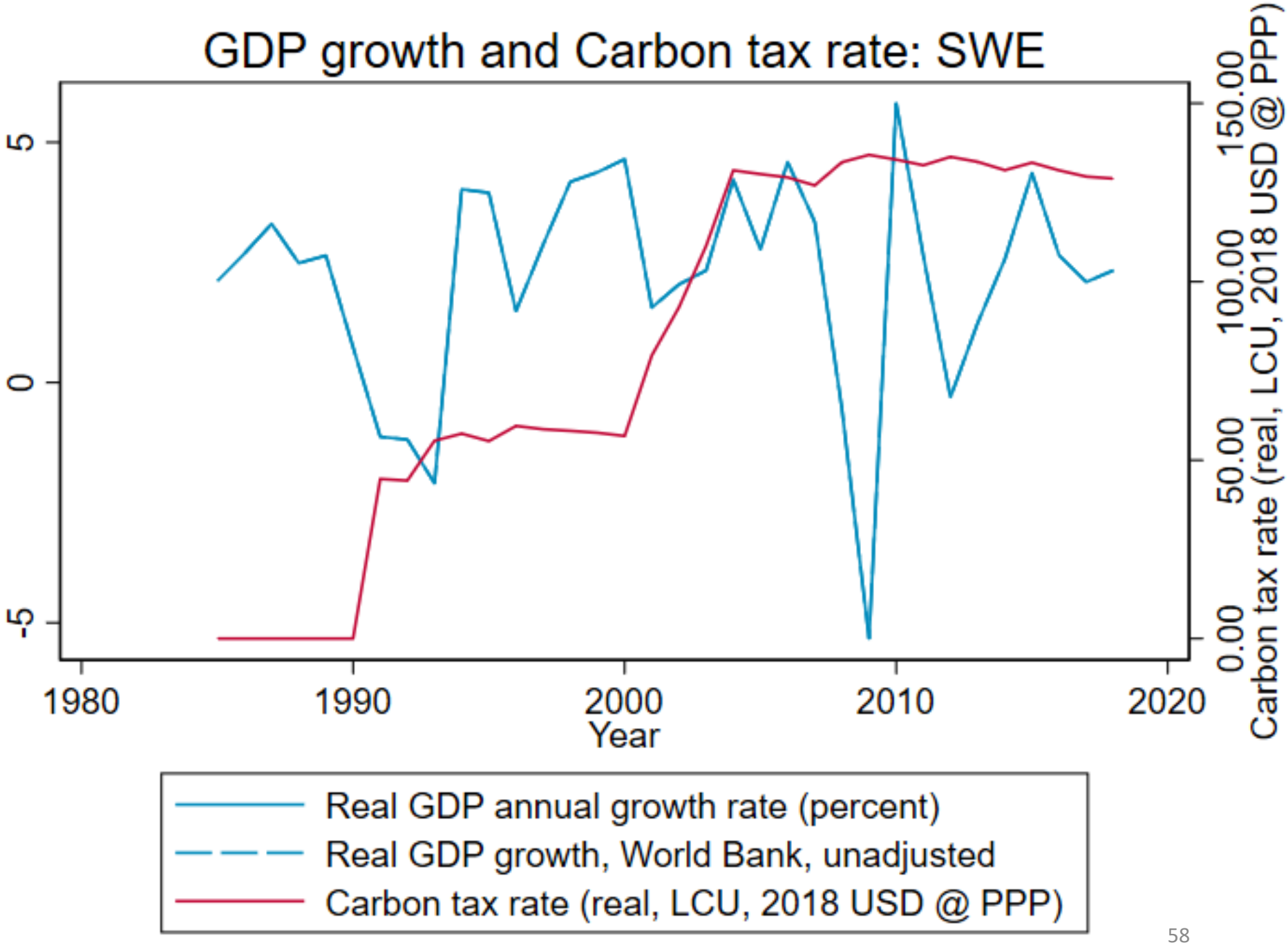
VAR IRF: Norway



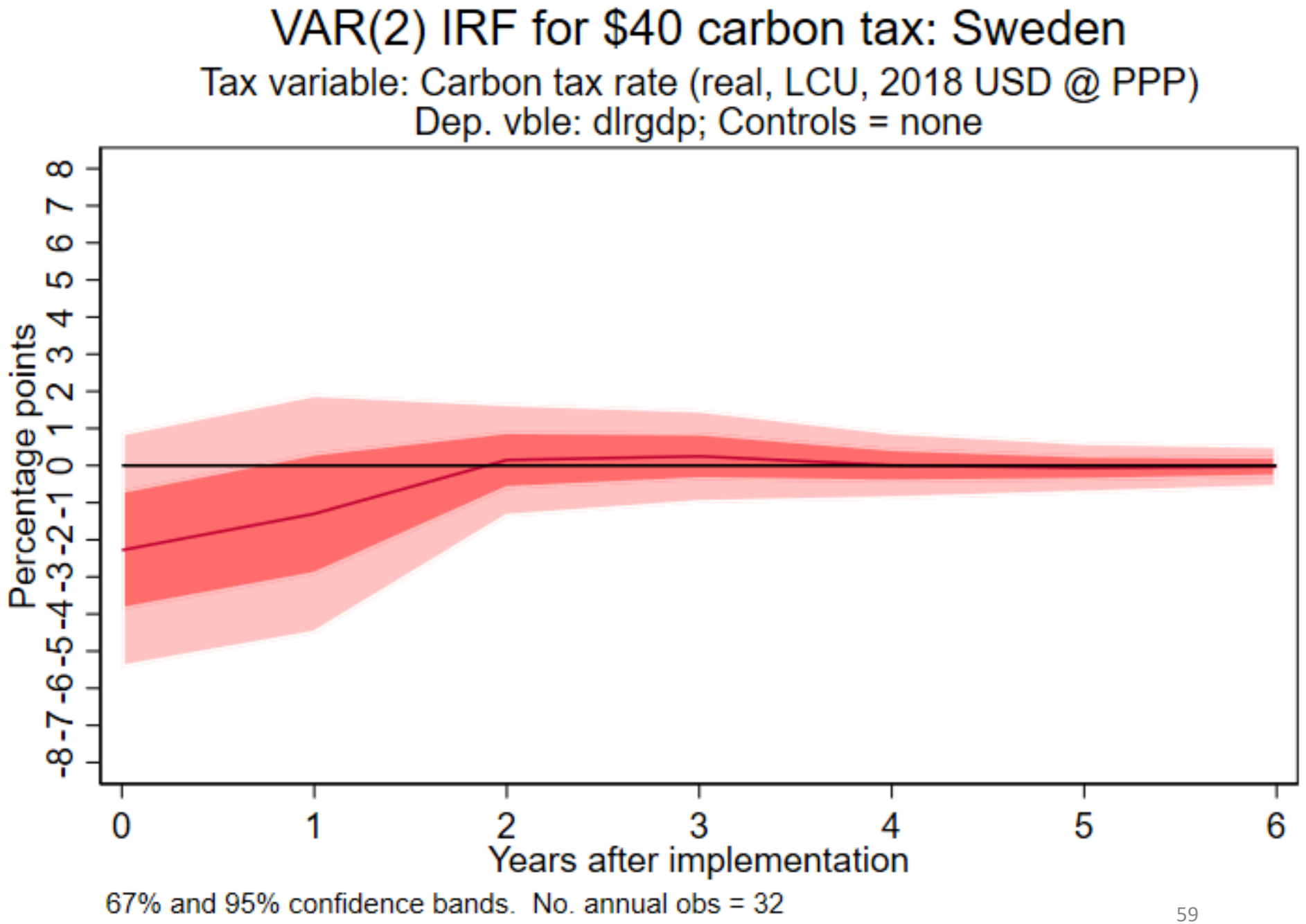
VAR IRF: Norway



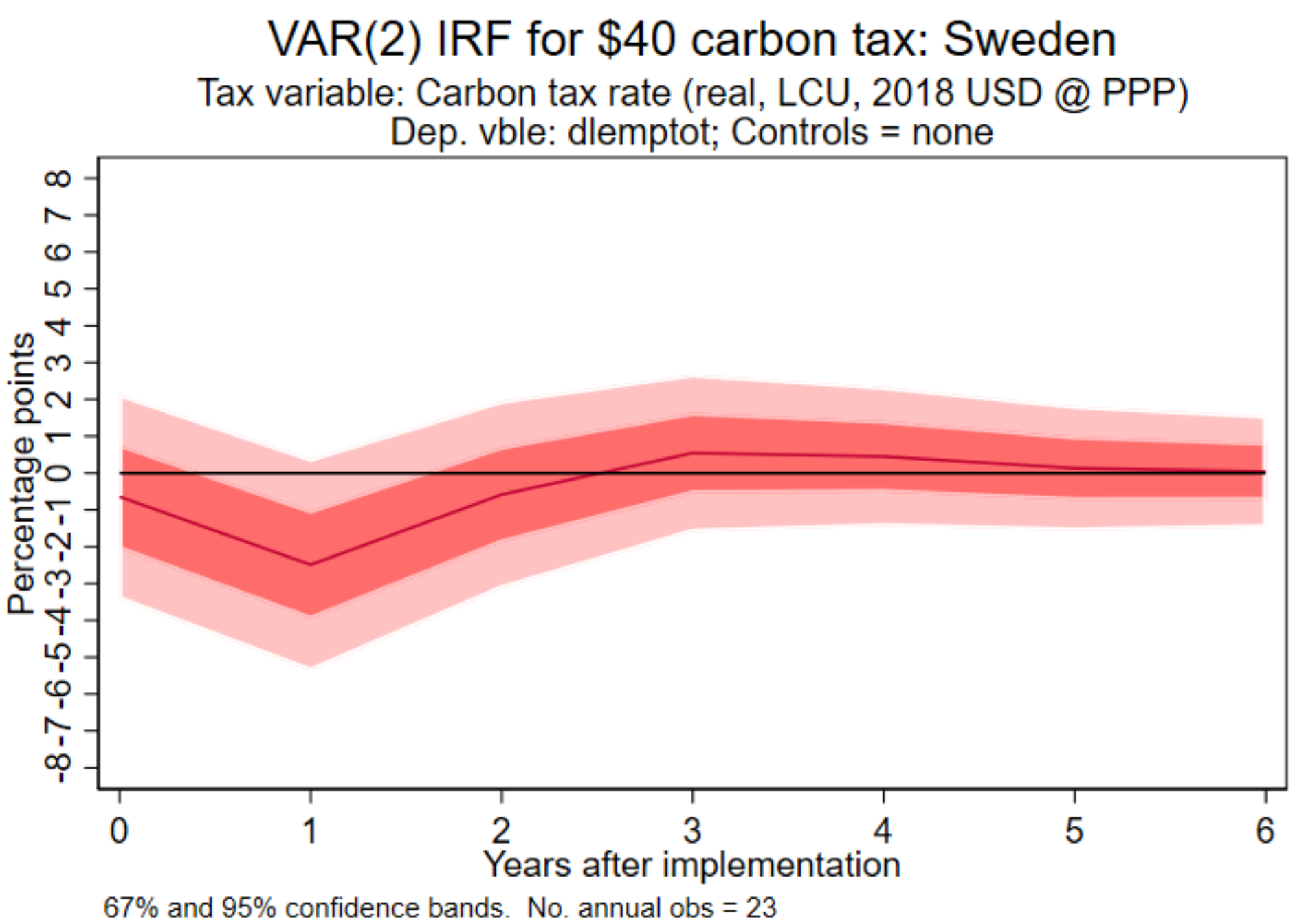
Sweden


GDP growth and Carbon tax rate: SWE
5
0
-5
1980
1990
2000
2010
2020
Year
0.00
50.00
100.00
150.00
Carbon tax rate (real, LCU, 2018 USD @ PPP)
Real GDP annual growth rate (percent)
Real GDP growth, World Bank, unadjusted
Carbon tax rate (real, LCU, 2018 USD @ PPP)

VAR IRF: Sweden



VAR IRF: Sweden



Any tax anticipation effect?

Augment distributed lag regressions with 1 or 2 *leads*
(*t*-statistics in parentheses)

Dependent variable (growth rate)	Tax variable	Cumulative lead effect (@ $40 tax) 1 lead	Cumulative lead effect (@ $40 tax) 2 leads
GDP	Real tax rate	-0.40 (1.28)	-0.10 (1.33)
Total employment	Real tax rate	-0.89 (1.01)	-0.84 (1.04)