Macroeconomics, Carbon Pricing, and Climate Policy

James Stock
Harvard

Markus Brunnermeier
Princeton

21. January 2021

Other Webinars on Climate Change

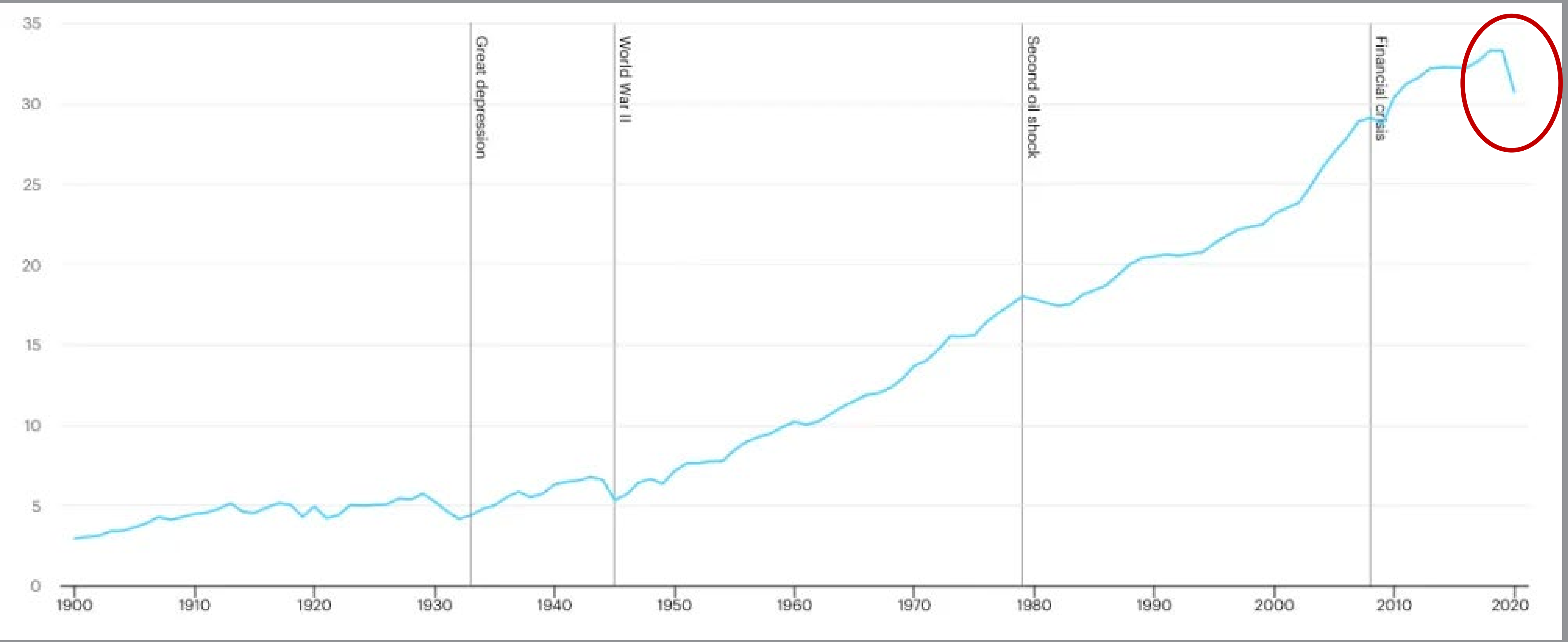
- Bill Nordhaus
  - … next week

- Esteban Rossi-Hansberg
  - … and geography, migration, …
  - Carbon taxes “flatten the curve”
    - Using less in near future, lowers costs for far future

- Richard Zeckhauser
  - Mitigation
  - Adaption, and
  - Amelioration (geoengineering, …)

Malthusian vs. Innovation Approach

- Malthusian approach
  - Supply shock → Reduces GDP/employment – inflationary
  - Value of currently free goods ↑ → Increases GDP (measured) (e.g. bottled water)
  - COVID lockdowns … largest decline, but not more than a bump



Cali et al. Nov. 2020
Brookings paper

  - GDP measurement

Malthusian vs. Innovation Approach

- Malthusian approach
  - Supply shock ⇨ Reduces GDP/employment – inflationary
  - Value of currently free goods ↑ ⇨ Increases GDP (measured) (e.g. bottled water)
  - COVID lockdowns … largest decline, but not more than a bump
  - Unpopular – esp. reduction in tourism

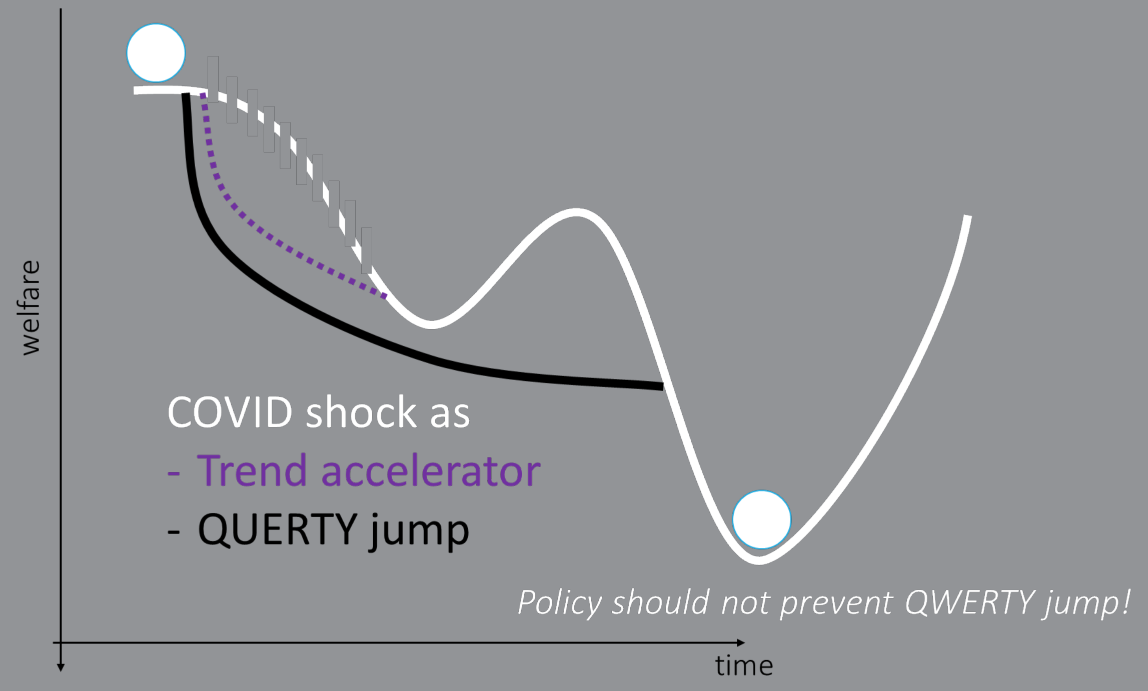
- Innovation approach
  - Increases investment ⇨ Increases GDP/employment
  - Resources are cheaper later ⇨ Reduces GDP

Cali et al. Nov. 2020
Brookings paper

- GDP measurement

COVID, QWERTY: Restarting on right path

- QWERTY
- Donut effect
  - Redesigning
    - (public) traffic



- Path: Planning certainty
  - Carbon tax path — C02 price certainty
  - Pollution permits — Pollution level certainty
    - For free vs. auction off
    - Short-term permits vs. central bank approach (Depla)
    - To keep C02 price within range

Poll Questions

- Over 10-20 years, effect of a $40 carbon tax on the level of GDP?
  - Big reduction (-5%+)
  - Small reduction (-1% to -5%)
  - Negligible effect (+/- 1%)
  - Small increase (1% to 5%)
  - Big increase (>5%+)
- … effect on the level of aggregate employment?
  - Big reduction (-5%+)
  - Small reduction (-1% to -5%)
  - Negligible effect (+/- 1%)
  - Small increase (1% to 5%)
  - Big increase (>5%+)
- What is the single most effective US climate policy?
  - Technology policies
  - Direct gov. investment (Green Infrastructure Bank, etc.)
  - Carbon tax starting at $40/ton, increasing 5%/yr
  - Supply-side policies (ban …)

BENDHEIM CENTER FOR FINANCE

Macroeconomics, Carbon Pricing, and Climate Policy

James H. Stock,
Economics Department and Harvard Kennedy School,
Harvard University

US Climate Policy Earthquake

All of a sudden!

- EOs on Paris, deregulatory reversal, Keystone XL, SCC
- A lot more on the way including legislation

The Administration Priorities COV

BRIEFING ROOM

Executive Order on Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis

JANUARY 20, 2021 • PRESIDENTIAL ACTIONS

The Administration P

BRIEFING ROOM

Paris Climate Agreement

JANUARY 20, 2021 • STATEMENTS AND RELEASES

US Climate Policy Earthquake

All of a sudden!

- EOs on Paris, deregulatory reversal, Keystone XL, SCC
- A lot more on the way including legislation

Main domestic climate policy bins:

- Price on carbon
- Transportation sector & EVs
- Green RD&D policy
- Supply side policies

  financial disclosures through keep-it-in-the-ground
- USG regulatory weeds

The Administration Priorities COV

BRIEFING ROOM

Executive Order on Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis

JANUARY 20, 2021 • PRESIDENTIAL ACTIONS

The Administration P

BRIEFING ROOM

Paris Climate Agreement

JANUARY 20, 2021 • STATEMENTS AND RELEASES

US Climate Policy Earthquake

All of a sudden!

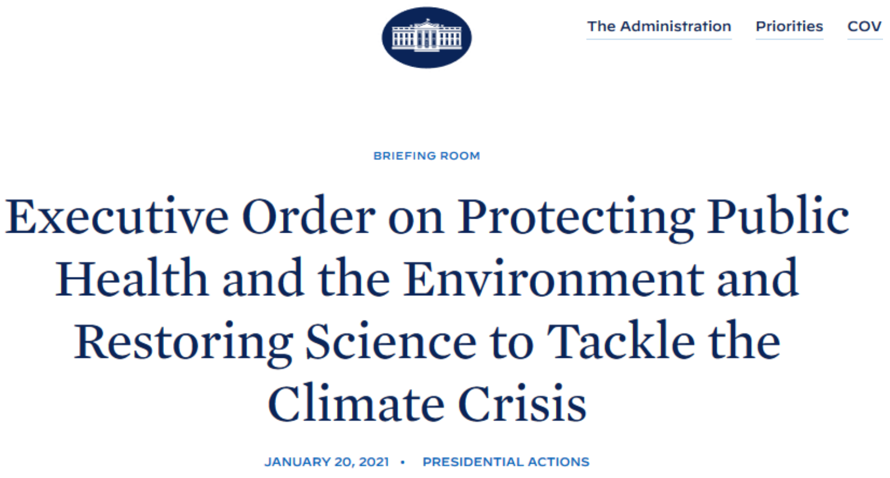
- EOs on Paris, deregulatory reversal, Keystone XL, SCC
- A lot more on the way including legislation

Main domestic climate policy bins:

- Price on carbon
- Transportation sector & EVs
- Green RD&D policy
- Supply side policies
    financial disclosures through keep-it-in-the-ground
- USG regulatory weeds

This talk:

- Some energy transition background
- Carbon tax: macro effect, effect on emissions (with Gib Metcalf 2020)
- Power sector alternatives (with Daniel Stuart 2021)
- Return to main list


The Administration Priorities COV

BRIEFING ROOM

Executive Order on Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis

JANUARY 20, 2021 • PRESIDENTIAL ACTIONS


The Administration P

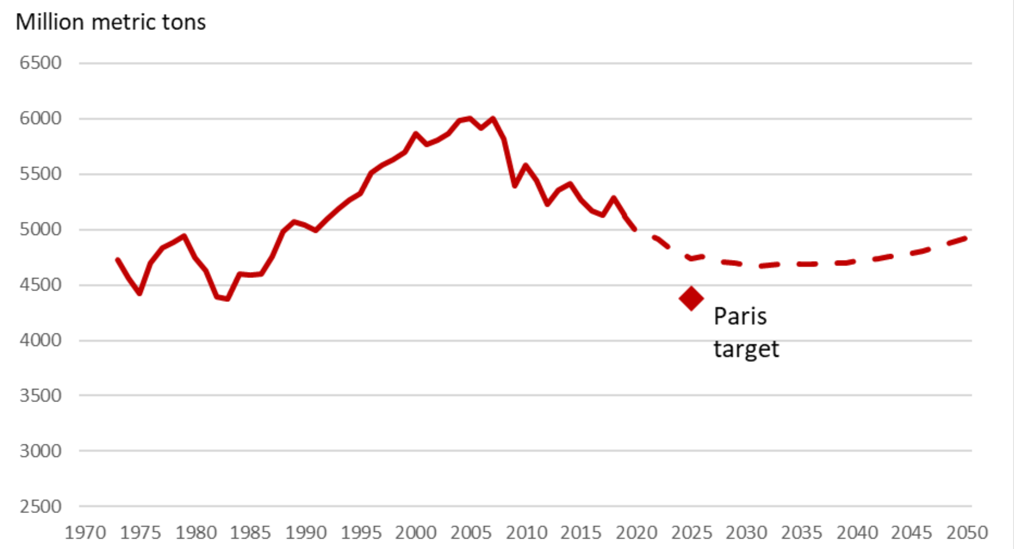
BRIEFING ROOM

Paris Climate Agreement

JANUARY 20, 2021 • STATEMENTS AND RELEASES

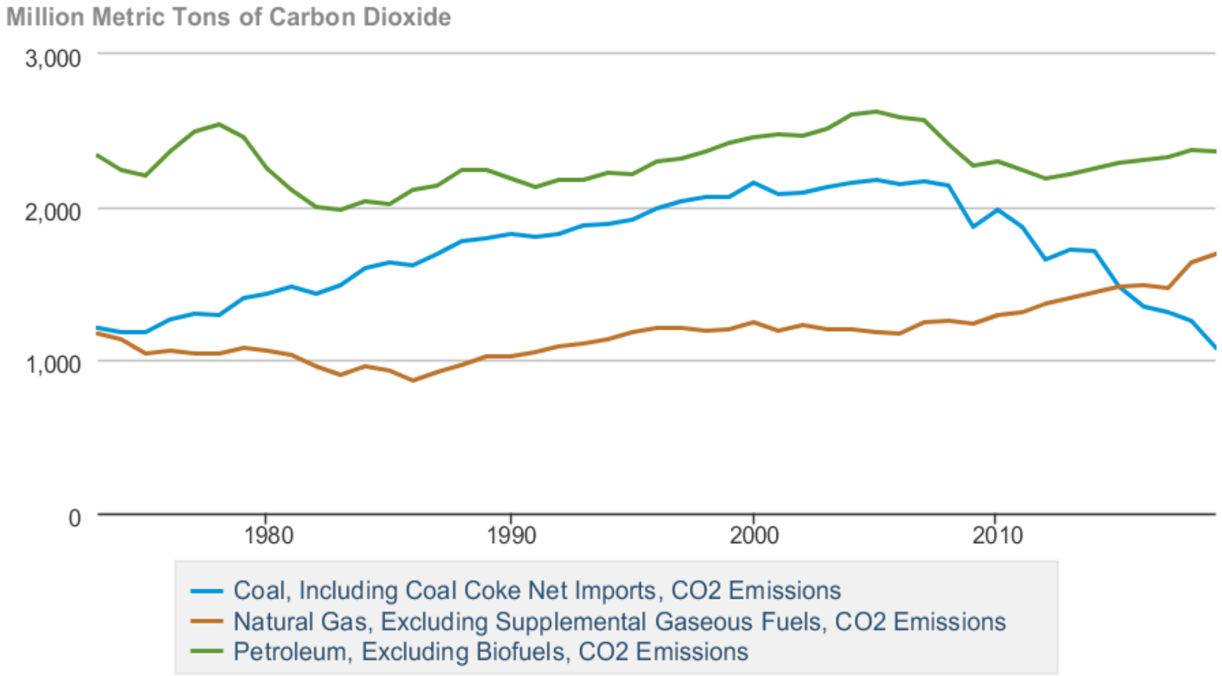
Background: Scope of Challenge (1)

US CO2 emissions from energy consumption



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

CO2 emissions by fuel type



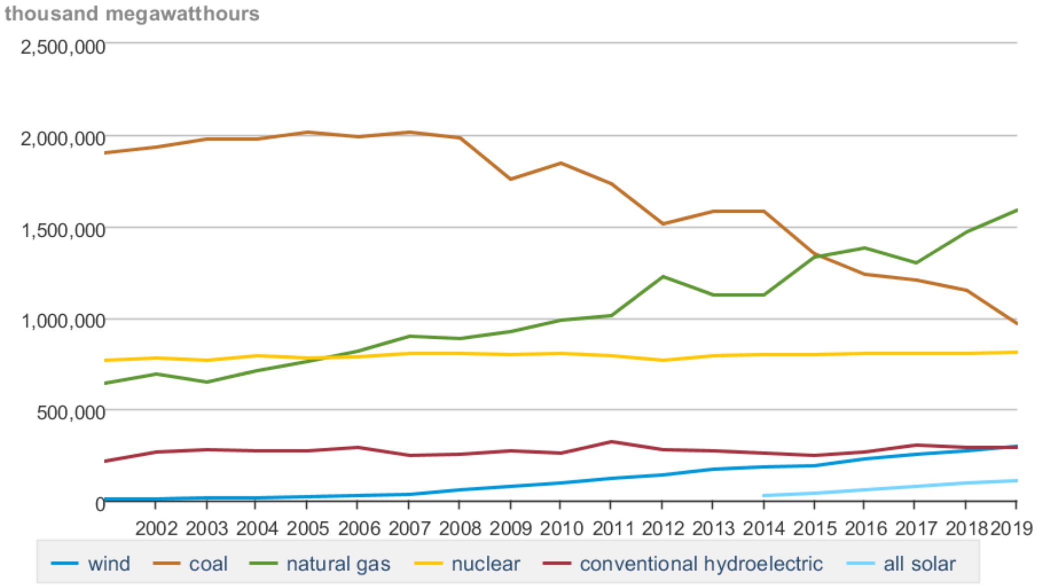
Source: U.S. Energy Information Administration

Decomposition of post-2005 decline

Component	Actual minus 1990-2005 trend (log points)
CO2 intensity of energy (CO2/Energy)	-0.158
Economy-wide energy efficiency (Energy/GDP)	0.038
GDP per capita	-0.161
Population	-0.060
Total: CO2 emissions	**-0.348**

Background: Scope of Challenge (2)

US electricity generation by source



Data source: U.S. Energy Information Administration

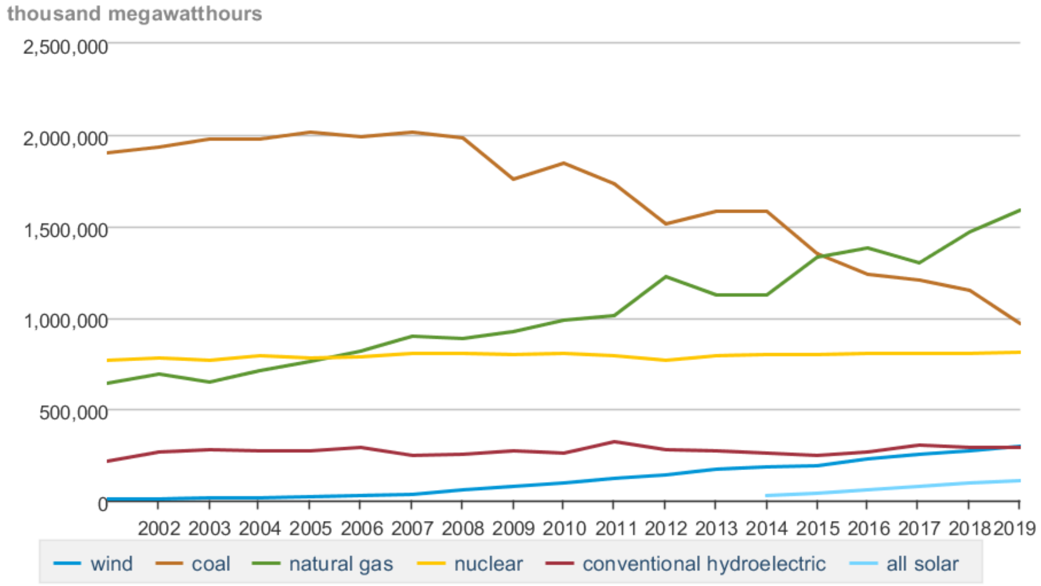
Decomposition of decline in coal consumption, 2008-2016

Source	Contribution (mst)
Relative prices, coal/gas	-397
Clean Air Act regulations	-28
RPS	-9
Electricity demand	-32
Other	+33
Total change, 2008-2016	**-433**

Source: Coglianese, Gerarden, and Stock (2020)

Background: Scope of Challenge (2)

US electricity generation by source



Data source: U.S. Energy Information Administration

Decomposition of decline in coal consumption, 2008-2016

Source	Contribution (mst)
Relative prices, coal/gas	-397
Clean Air Act regulations	-28
RPS	-9
Electricity demand	-32
Other	+33
Total change, 2008-2016	**-433**

Source: Coglianese, Gerarden, and Stock (2020)

Net zero power sector by 2035 means…

Qty: 51

Add to Cart

Buy Now

Qty: 55

Add to Cart

Buy Now

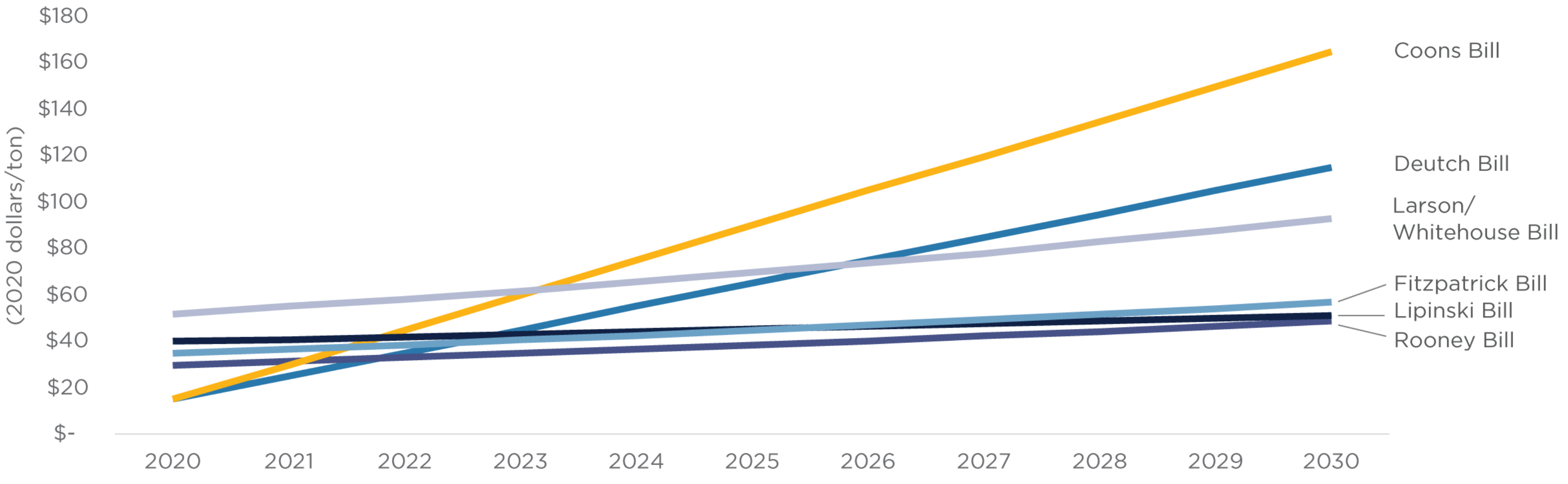
…per year for 15 years

Carbon tax

A number of carbon tax bills were introduced in the previous Congress, but there are legitimate concerns…

- Jobs and economy
- Regressive
- Impacted sectors (concentrated negatively affected interests)
- Won’t produce the necessary emissions reductions

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



Source: CGEP Analysis

Carbon tax

A number of carbon tax bills were introduced in the previous Congress, but there are legitimate concerns…

- Jobs and economy (this paper)
- Regressive
- Impacted sectors (concentrated negatively affected interests)
- Won't produce the necessary emissions reductions

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.

Carbon tax

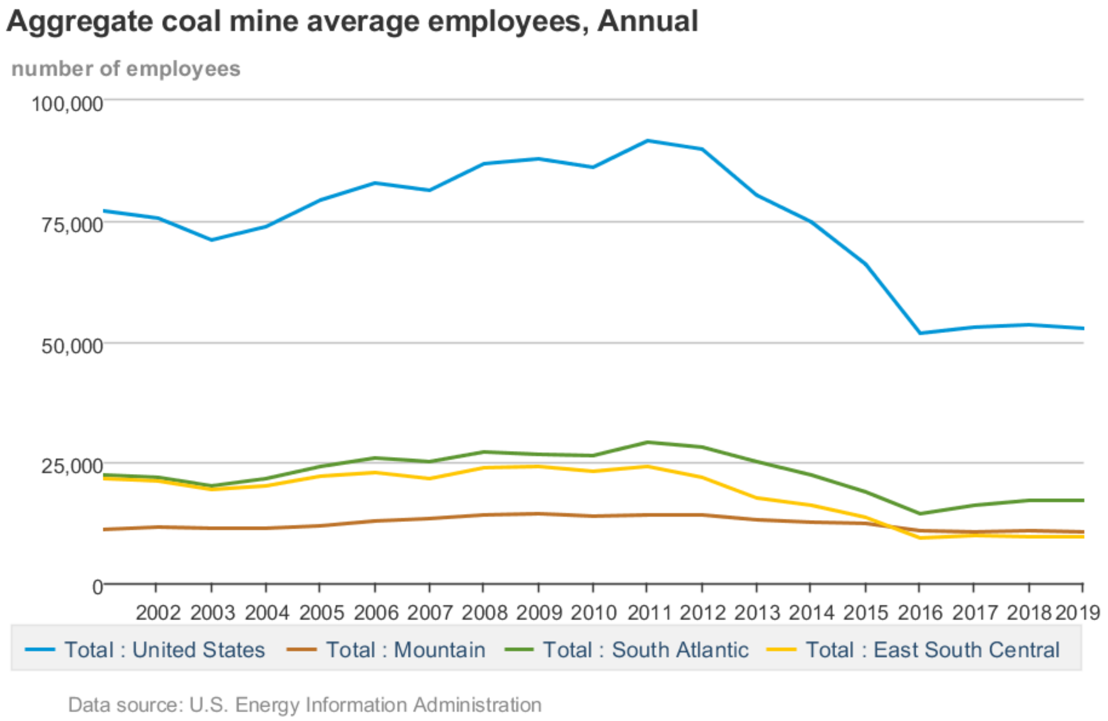
A number of carbon tax bills were introduced in the previous Congress, but there are legitimate concerns…

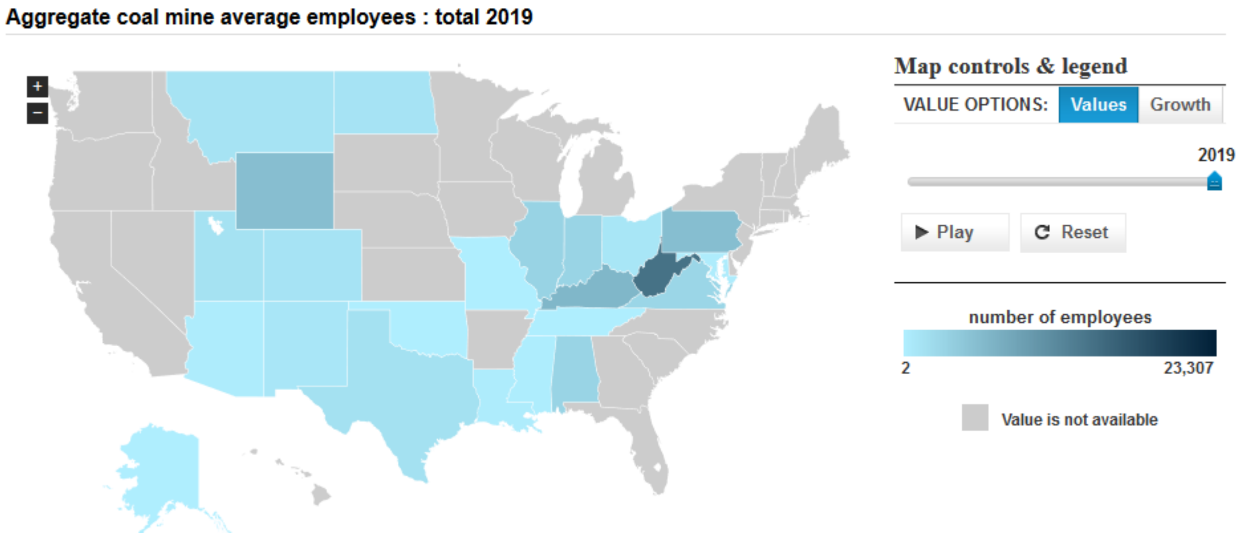
- Jobs and economy
- Regressive
- Impacted sectors (concentrated negatively affected interests)
- Won’t produce the necessary emissions reductions

Carbon tax

A number of carbon tax bills were introduced in the previous Congress, but there are legitimate concerns…

- Jobs and economy
- Regressive
- Impacted sectors (concentrated negatively affected interests)
- Won't produce the necessary emissions reductions





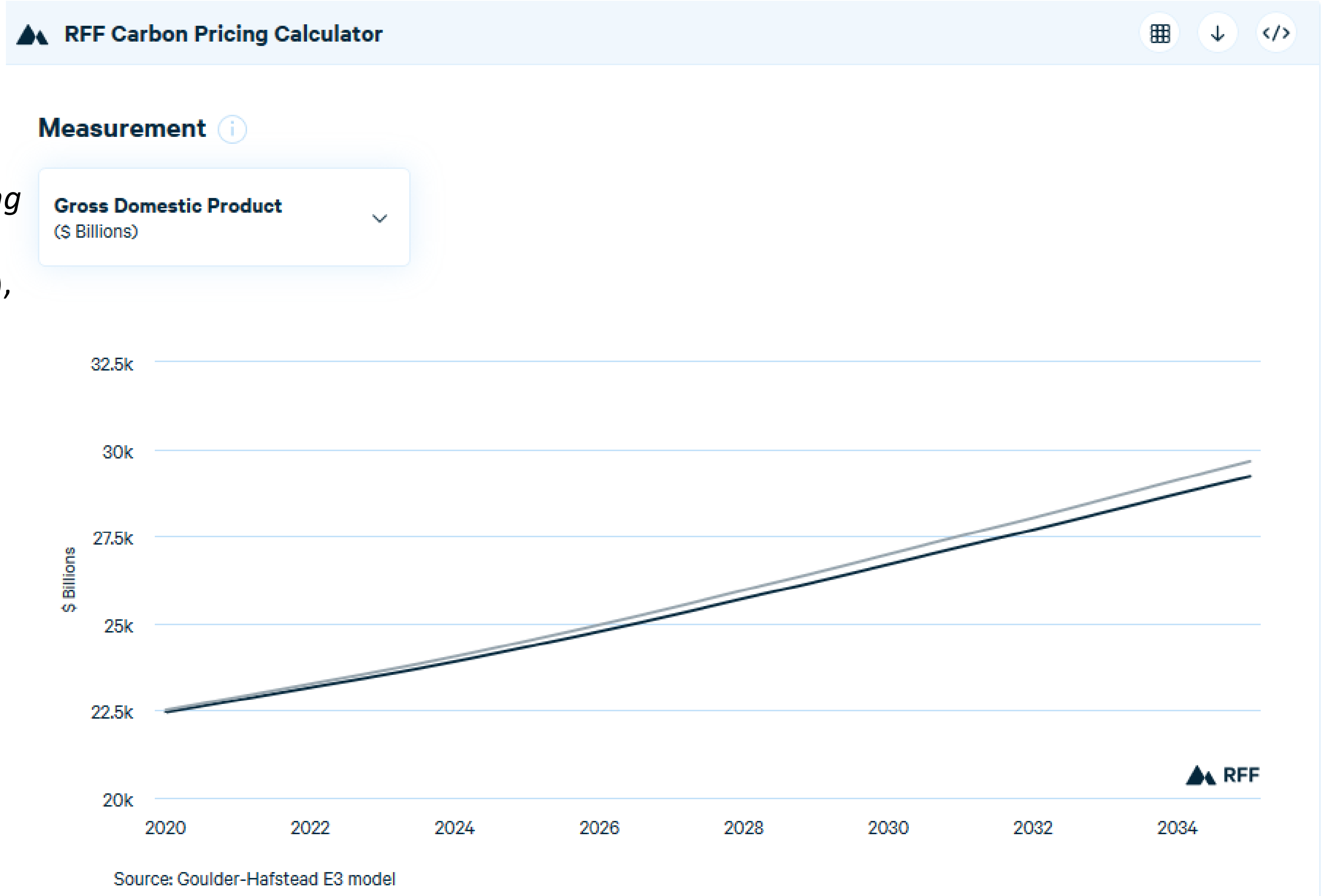
Carbon tax

A number of carbon tax bills were introduced in the previous Congress, but there are legitimate concerns…

- Jobs and economy
- Regressive
- Impacted sectors (concentrated negatively affected interests)
- Won't produce the necessary emissions reductions

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/)

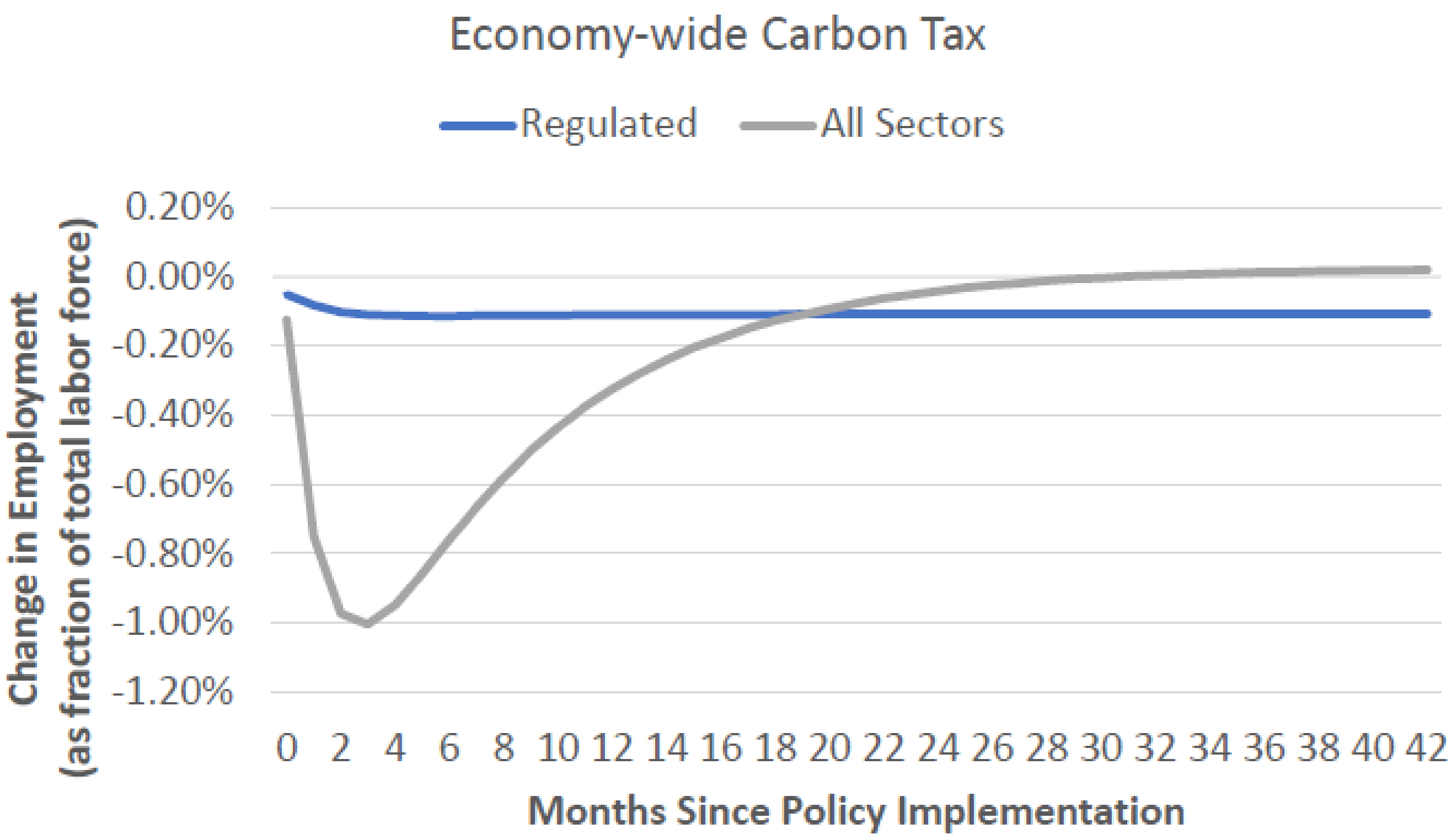


- **Parallel shift down**
- Importance of revenue recycling method
- Example:
  Tax of $40/ton @5%/year:
  GDP loss in 2035 =
  -1.5% (tax & dividend)
  -1.2% (payroll tax cut)

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)

Metcalf-Stock (2020) (NBER WP 27488): 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

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

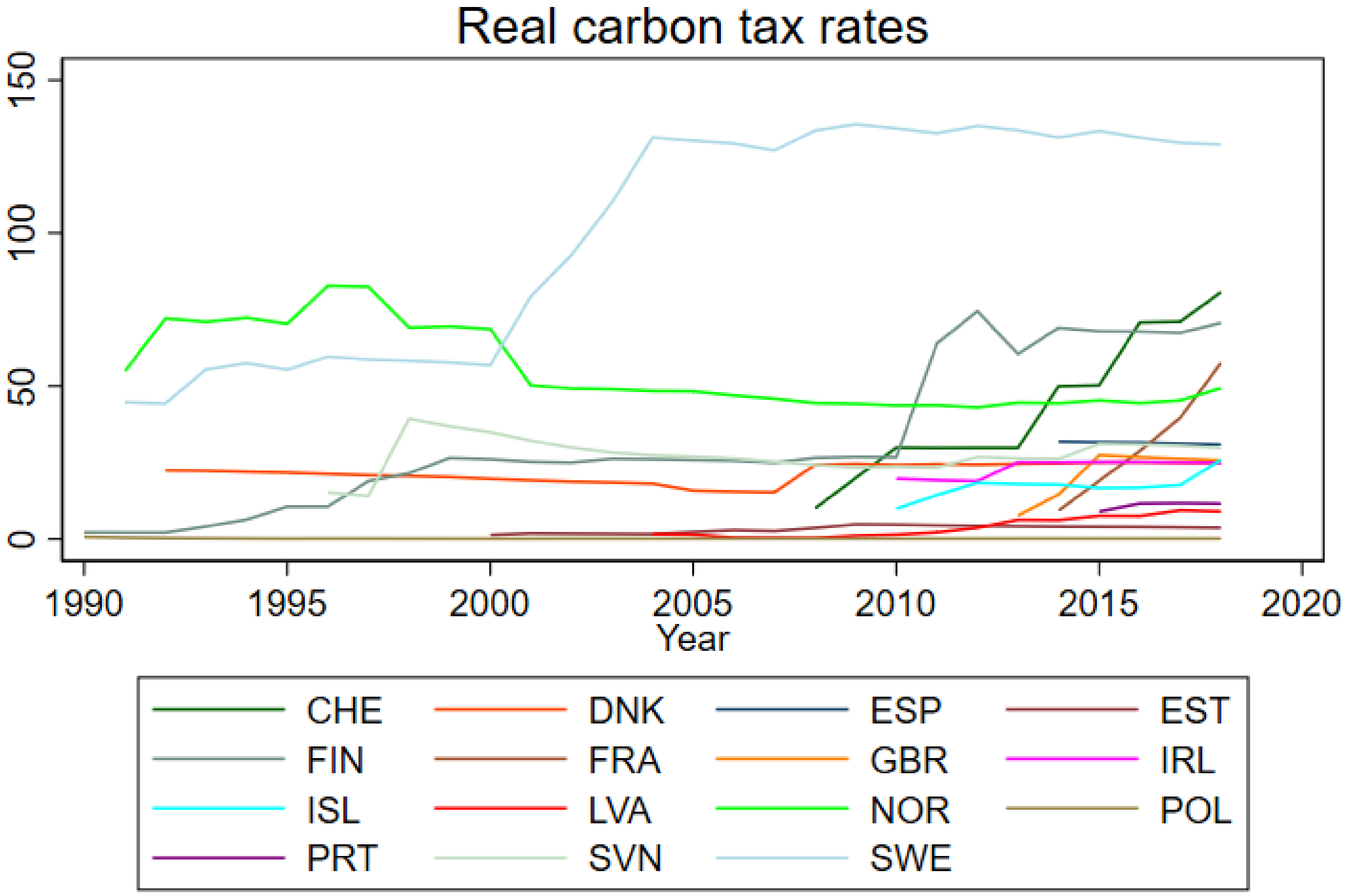
Data description

Carbon tax history for the 15 countries with carbon taxes

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

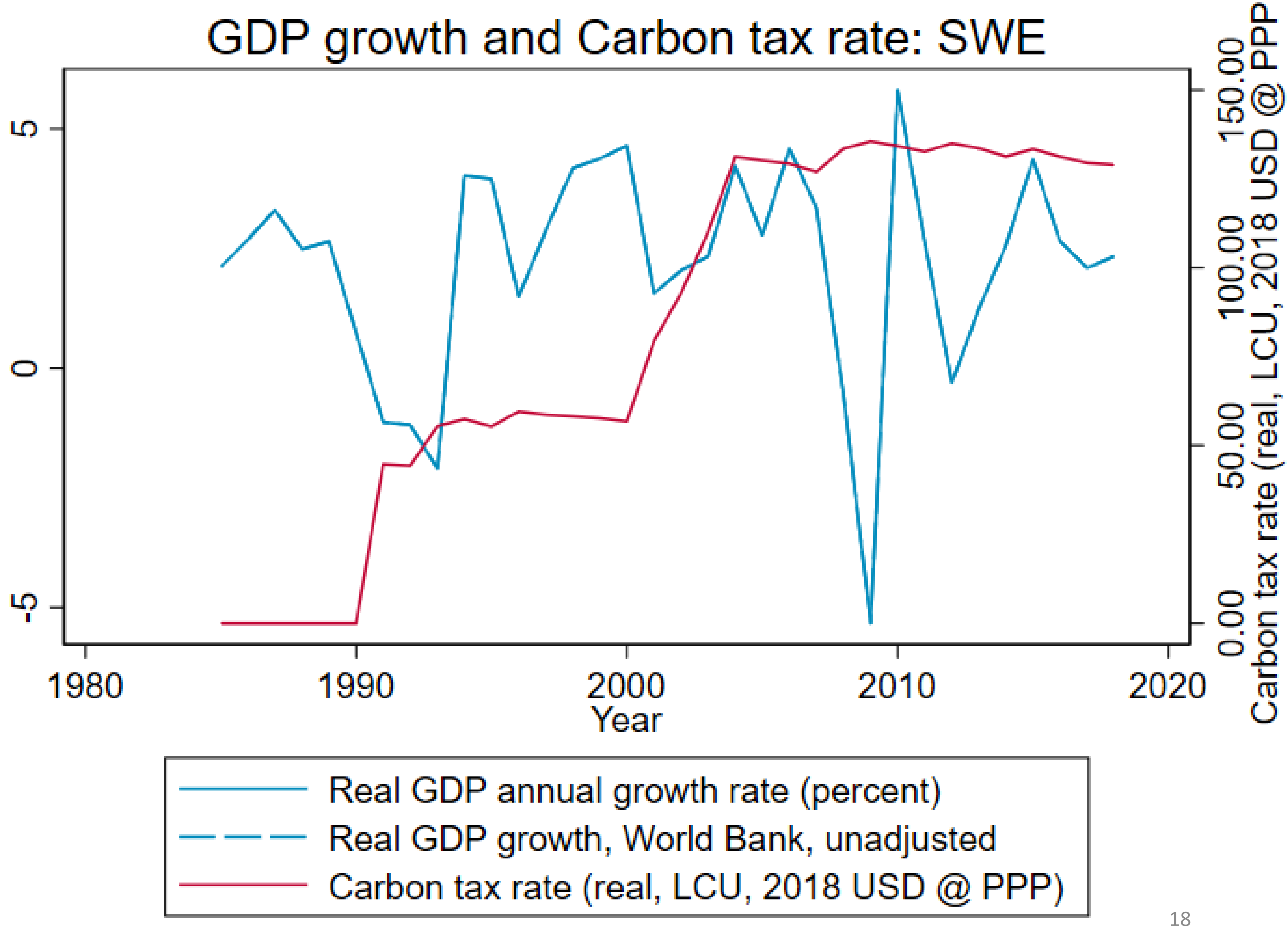
Carbon tax rates are real local currency, scaled to 2018 USD using 2018 PPP

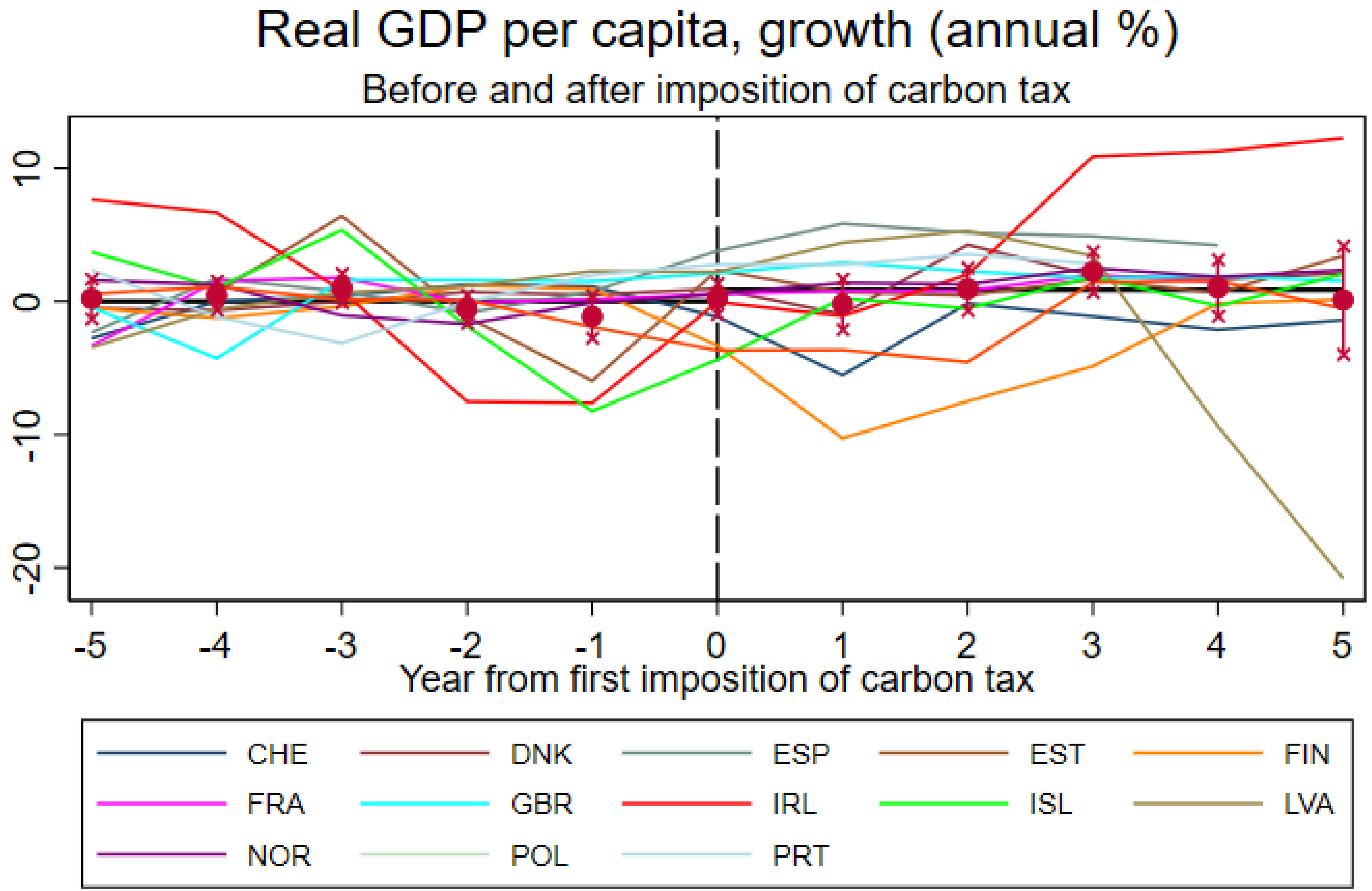
GDP growth: World Bank (except as noted below)



Real rate in local currency, normalized to 2018 USD

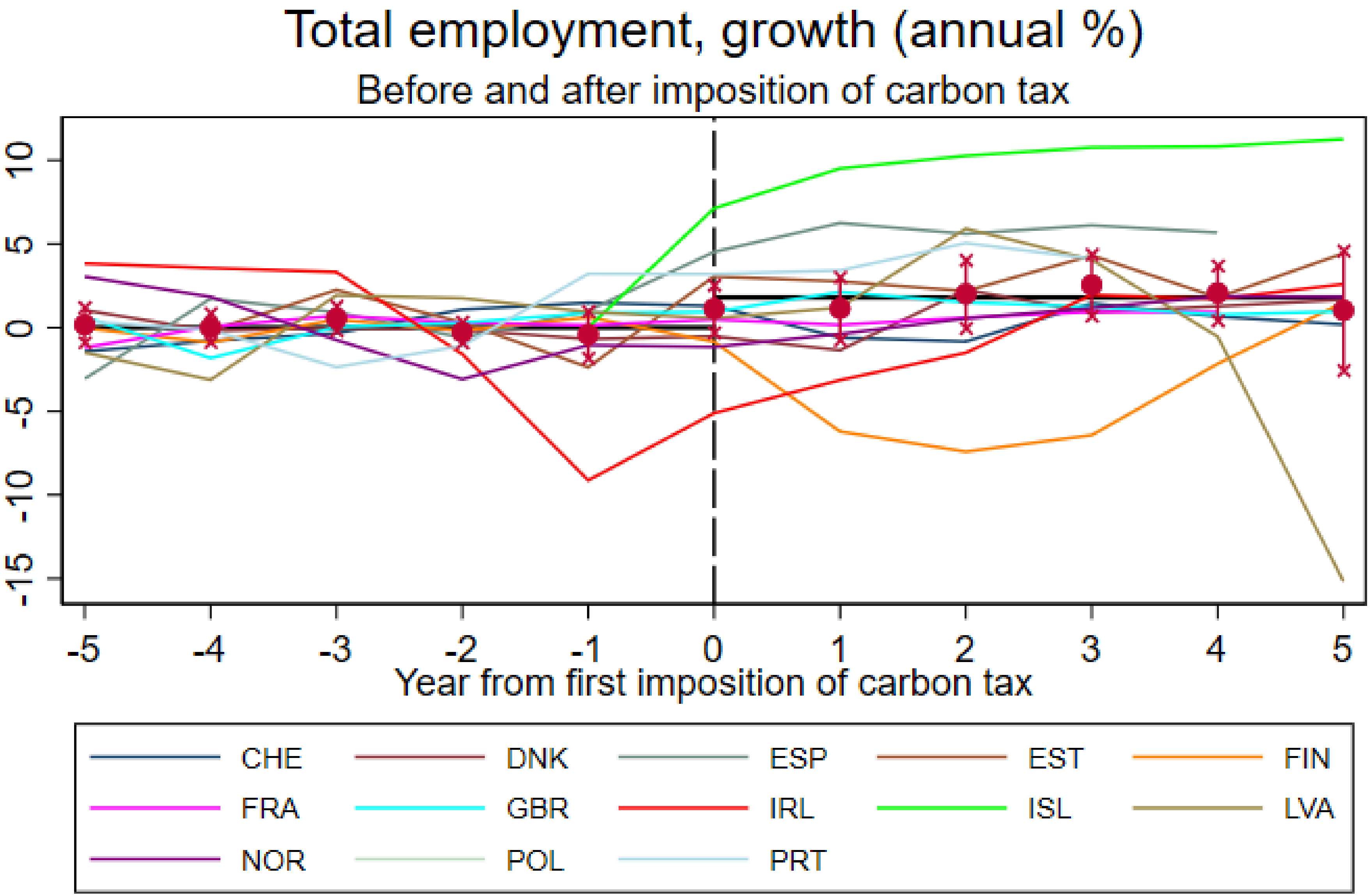
Sweden


GDP growth and Carbon tax rate: SWE
5
0
-5
1980
1990
2000
2010
2020
Year
150.00
100.00
50.00
0.00
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)



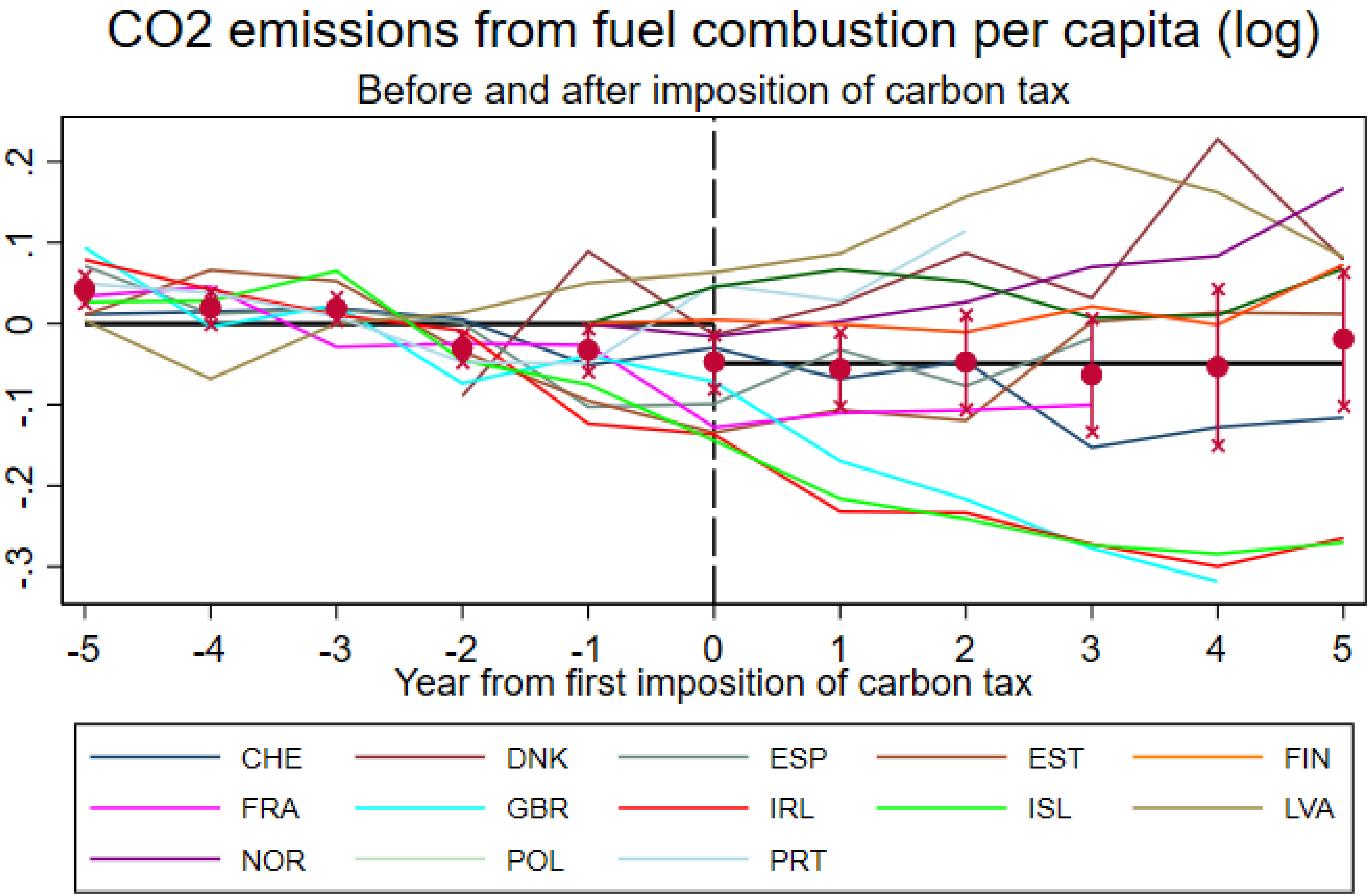
Deviated from country's pre-tax mean. Horizontal lines are pre/post means.
Dots and bars denote mean and 90% confidence interval by year.

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.

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 and identifying assumptions

- Estimand: cumulative dynamic causal effect of change in tax rate on real variables
- Two methods (LP, SVAR), 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*

+ Country fixed effects (rich nations adopt CT)
+ year FE (EU-wide confounders, financial crisis, etc.)

Identification comes from the time series variation: think "SVAR", not "event study"

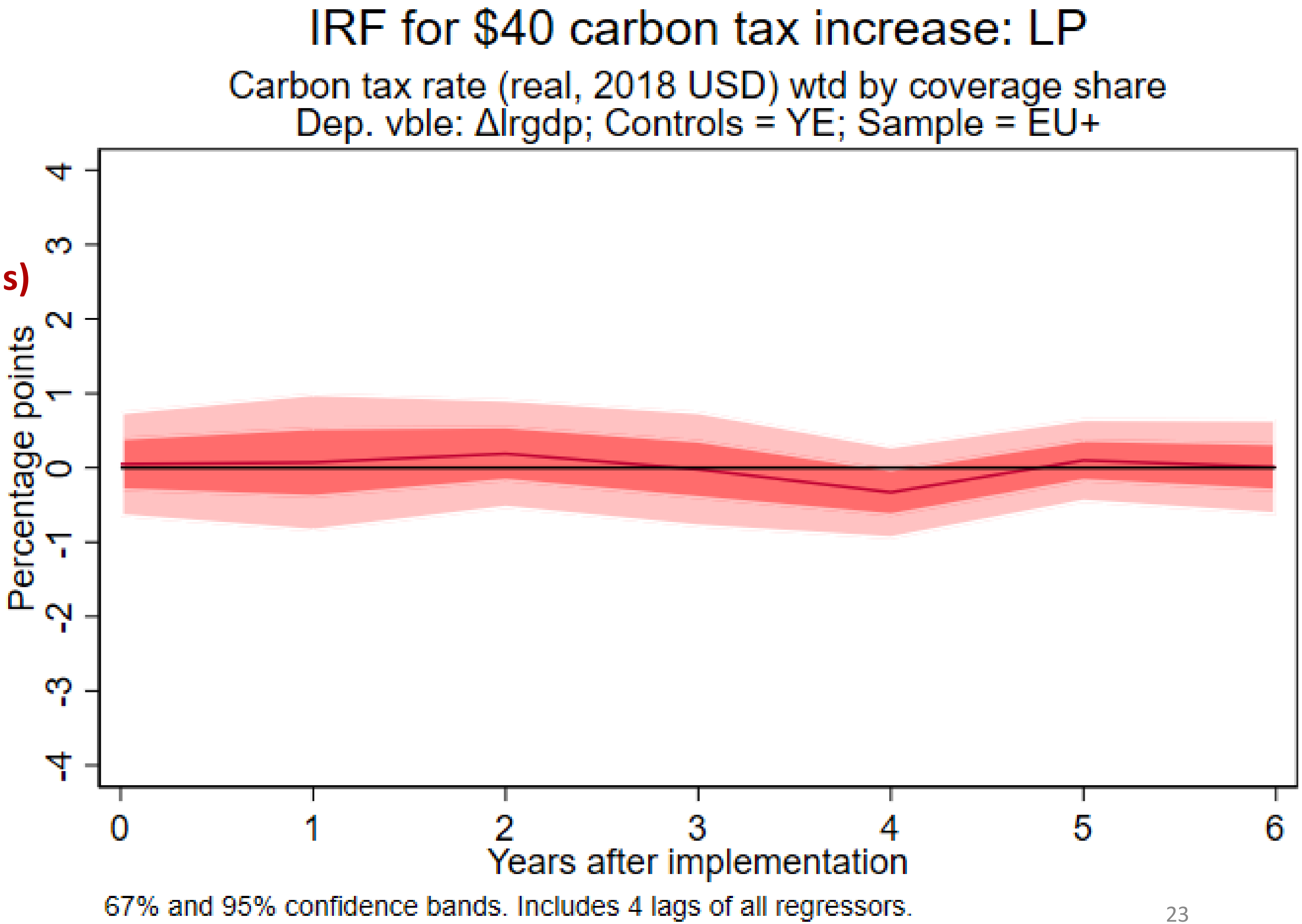
Odds & ends:

- Also estimate panel VAR
- Tax rate is interaction with coverage share
- Results calibrated to $40 tax covering 30% of emissions
- 4 lags of control variables/SVAR(4)
- Test & fail to reject parallel paths assumption (i.e., no long-run growth rate effect) – *results today impose parallel paths*

Results: GDP growth

Sample: **EU+**

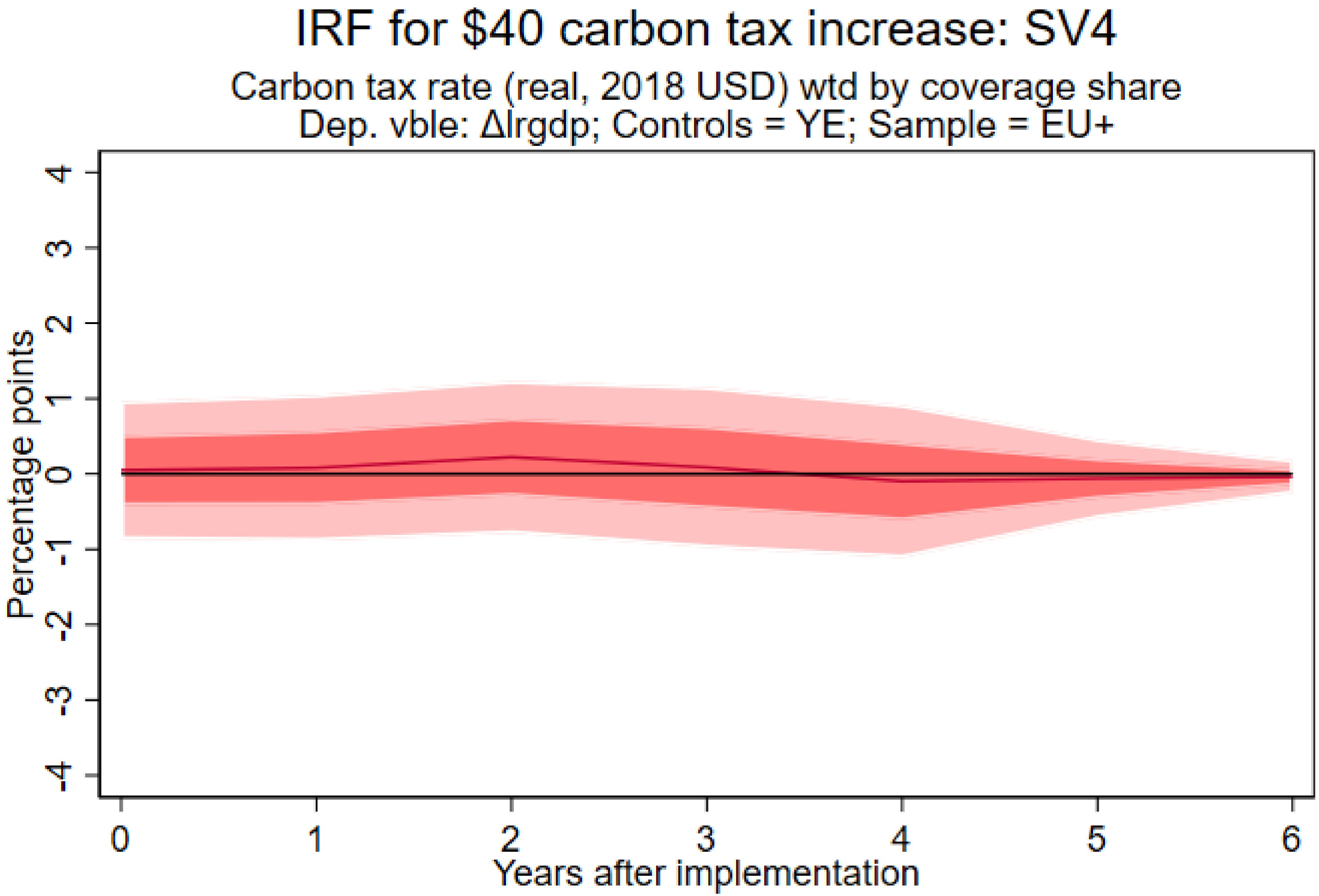
Method: **Linear Projection**
Restricted
(i.e., parallel paths)



Results: GDP growth

Sample: **EU+**

Method: **SVAR**
Restricted



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

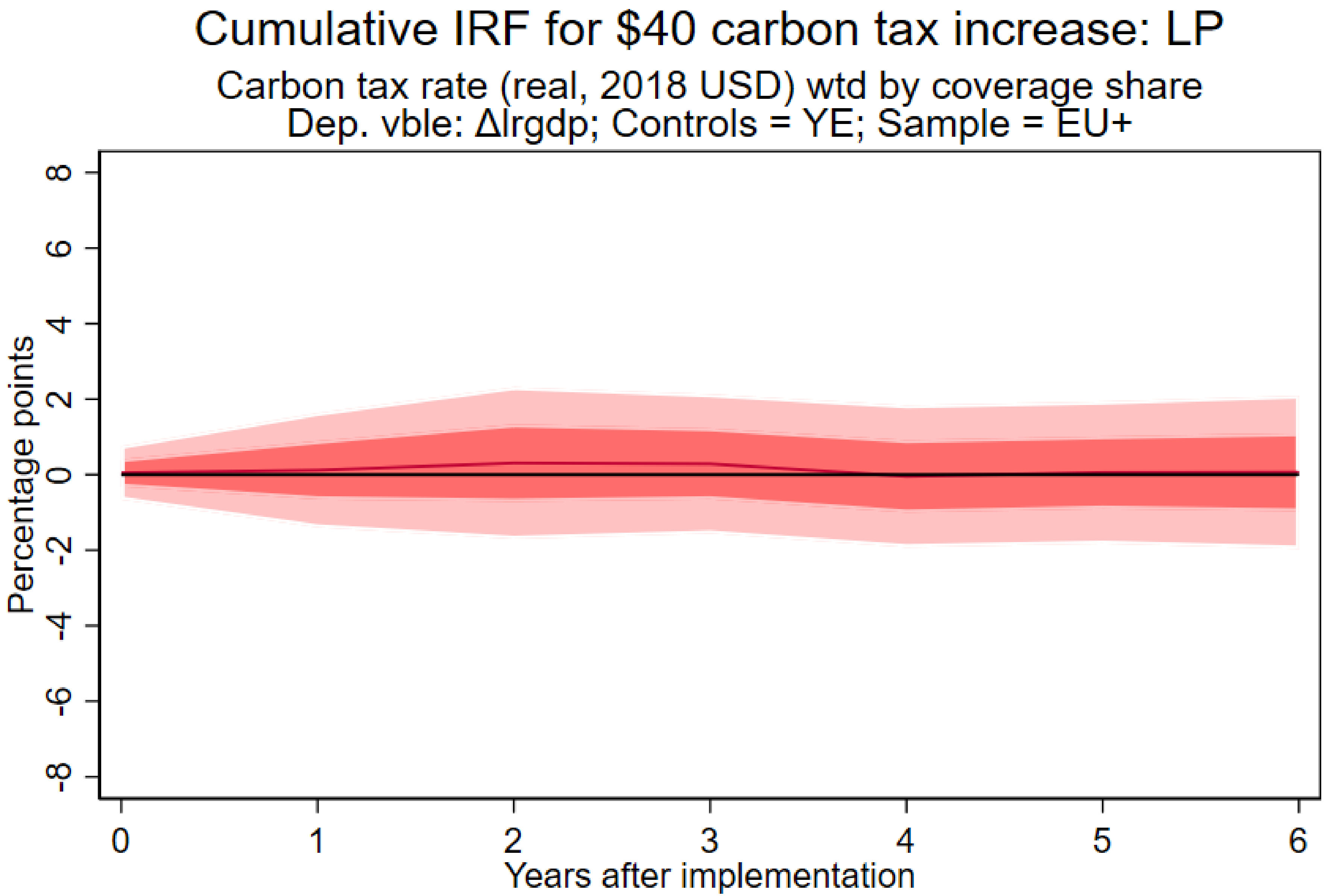
Results: GDP log level

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

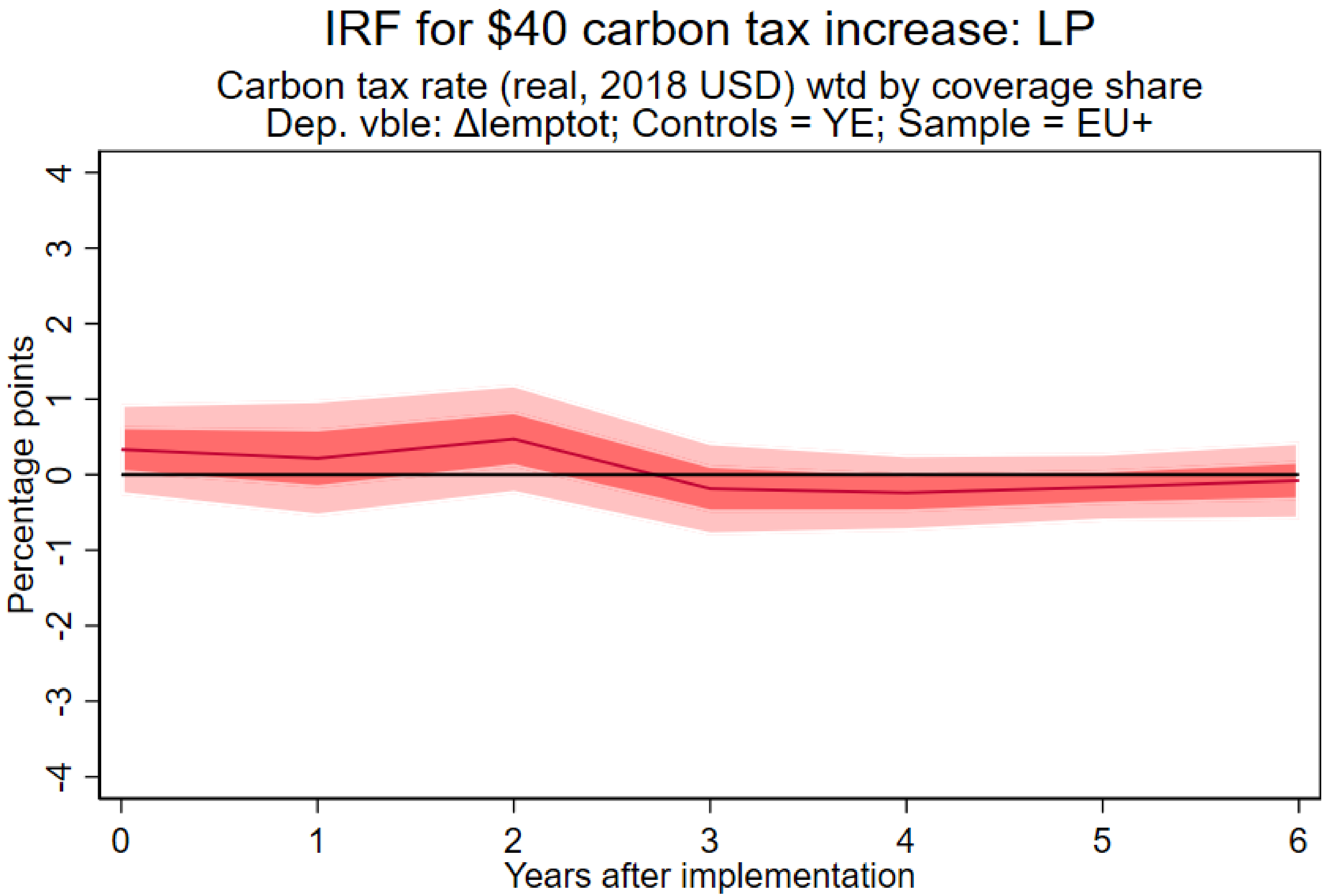


67% and 95% confidence bands. Includes 4 lags of all regressors.

Results: Employment growth

Sample: **EU+**

Method: **LP**
Restricted

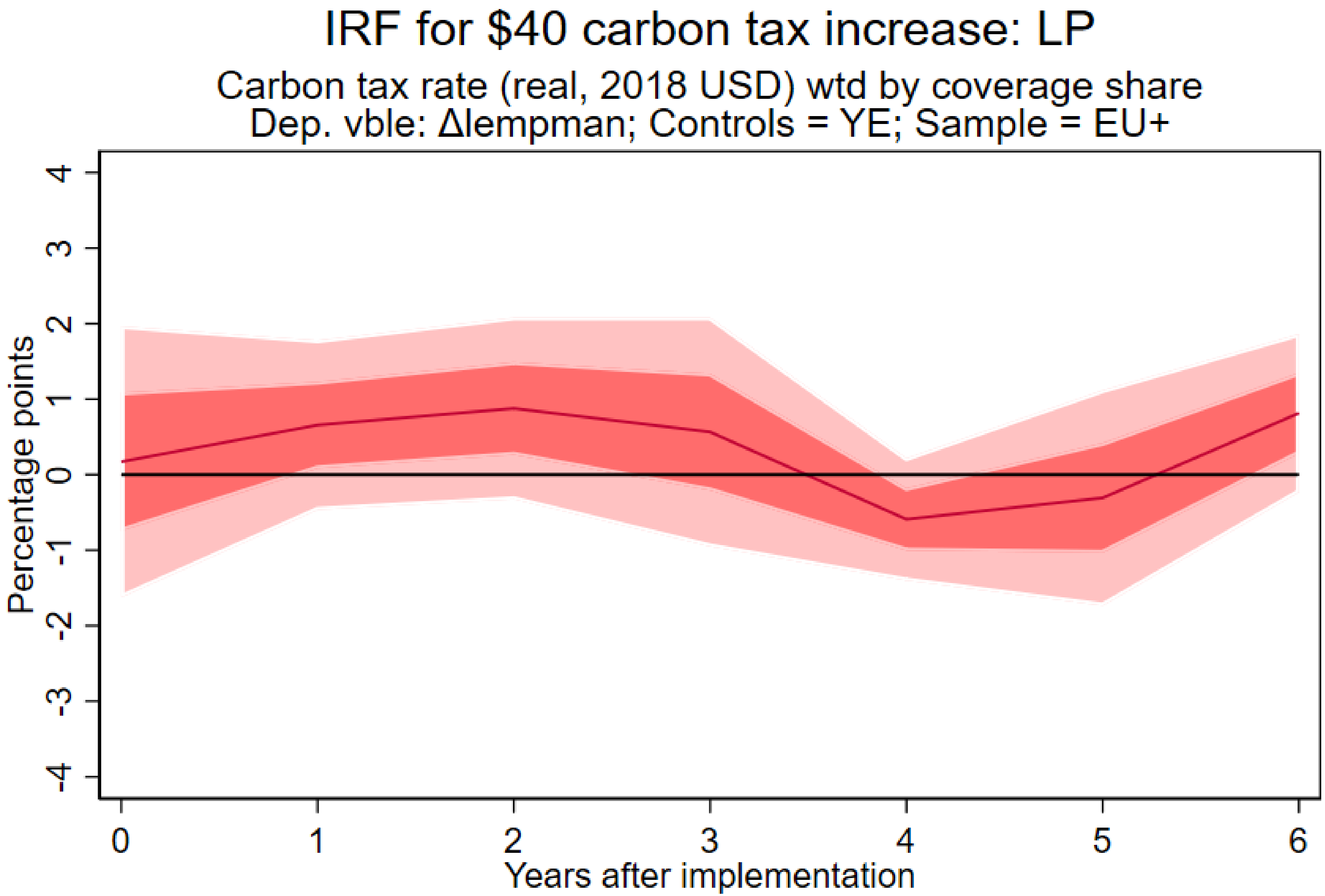


67% and 95% confidence bands. Includes 4 lags of all regressors.

Results: Manufacturing employment growth

Sample: **EU+**

Method: **LP**
Restricted



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

Results: Emissions log level

Sample: **EU+**

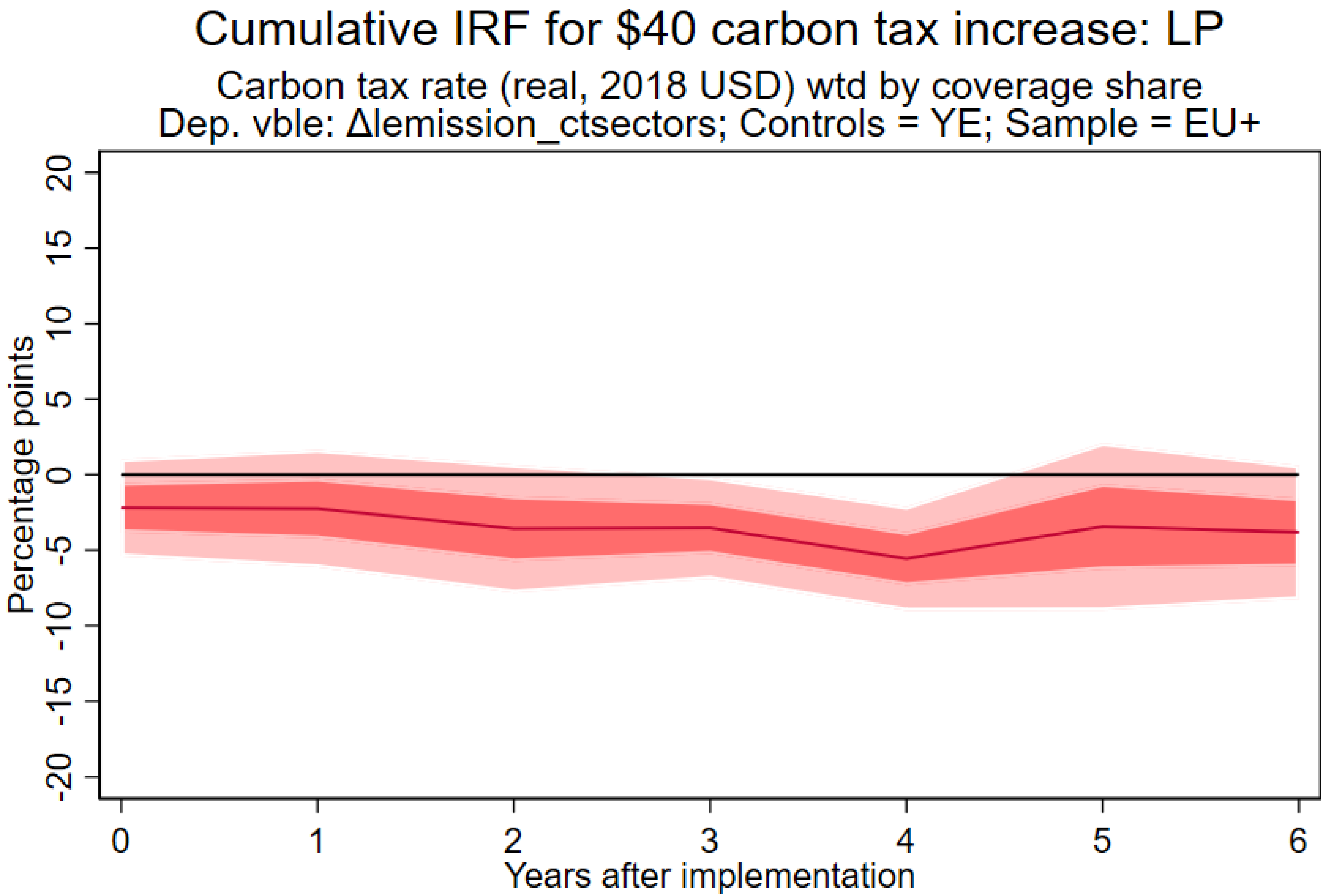
Method: **LP**
Restricted
Cumulative IRF

Emissions from sectors exposed to the CT

- This cumulative IRF is the estimated effect of the tax increase on the *level* of log(emissions)

Back of envelope:

- \$40 CT = \$0.36/gal
  ≈ 7% increase
  × -0.37 ≈ -3%
- Elasticity source: Coglianese, Davis, Kilian, Stock (2017)
- Similar results in Rafaty et al (2020)



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

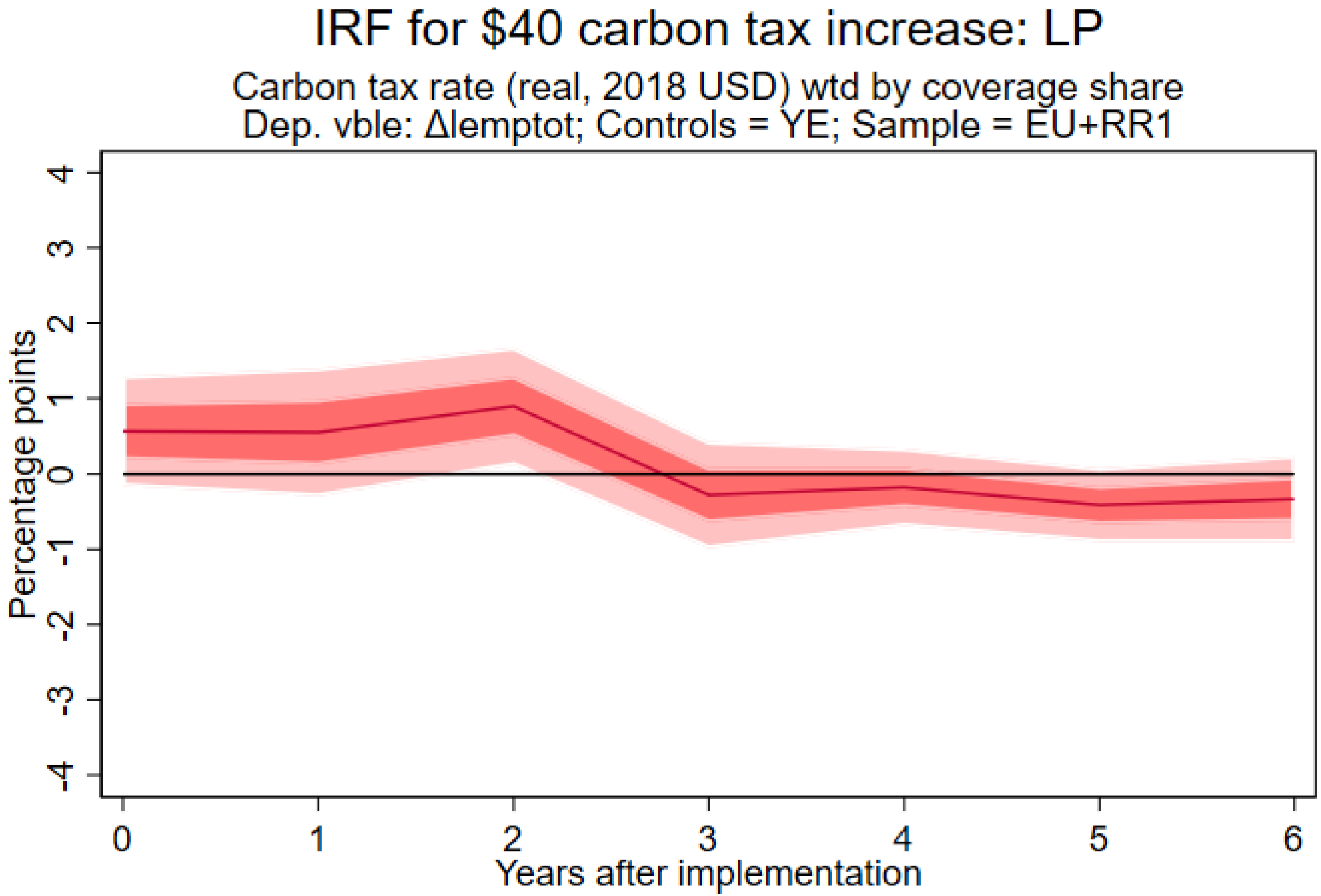
Results: Effect of revenue recycling

Sample: **EU+**
Revenue recycling

Dep vble: **Empl. growth**

Method: **LP**
Restricted

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



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

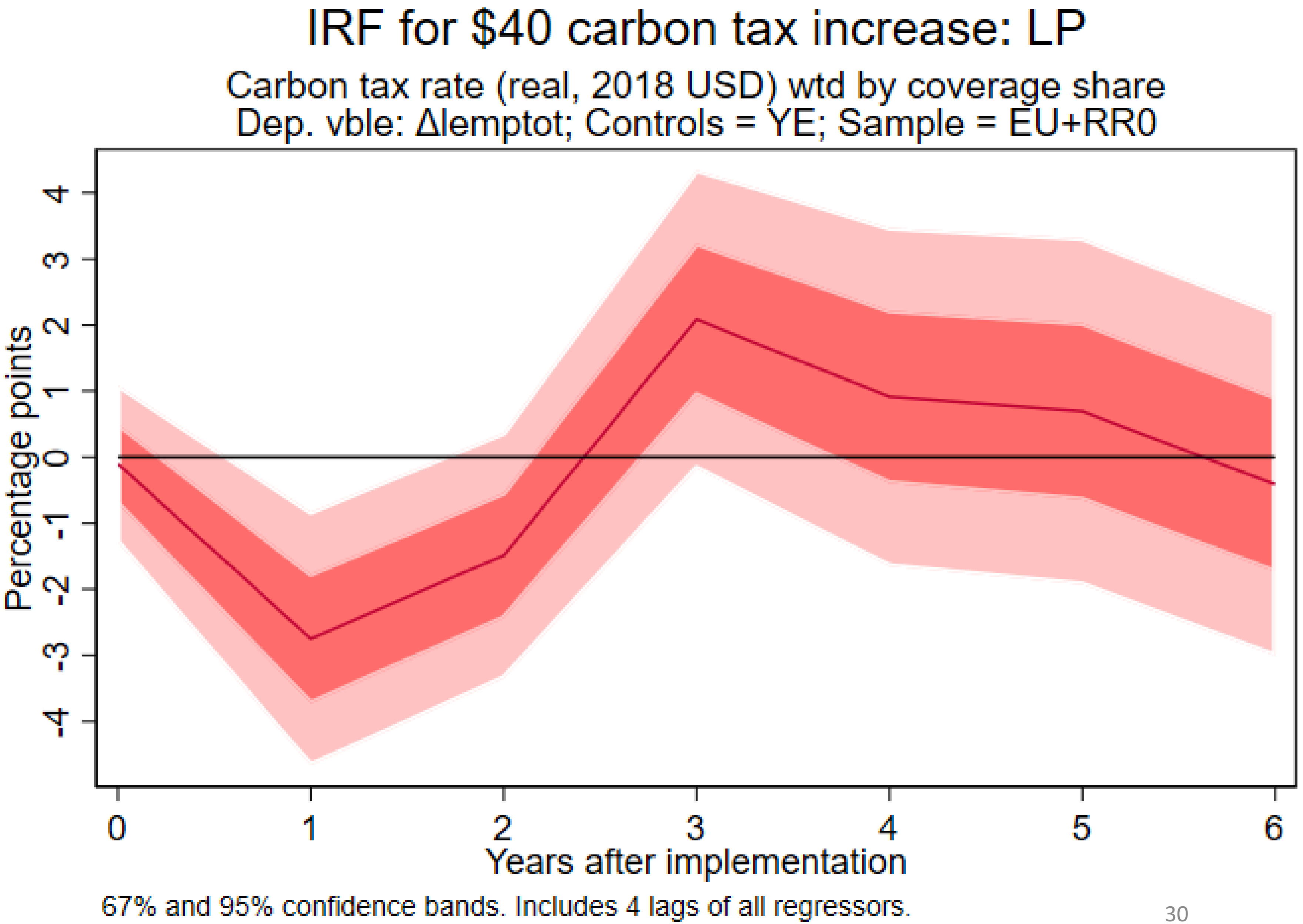
Results: Effect of revenue recycling

Sample: **EU+**
No revenue recycling

Dep vble: **Empl. growth**

Method: **LP**
Restricted

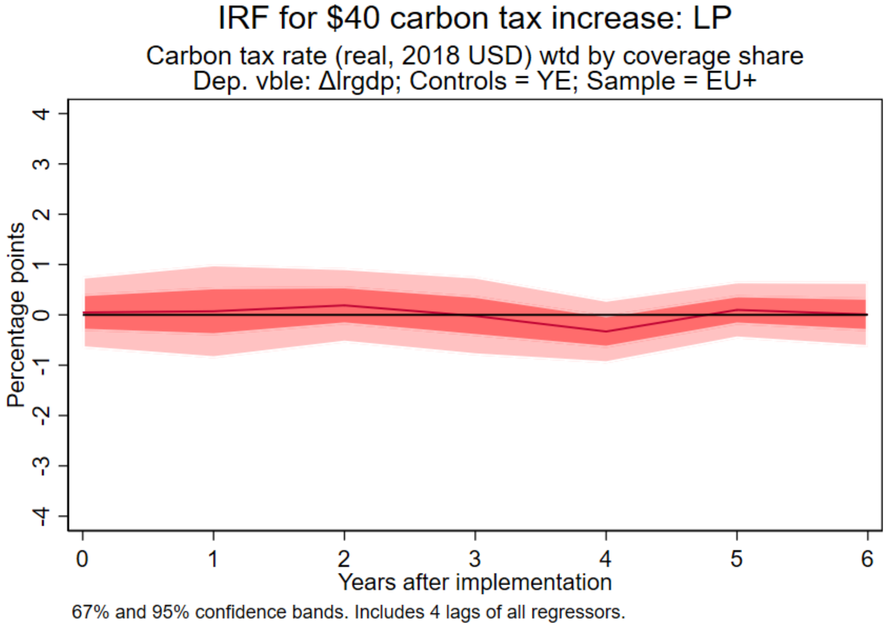
<u>Revenue recycling countries</u>
Denmark, Sweden, Norway, Finland, Switzerland, Portugal



Summary

GDP

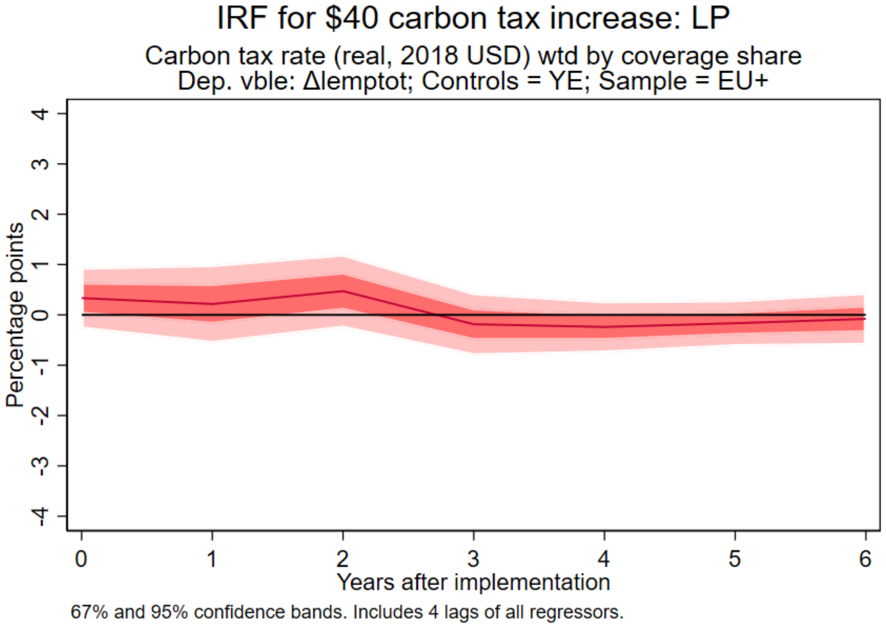
No effect



Employment

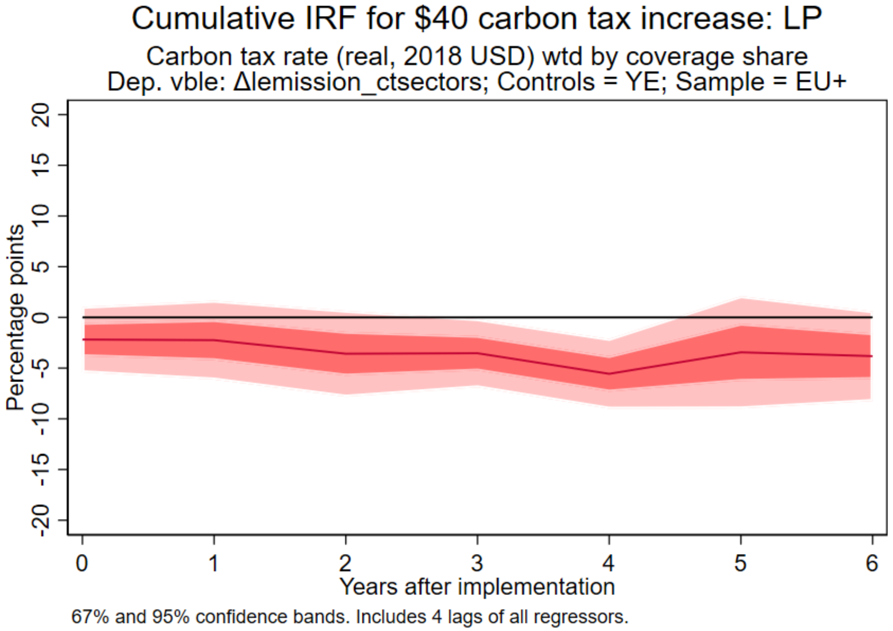
No effect

- *initial positive bump?*

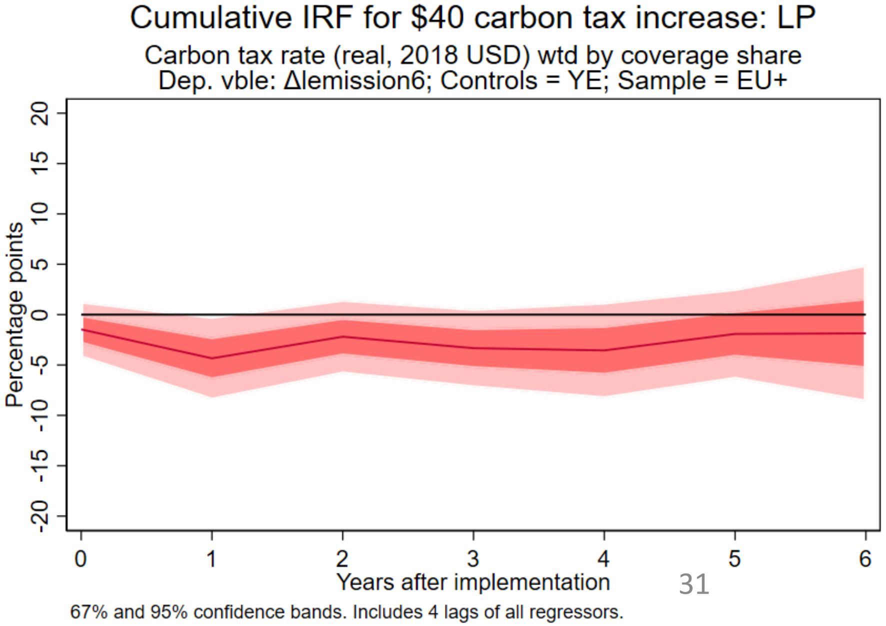


Emissions from covered sectors

2-6% reduction



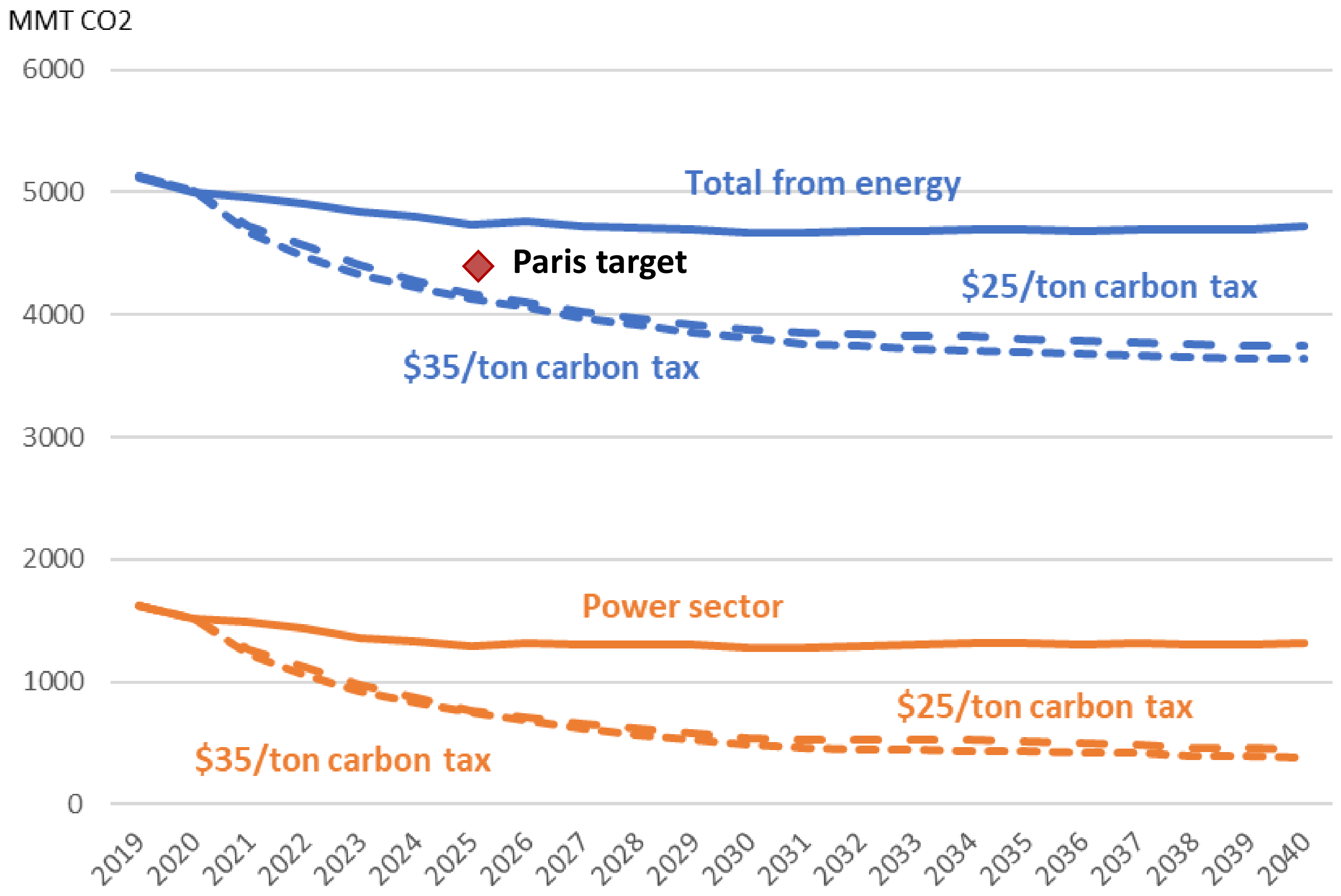
Emissions from fuel consumption



Back to original policy problem: Expect effect of CT in US?

The EU CT covers (mainly) the transportation sector – the power sector is covered by the EU ETS. In the US, it would cover the power sector too.

EIA *Annual Energy Outlook* 2020 Projections of CO2 Emissions: Reference Case and $25 and $35/ton carbon tax side cases



Key features ($35/ton case):

- Power sector emissions are reduced by 67% by 2035
- Total emissions fall by 21% by 2035
- 90% of emissions reductions come from the power sector
- EIA's gasoline elasticities are too low, but even with -0.37, a $35/ton CT yields an emissions reduction of only 5% in the transportation sector ≈ 1.3% reduction in total emissions
    - This could change significantly when EVs achieve price parity

Source: EIA simulations of NEMS model

What about other power sector policies?

Legislative

1) Carbon tax, economy-wide
2) Carbon tax, power sector only
3) Clean electricity standard (CES)
    - Binary (clean/not clean)
    - Proportional to CO_2 emissions
4) Extend investment & production tax credits

What about other power sector policies?

Legislative

1) Carbon tax, economy-wide
2) Carbon tax, power sector only
3) Clean electricity standard (CES)
    - Binary (clean/not clean)
    - Proportional to CO_2 emissions
4) Extend investment & production tax credits

Regulatory

5) Clean Air Act regulation
6) End federal coal program

United States Court of Appeals

FOR THE DISTRICT OF COLUMBIA CIRCUIT

Argued October 8, 2020 Decided January 19, 2021

No. 19-1140

AMERICAN LUNG ASSOCIATION AND AMERICAN PUBLIC HEALTH ASSOCIATION,
PETITIONERS

v.

ENVIRONMENTAL PROTECTION AGENCY AND ANDREW WHEELER, ADMINISTRATOR,
RESPONDENTS

The question in this case is whether the Environmental Protection Agency (EPA) acted lawfully in adopting the 2019 Affordable Clean Energy Rule (ACE Rule) … as a means of regulating power plants' emissions of greenhouse gases. It did not. Although the EPA has the legal authority to adopt rules regulating those emissions, the central operative terms of the ACE Rule and the repeal of its predecessor rule, the Clean Power Plan hinged on a fundamental misconstruction of Section 7411(d) of the Clean Air Act. In addition, the ACE Rule's amendment of the regulatory framework to slow the process for reduction of emissions is arbitrary and capricious. For those reasons, the ACE Rule is vacated, and the record is remanded to the EPA for further proceedings consistent with this opinion.

p. 16-17

What about other power sector policies?

Legislative

1) Carbon tax, economy-wide
2) Carbon tax, power sector only
3) Clean electricity standard (CES)
   - Binary (clean/not clean)
   - Proportional to CO2 emissions
4) Extend investment & production tax credits

Regulatory

5) Clean Air Act regulation
6) End federal coal program

Rely on stronger state policies

7) Strengthen state RPS's (e.g., New York state)
8) Strengthen state/regional emissions trading systems (CA AB32, RGGI)

United States Court of Appeals
FOR THE DISTRICT OF COLUMBIA CIRCUIT

Argued October 8, 2020 Decided January 19, 2021

No. 19-1140

AMERICAN LUNG ASSOCIATION AND AMERICAN PUBLIC HEALTH ASSOCIATION,
PETITIONERS

v.

ENVIRONMENTAL PROTECTION AGENCY AND ANDREW WHEELER, ADMINISTRATOR,
RESPONDENTS

The question in this case is whether the Environmental Protection Agency (EPA) acted lawfully in adopting the 2019 Affordable Clean Energy Rule (ACE Rule) … as a means of regulating power plants' emissions of greenhouse gases. It did not. Although the EPA has the legal authority to adopt rules regulating those emissions, the central operative terms of the ACE Rule and the repeal of its predecessor rule, the Clean Power Plan hinged on a fundamental misconstruction of Section 7411(d) of the Clean Air Act. In addition, the ACE Rule's amendment of the regulatory framework to slow the process for reduction of emissions is arbitrary and capricious. For those reasons, the ACE Rule is vacated, and the record is remanded to the EPA for further proceedings consistent with this opinion.

p. 16-17

What about other power sector policies?

Effects of selected power sector policies

Policy	Cumulative abatement 2020-2036 (mmt)	Average cost per ton CO_2 abated
Federal $40 carbon tax	13,400	$24/ton
Federal 80% CES (binary)	10,200	$43/ton
Federal ITC, PTC extension	2,800	$48/ton
State 80% CES	5	$395/ton

Source: Daniel Stuart (2021), modified NREL ReEDS model

Notes:

- For comparison: Obama era SCC = $51 ($125 at 2% discount rate)
- $40 carbon tax increases @ 5%/yr. National CES ramps from 24% in 2020 to 80% in 2035.
- State CES policy applies to CA, CO, MA, NM, NY, WA, and VA
- State $40 carbon price applies to CA (AB32) and CT, DE, ME, MD, MA, NH, NJ, NY, RI, and VA (RGGI)

Understanding these results:

- The carbon tax increases the marginal cost of FF electricity in proportion to CO_2 emissions
- A proportional CES increases the marginal cost in proportion to CO_2 and subsidizes clean sources
- The PTC subsidizes onshore wind generation ($24/MWh) but does not affect the marginal cost of FF generation
- The ITC subsidizes the capital cost of solar & offshore wind but does not affect marginal costs

Carbon tax – can't go it alone

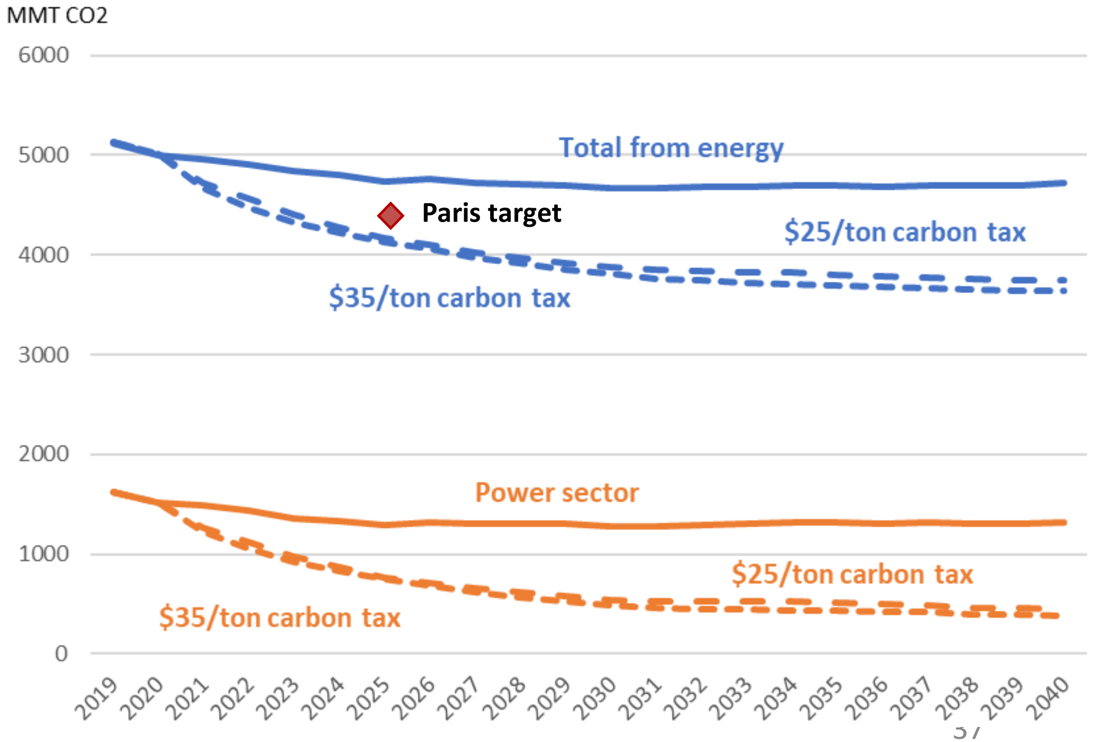
A number of carbon tax bills were introduced in the previous Congress, but there are legitimate concerns…

- Jobs and economy
- Regressive
- Impacted sectors (concentrated negatively affected interests)
- Won't produce the necessary emissions reductions

- What about a higher tax rate?
  - IPCC SR 1.5: \$75-\$125 @ 5% real = \$325-\$540 in 2050 (other scenarios in thousands)

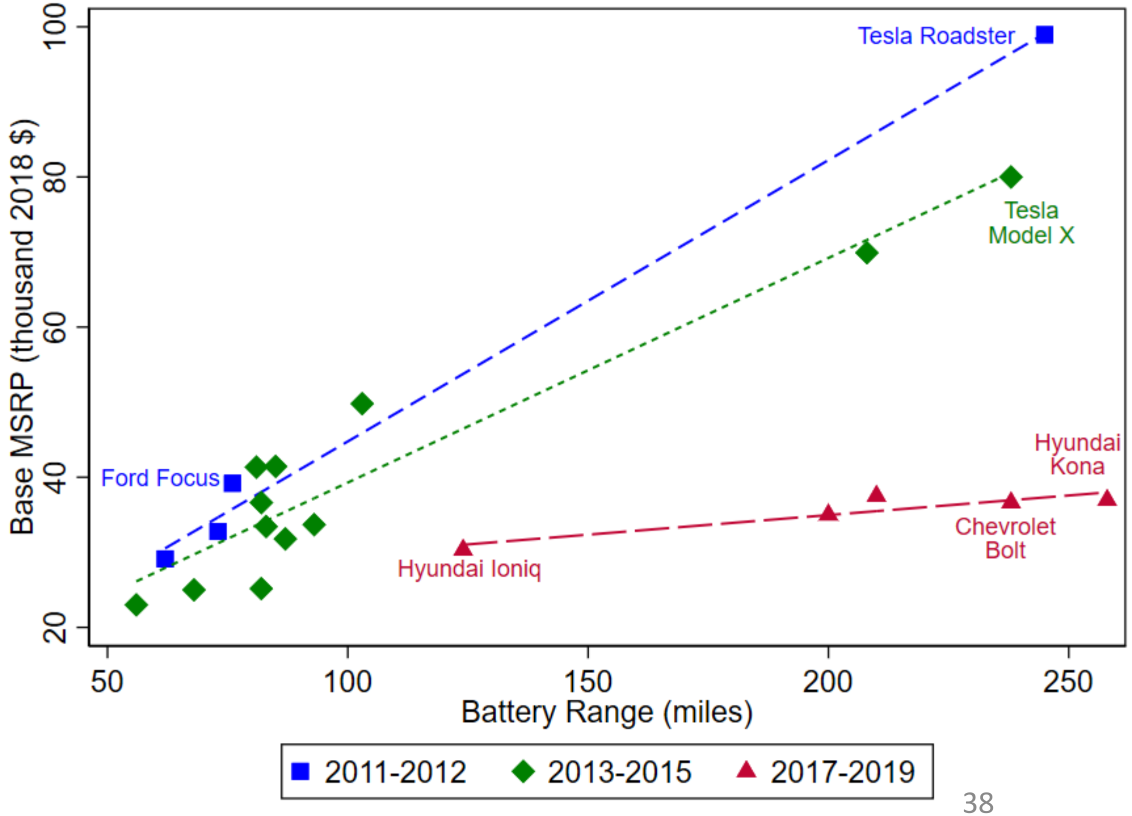
➢ Main problem is that there are multiple externalities:
  - Carbon price externality
  - R&D
  - Network externalities
  - …

➢ Multiple externalities => multiple tools



Main domestic climate policy bins:

- Price on carbon
- Transportation sector & EVs
- Green RD&D policy
- Supply side policies
    - financial disclosures through keep-it-in-the-ground
- USG regulatory weeds

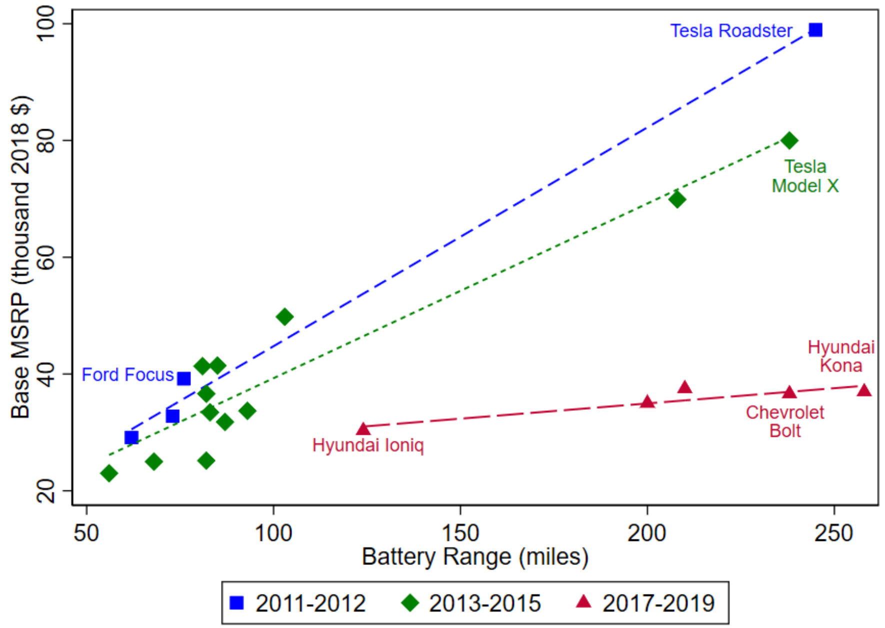


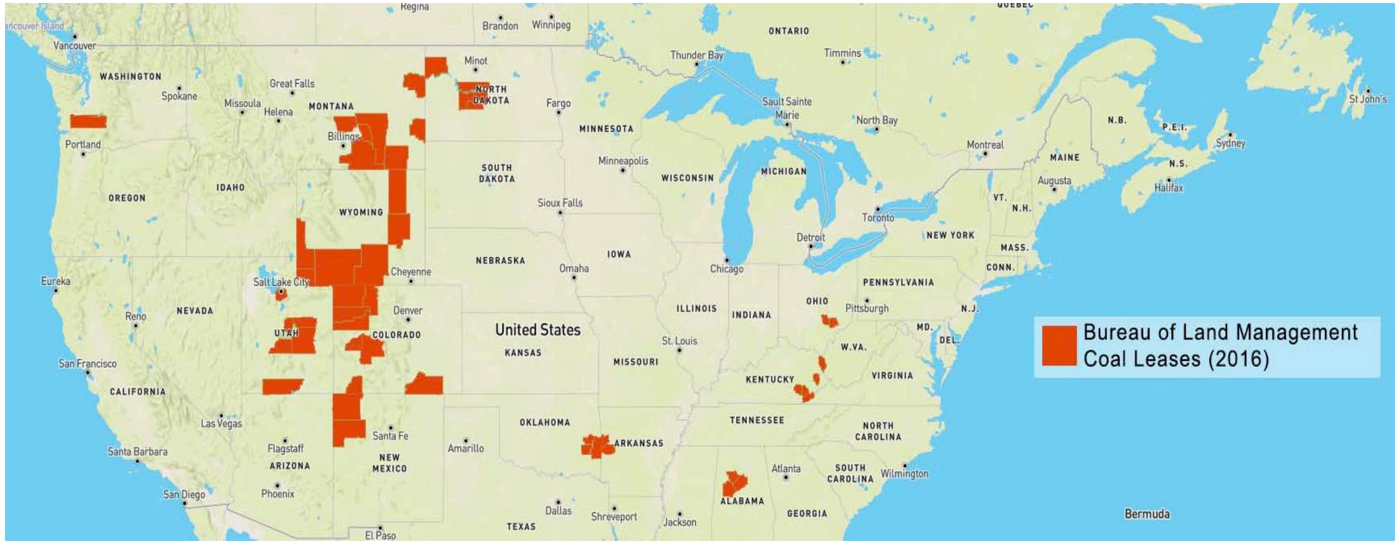
Carbon tax – can't go it alone

Main domestic climate policy bins:

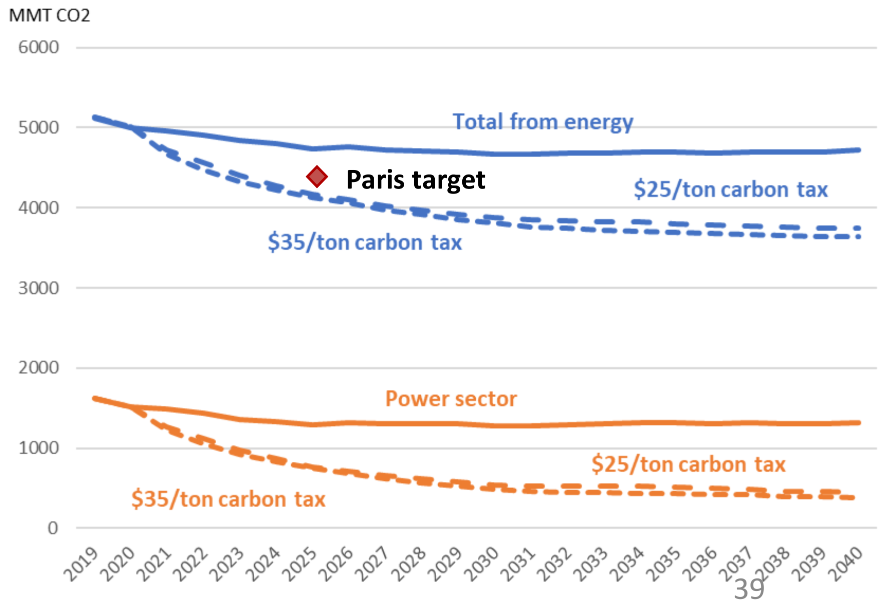
- Price on carbon
- Transportation sector & EVs
- Green RD&D policy
- Supply side policies

  financial disclosures through keep-it-in-the-ground
- USG regulatory weeds





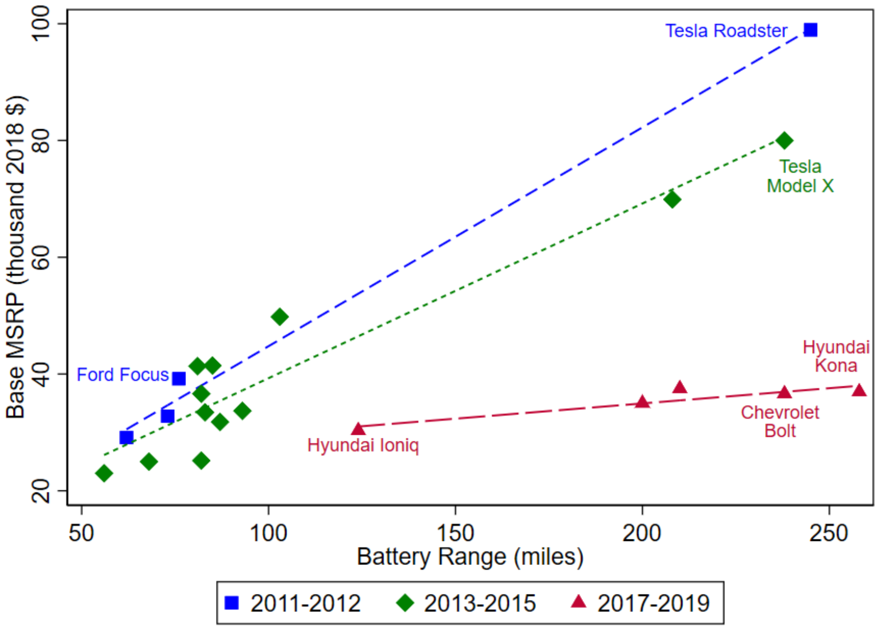
References: USDOI (2017); Gerarden, Reeder, & Stock (2019)

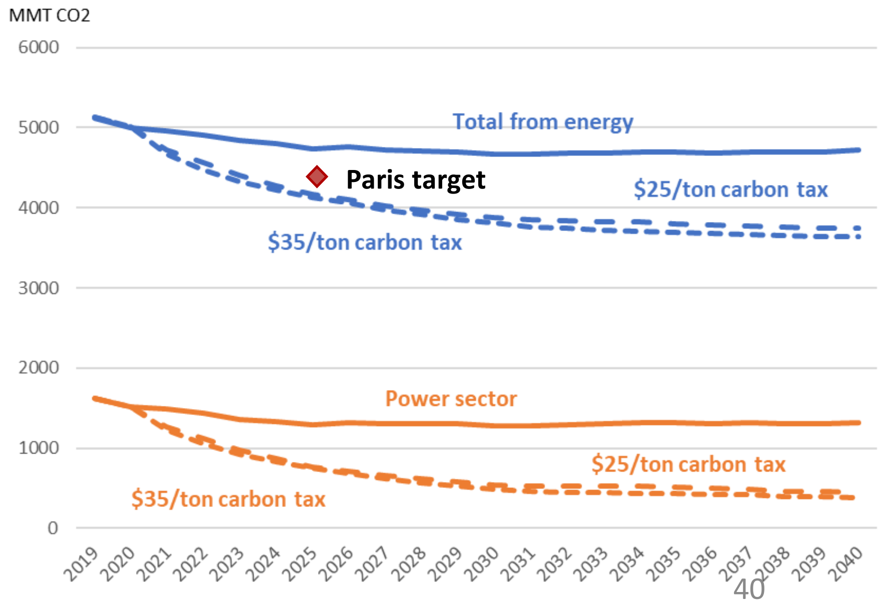


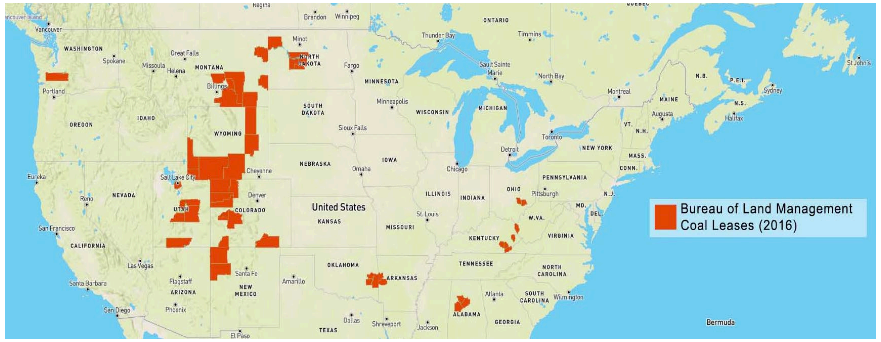
Carbon tax – can't go it alone

Main domestic climate policy bins:

- Price on carbon
- Transportation sector & EVs
- Green RD&D policy
- Supply side policies
  - financial disclosures through keep-it-in-the-ground
- USG regulatory weeds
  - SCC & OMB Circular A-4
  - FERC transmission siting authority
  - Command & control regulation for methane
  - …







Additional Slides

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

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: 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?

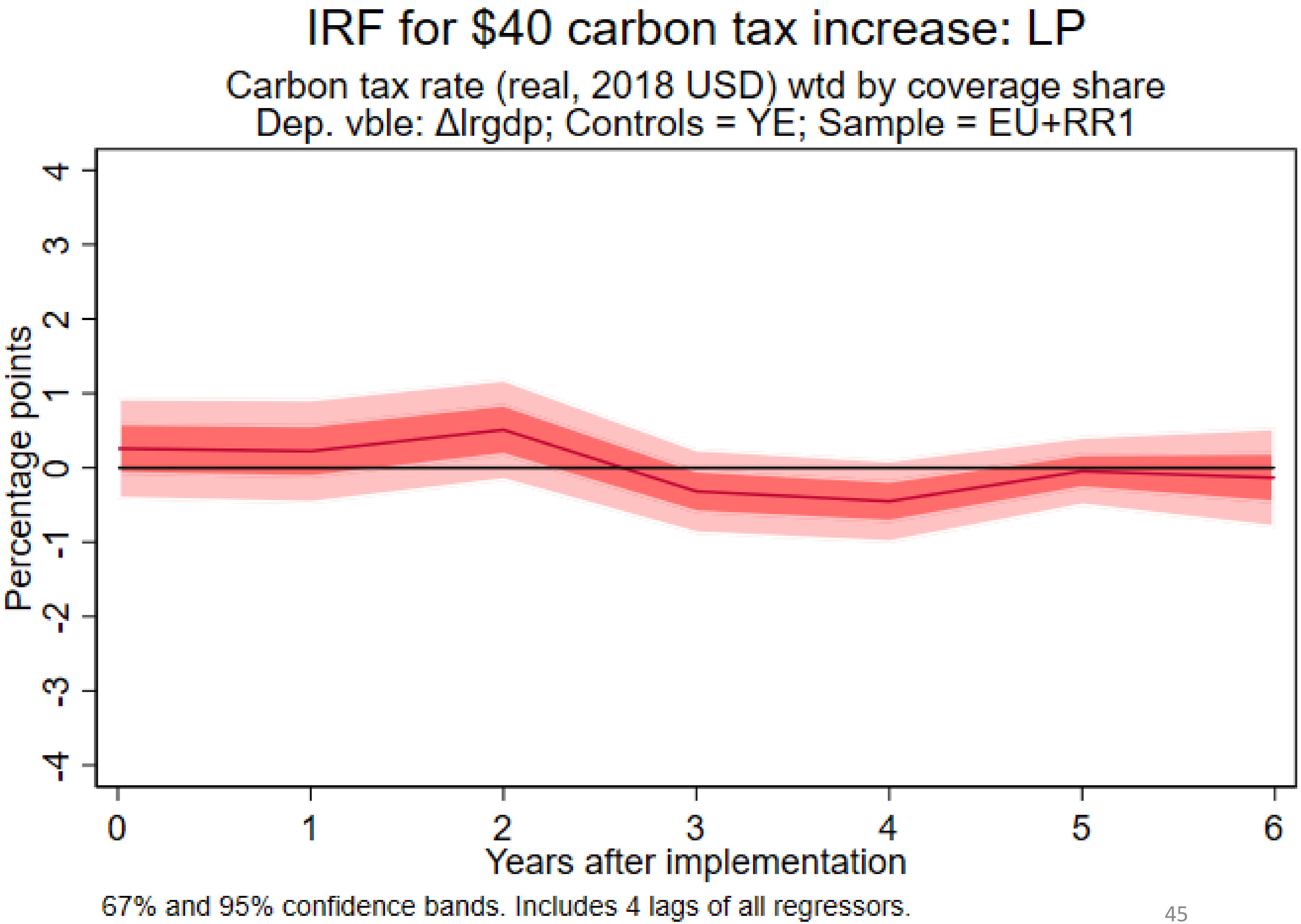
Results: Effect of revenue recycling

Sample: **EU+**
Revenue recycling

Dep vble: **GDP growth**

Method: **LP**
Restricted

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



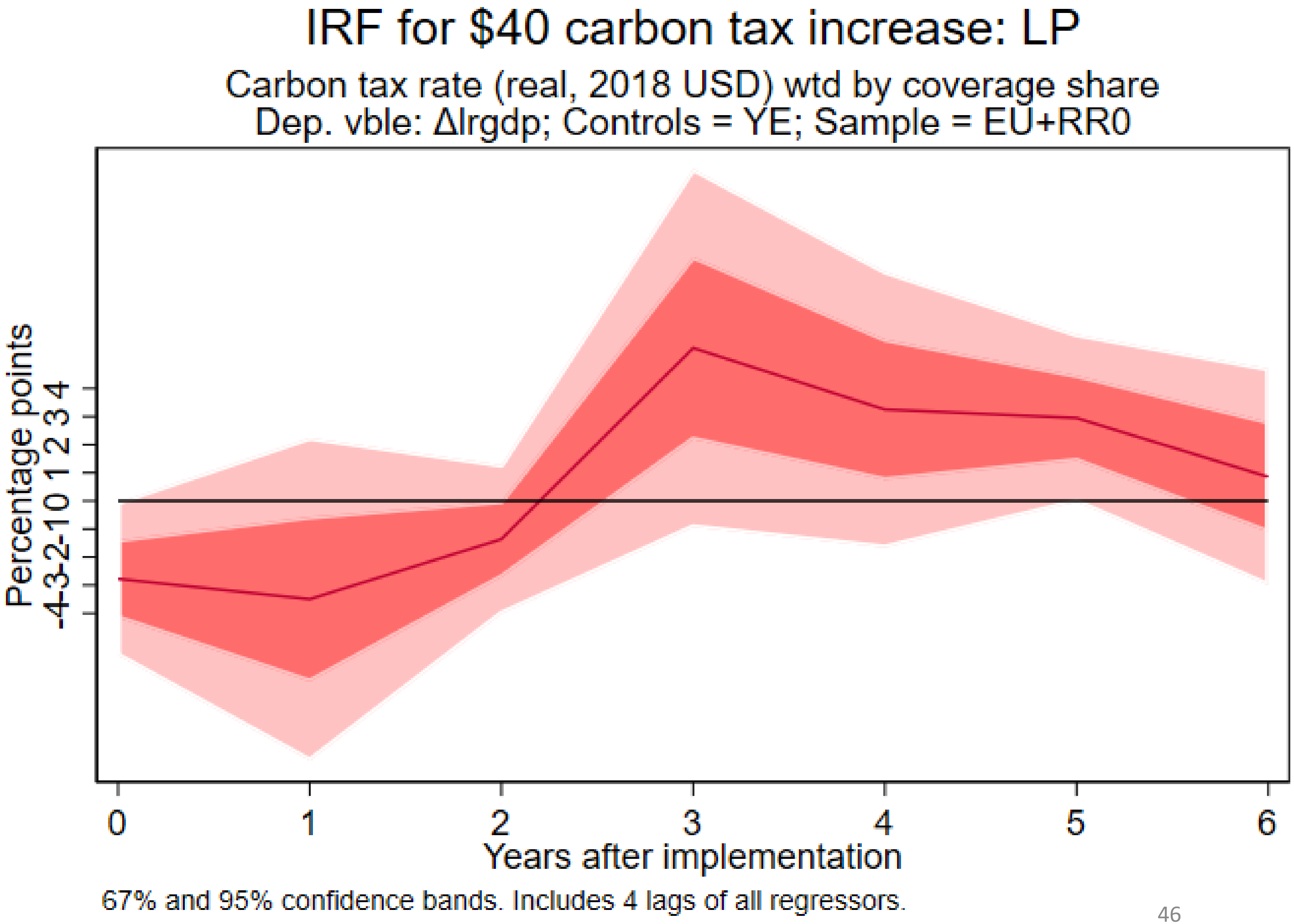
Results: Effect of revenue recycling

Sample: **EU+**
No revenue recycling

Dep vble: **GDP growth**

Method: **LP**
Restricted

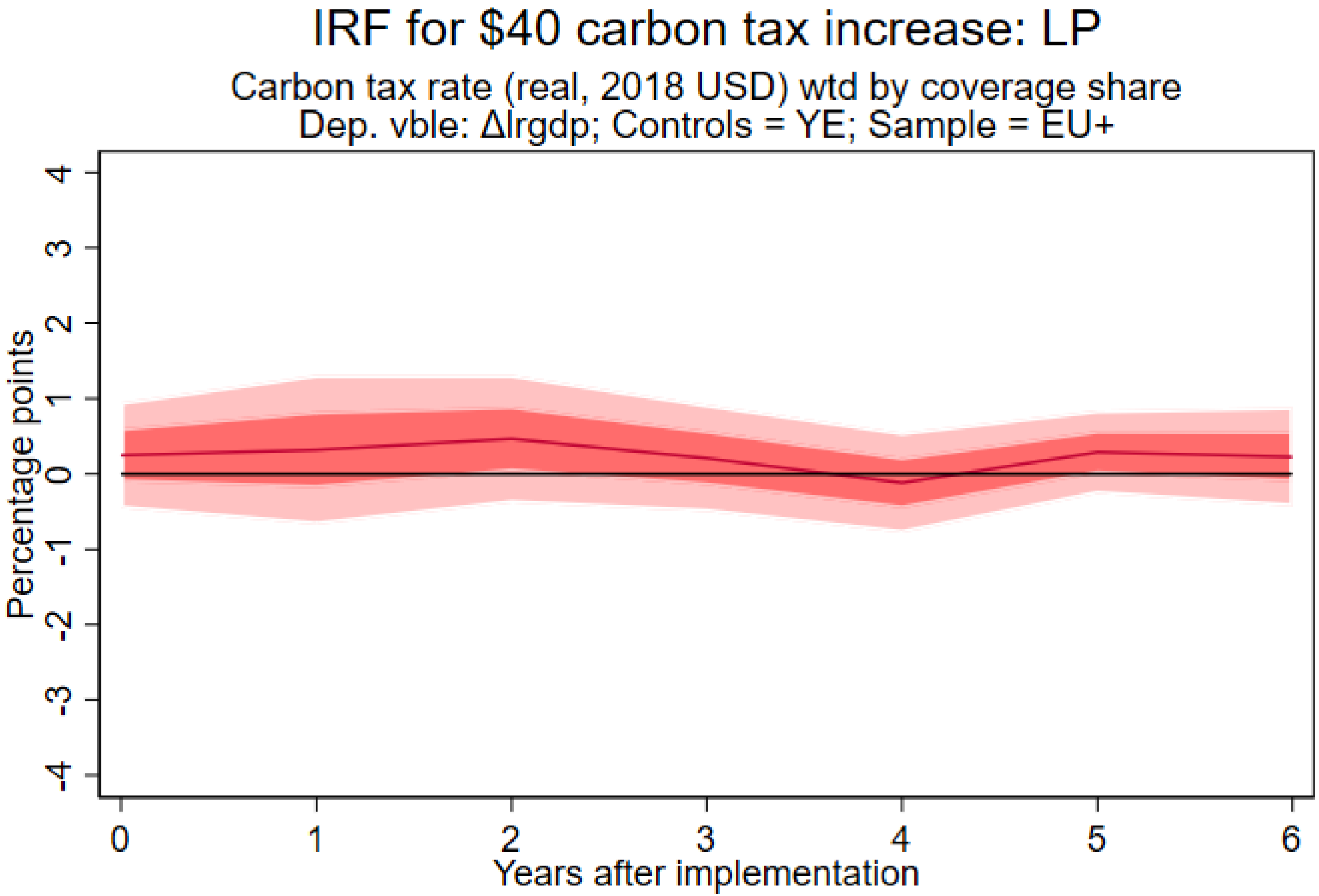
Revenue recycling countries
Denmark, Sweden, Norway, Finland, Switzerland, Portugal



Results: GDP growth

Sample: **EU+**

Method: **Linear Projection Unrestricted**

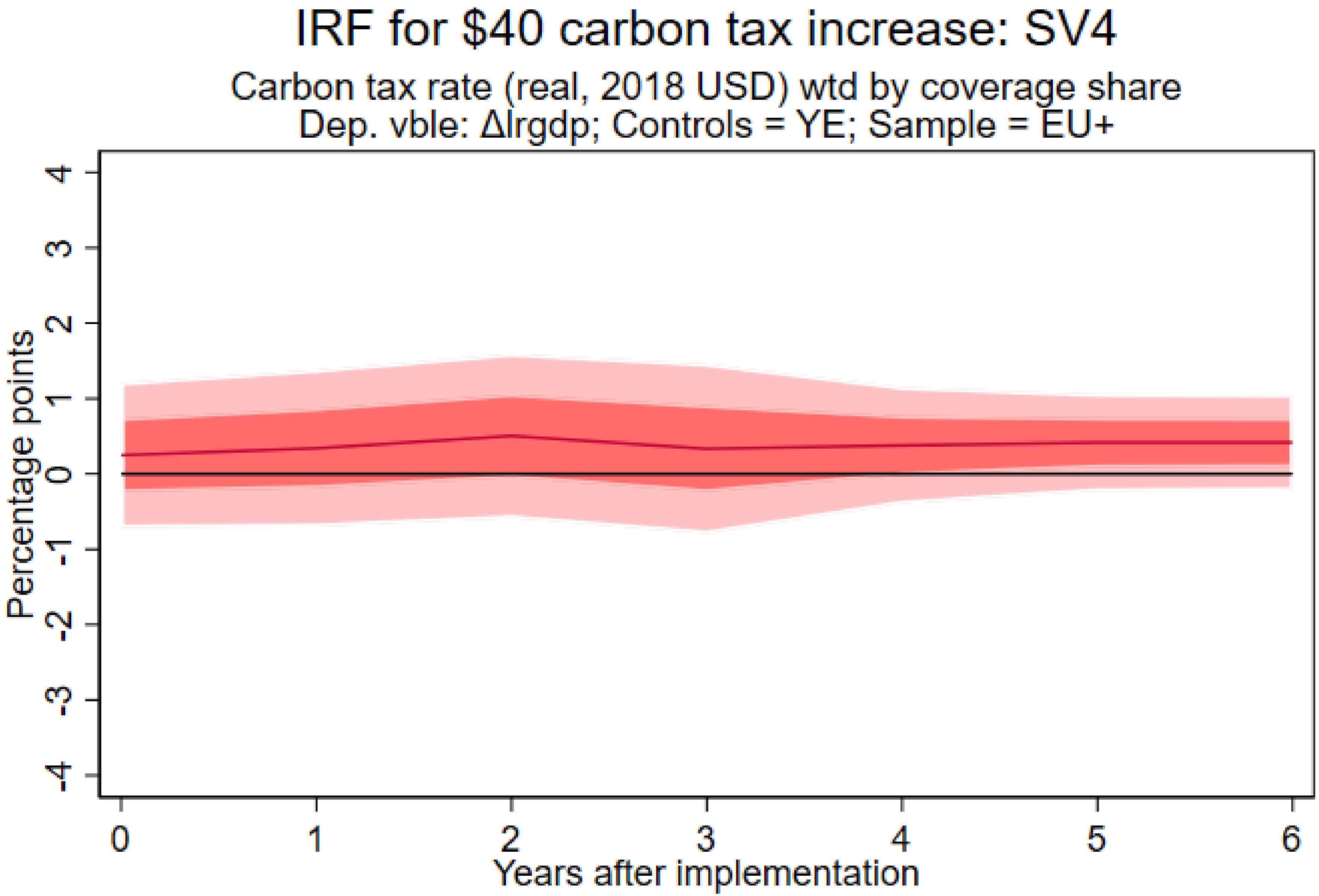


67% and 95% confidence bands. Includes 4 lags of all regressors.

Results: GDP growth

Sample: **EU+**

Method: **SVAR**
Unrestricted

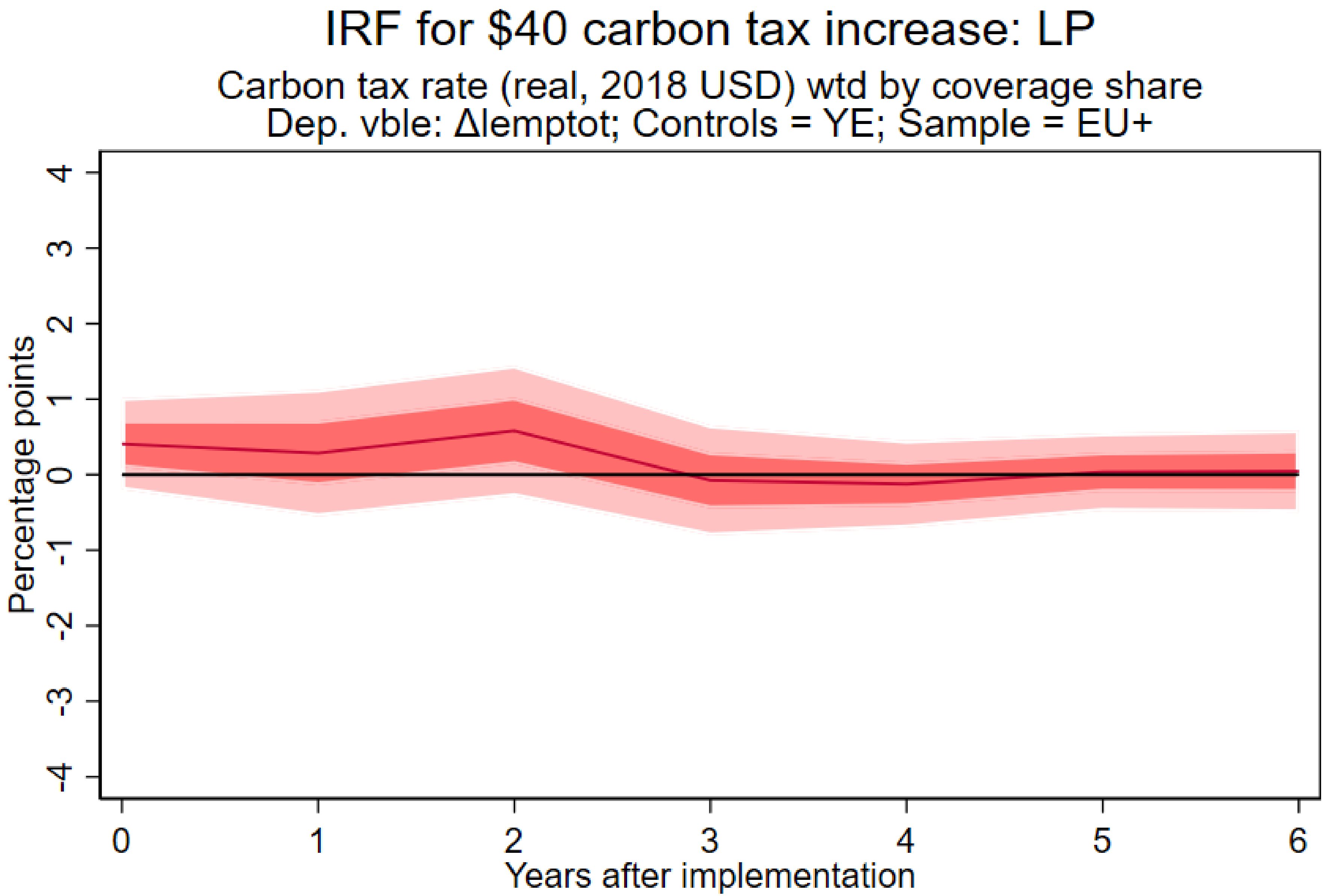


67% and 95% confidence bands. Includes 4 lags of all regressors.

Results: Employment

Sample: **EU+**

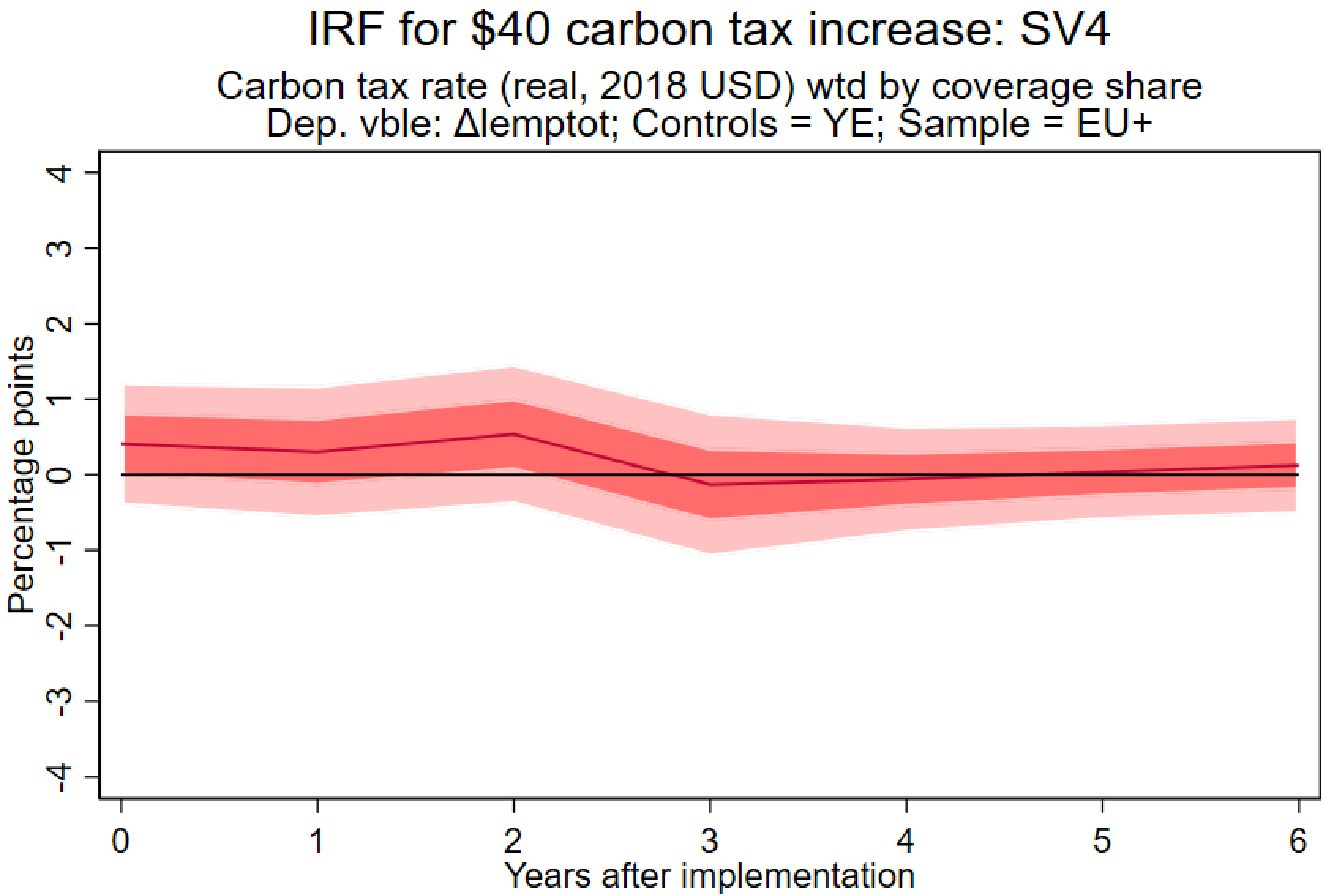
Method: **LP**
Unrestricted



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

Sample: **EU+**

Method: **SVAR Unrestricted**



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

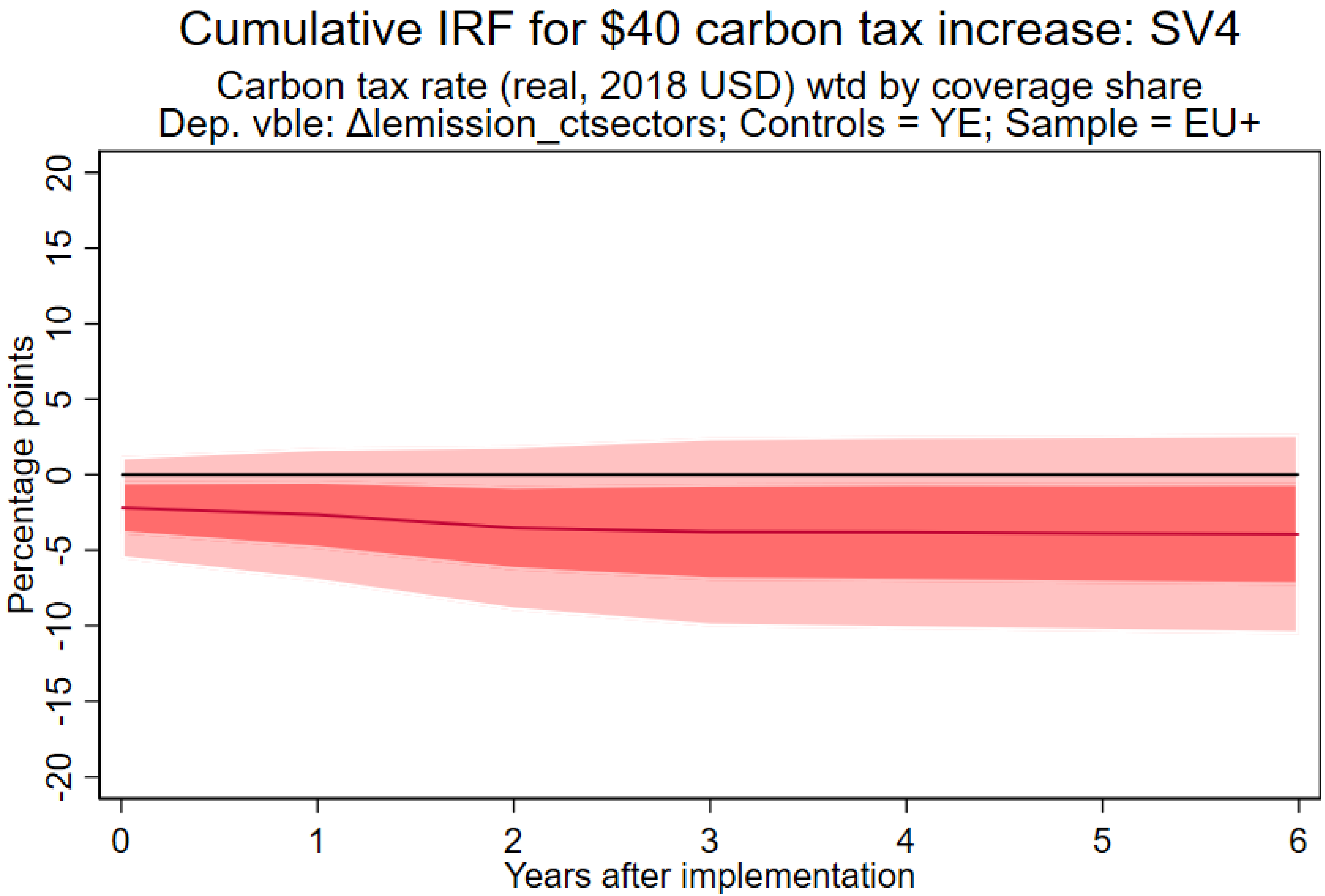
Results: Emissions

Sample: **EU+**

Method: **SVAR**
Restricted
Cumulative IRF

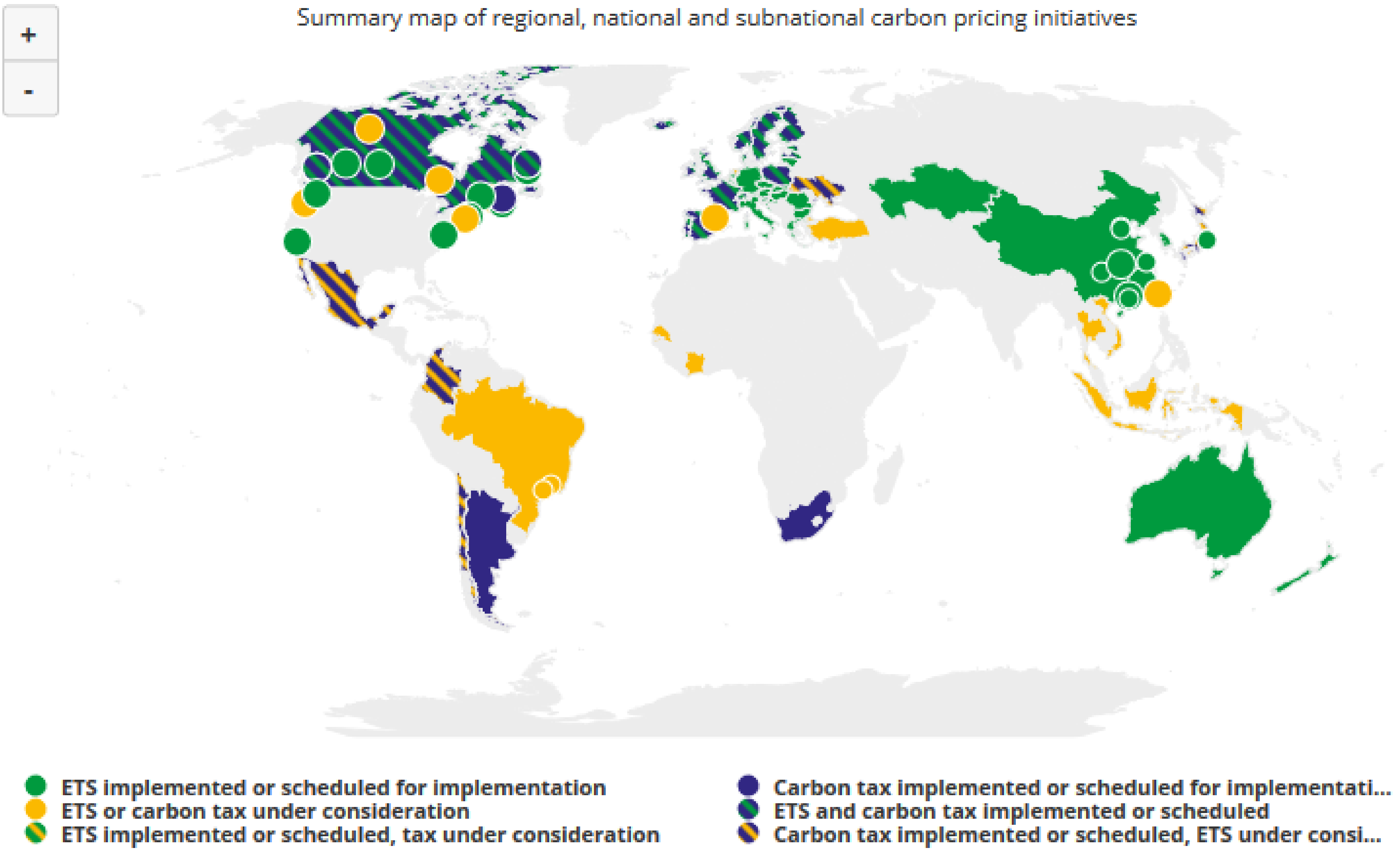
This cumulative IRF is the estimated effect of the tax increase on the *level* of log(emissions), imposing the “parallel path” assumption

Emissions series:
Emissions in sectors exposed to the carbon tax



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

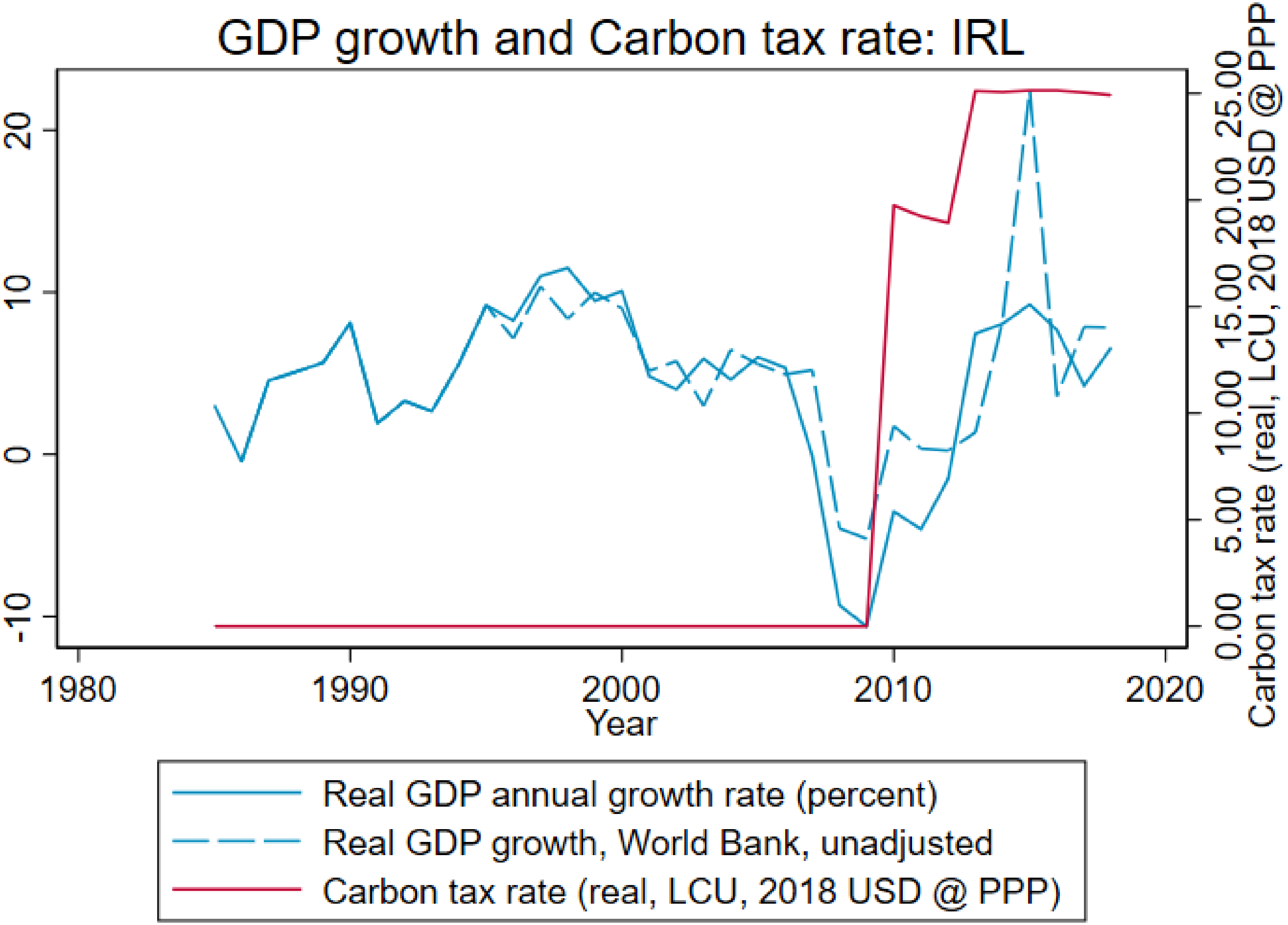
More details on carbon pricing schemes internationally



Data odds and ends

Ireland:

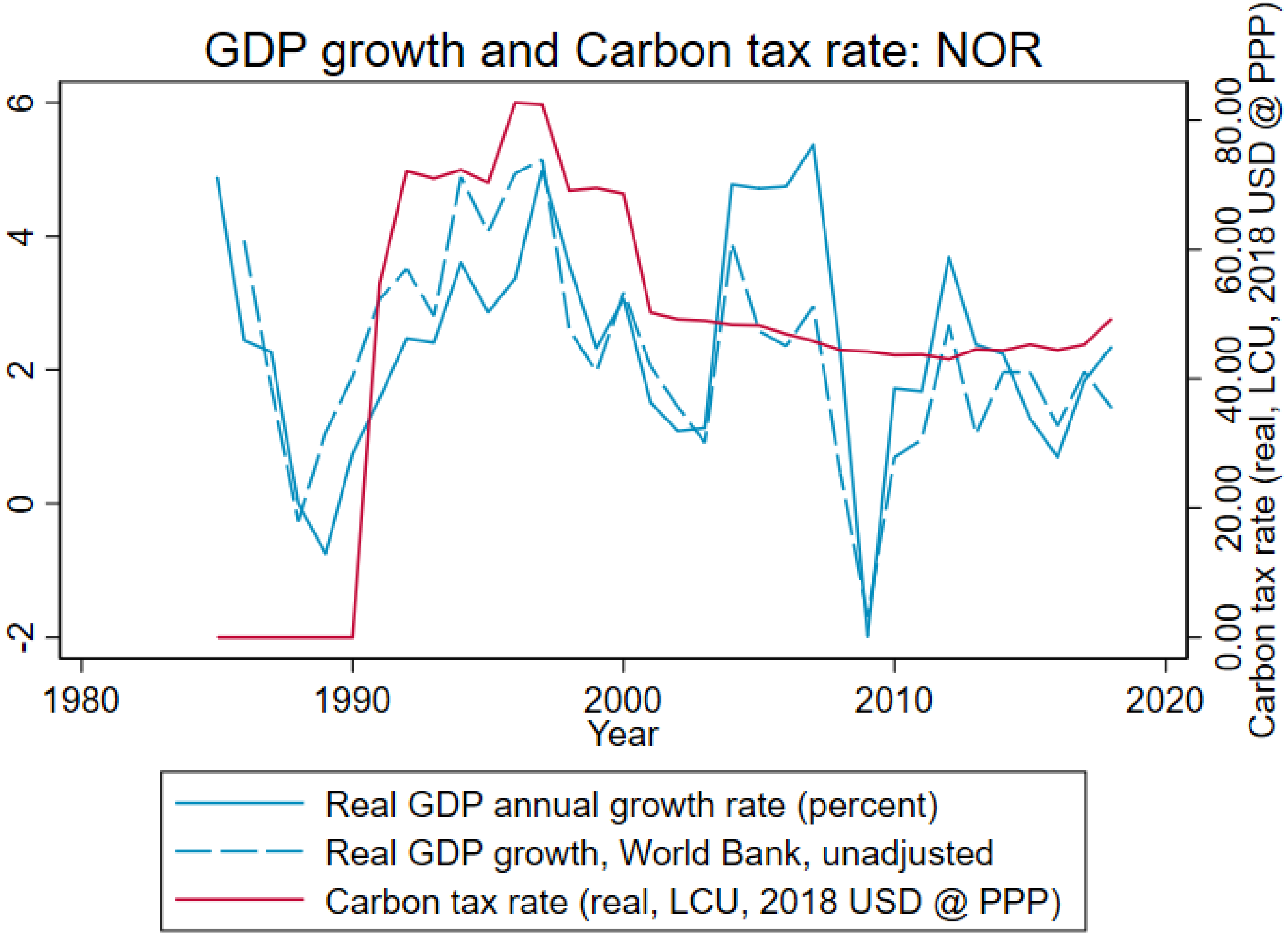
Replace World Bank GDP data with adjusted Irish statistical agency data



Data odds and ends

Norway:

Use "Onshore GDP" from Statistics Norway

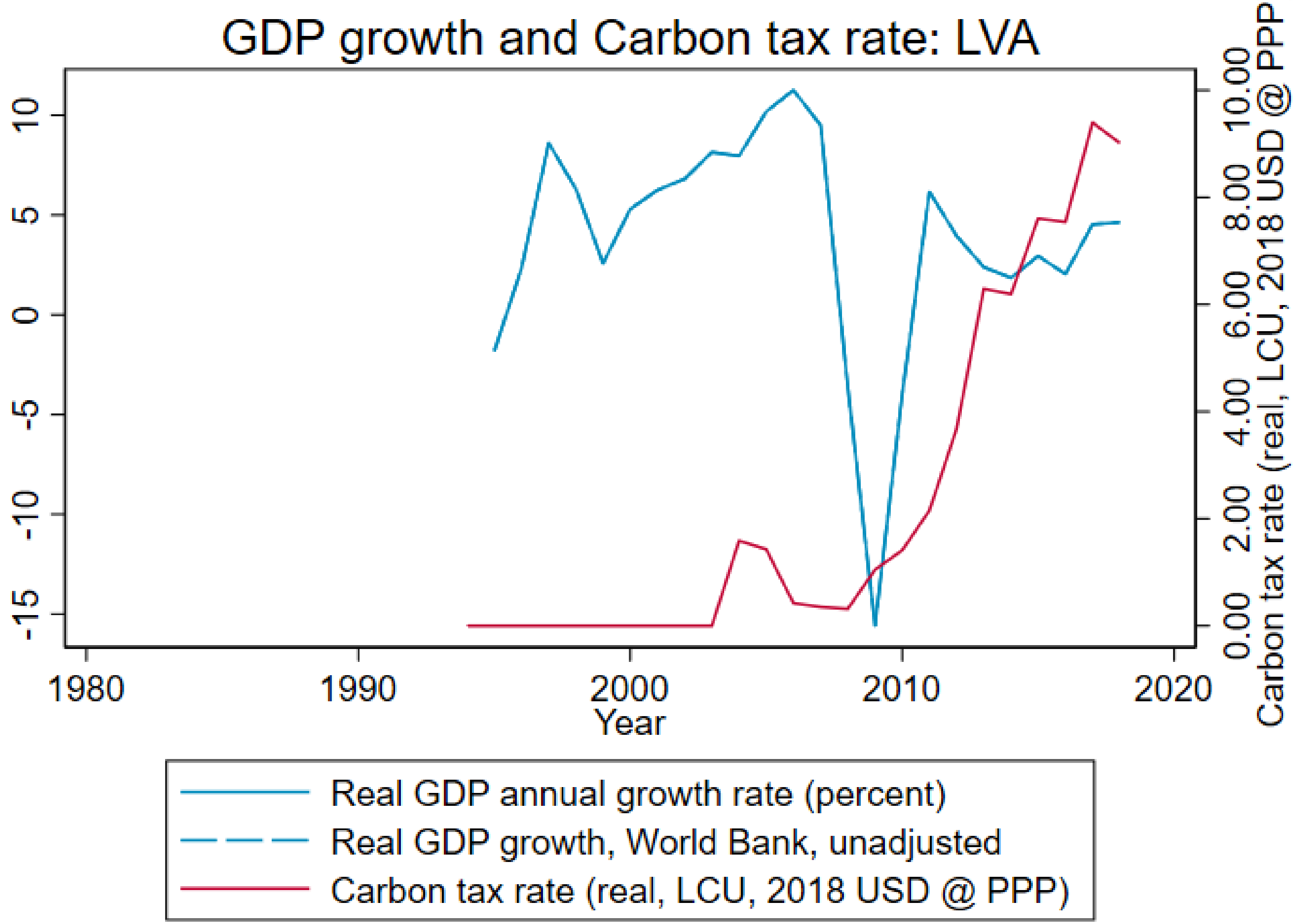


Data odds and ends

Latvia:
No adjustments

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

<u>Reference</u>
Åslund and Dombrovskis (PIIE, 2011)

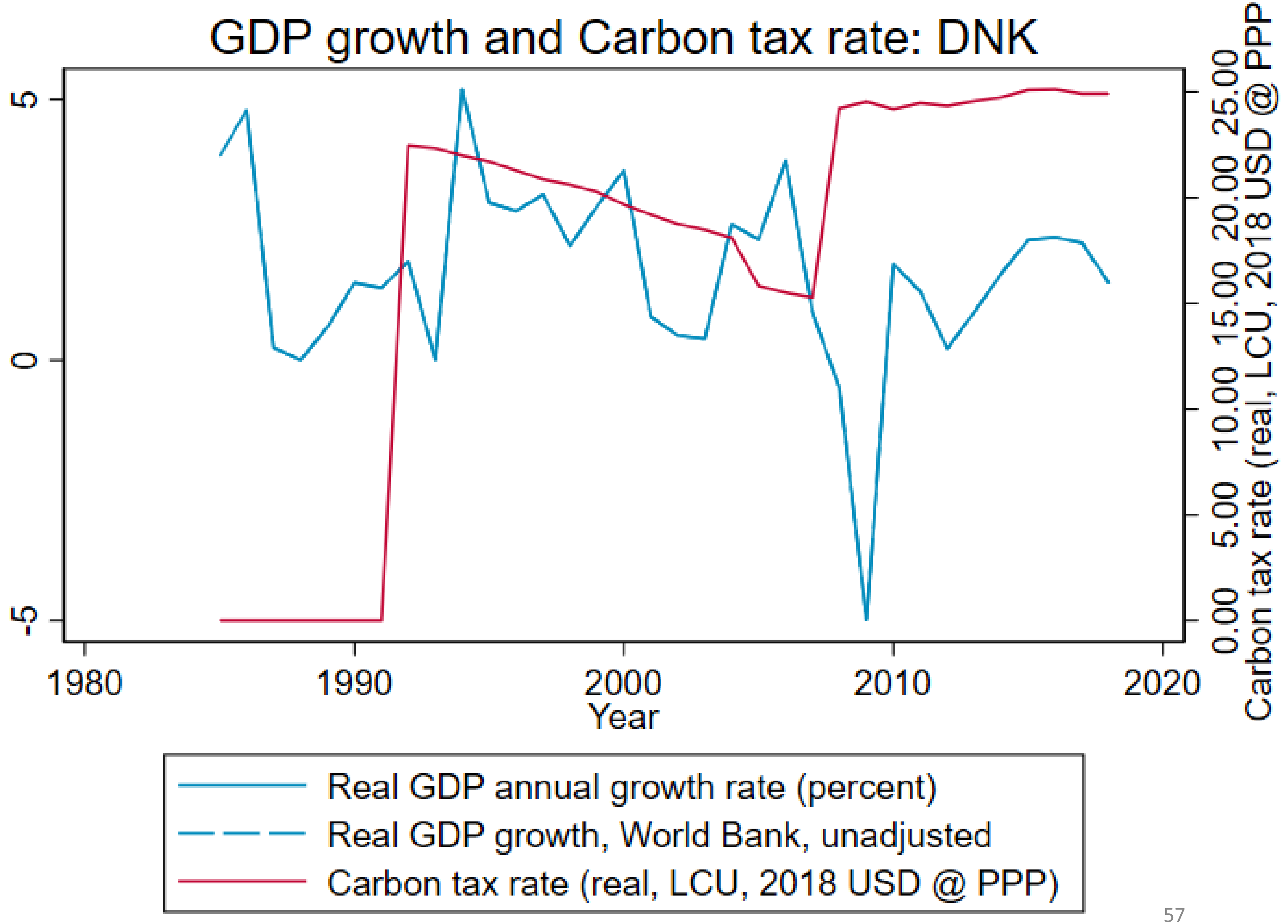


Focus on Scandinavia

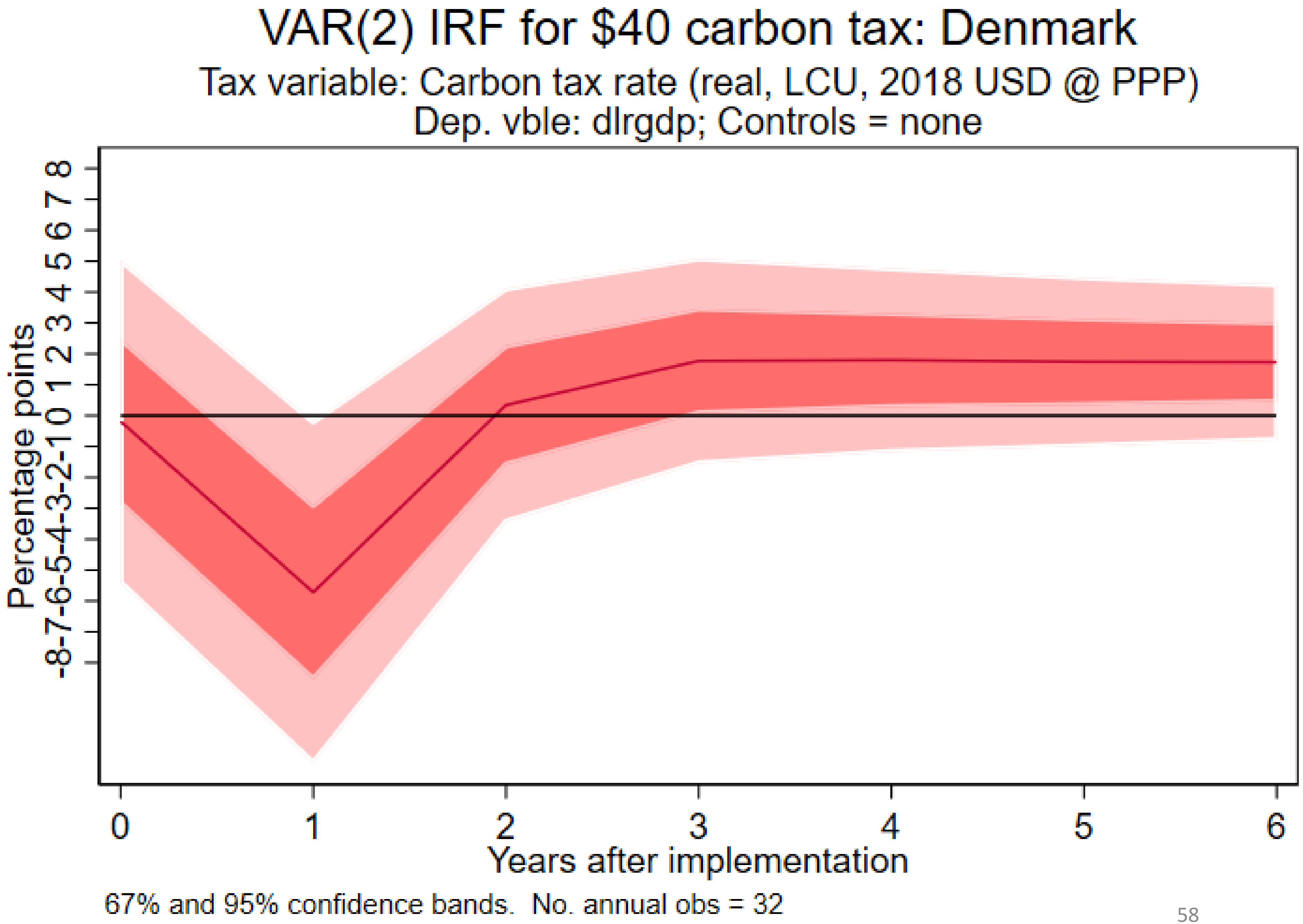
Data source: World Bank (carbon price data in press)

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

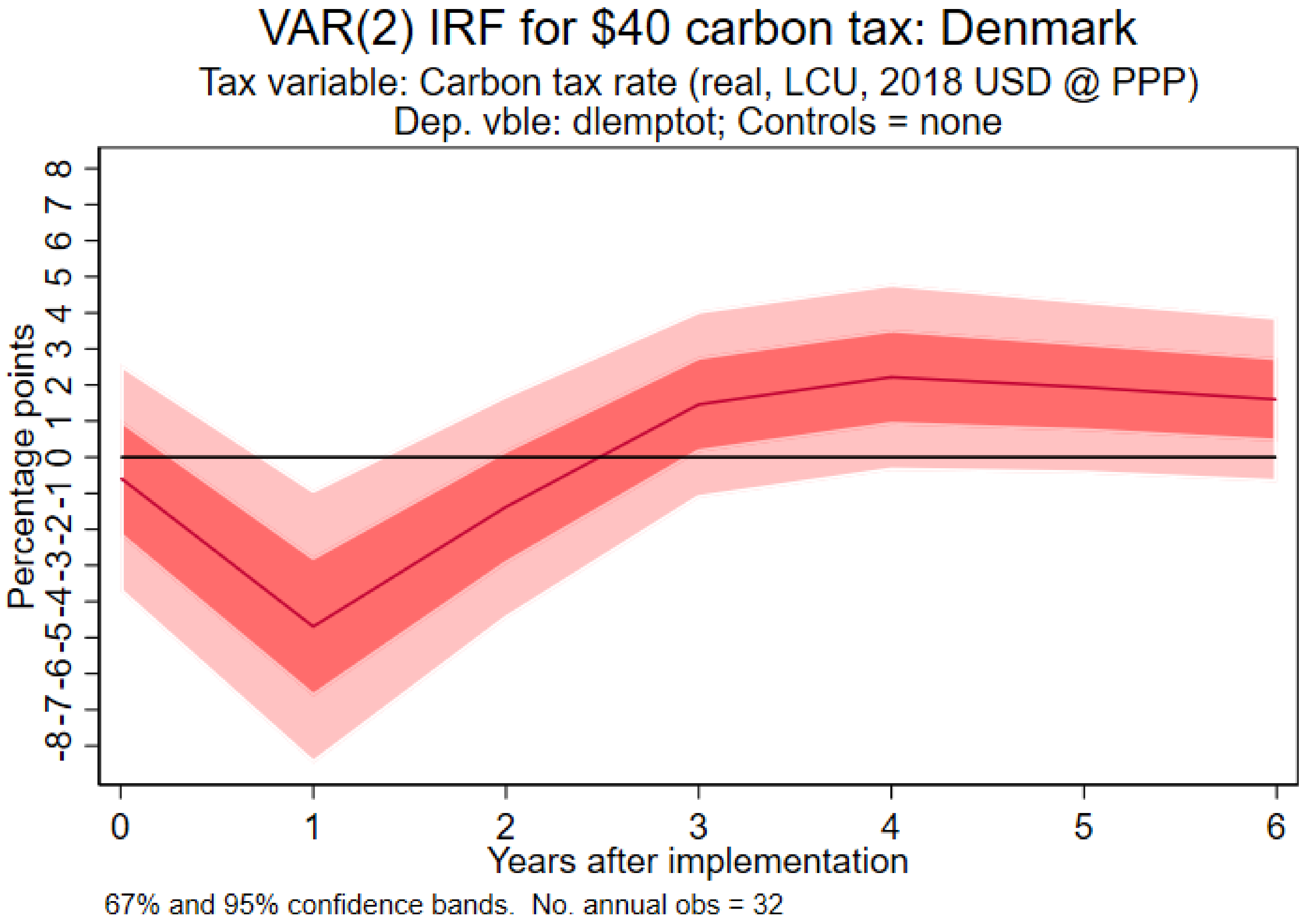
Denmark


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)

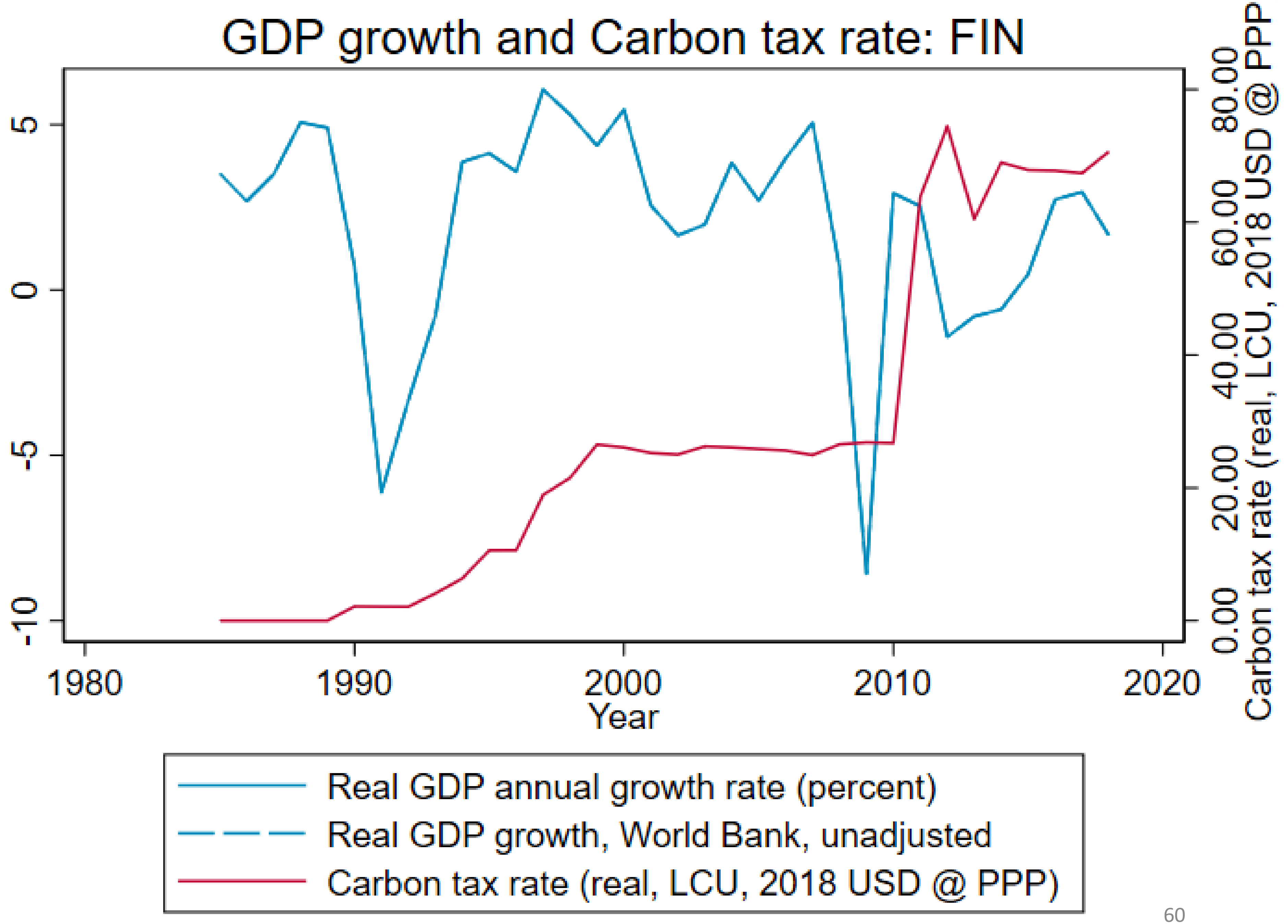
VAR IRF: Denmark



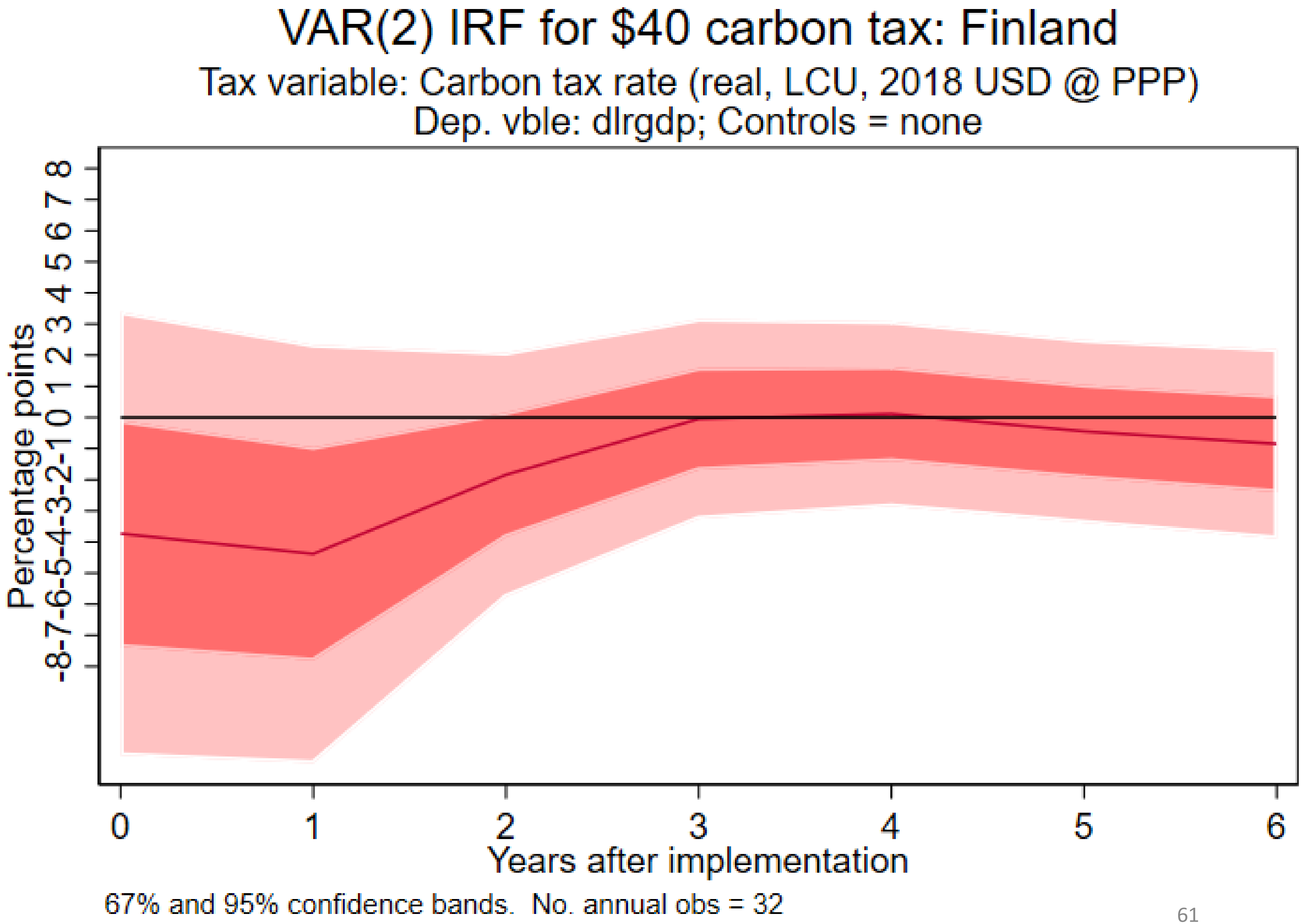
VAR IRF: Denmark



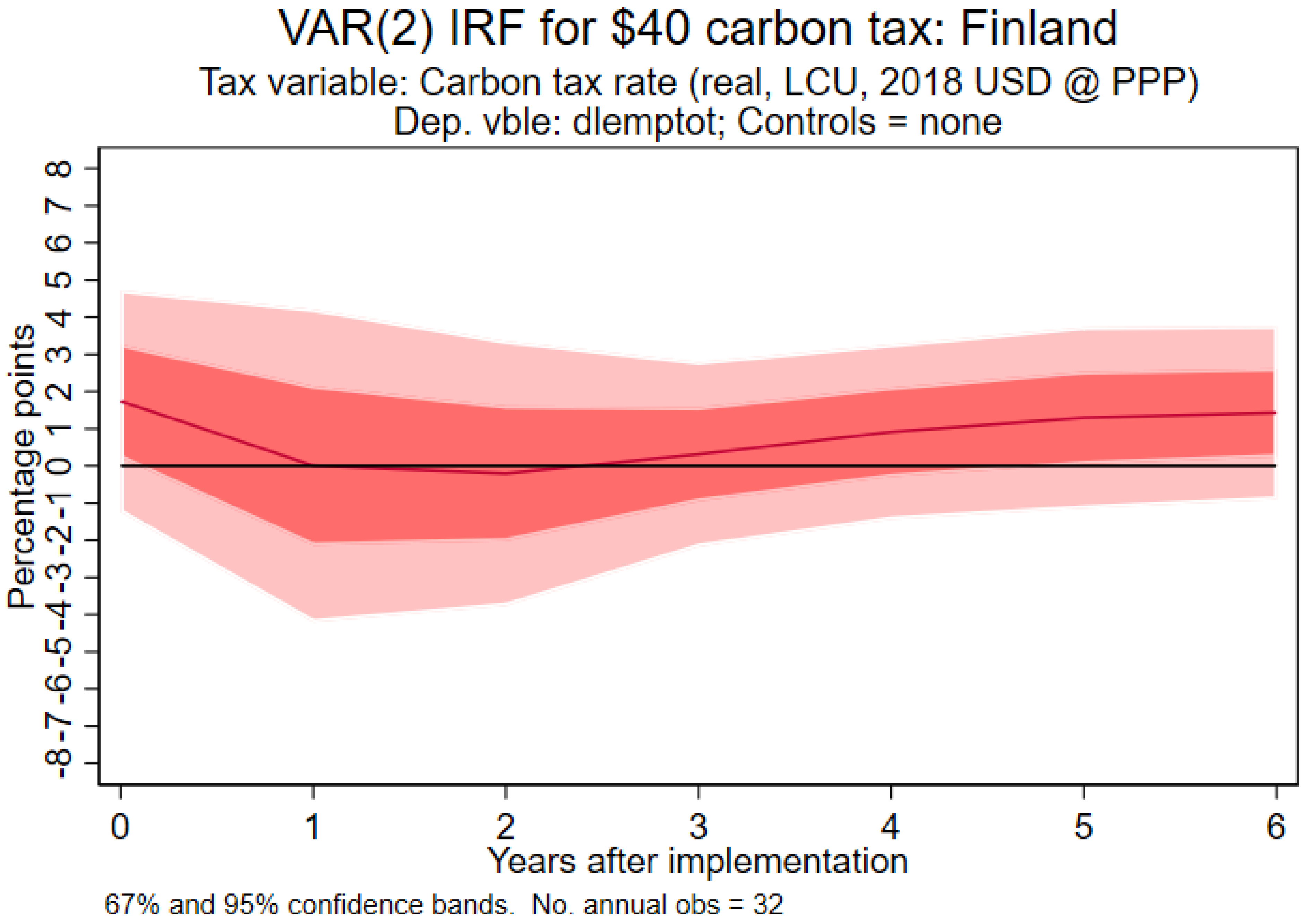
Finland


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

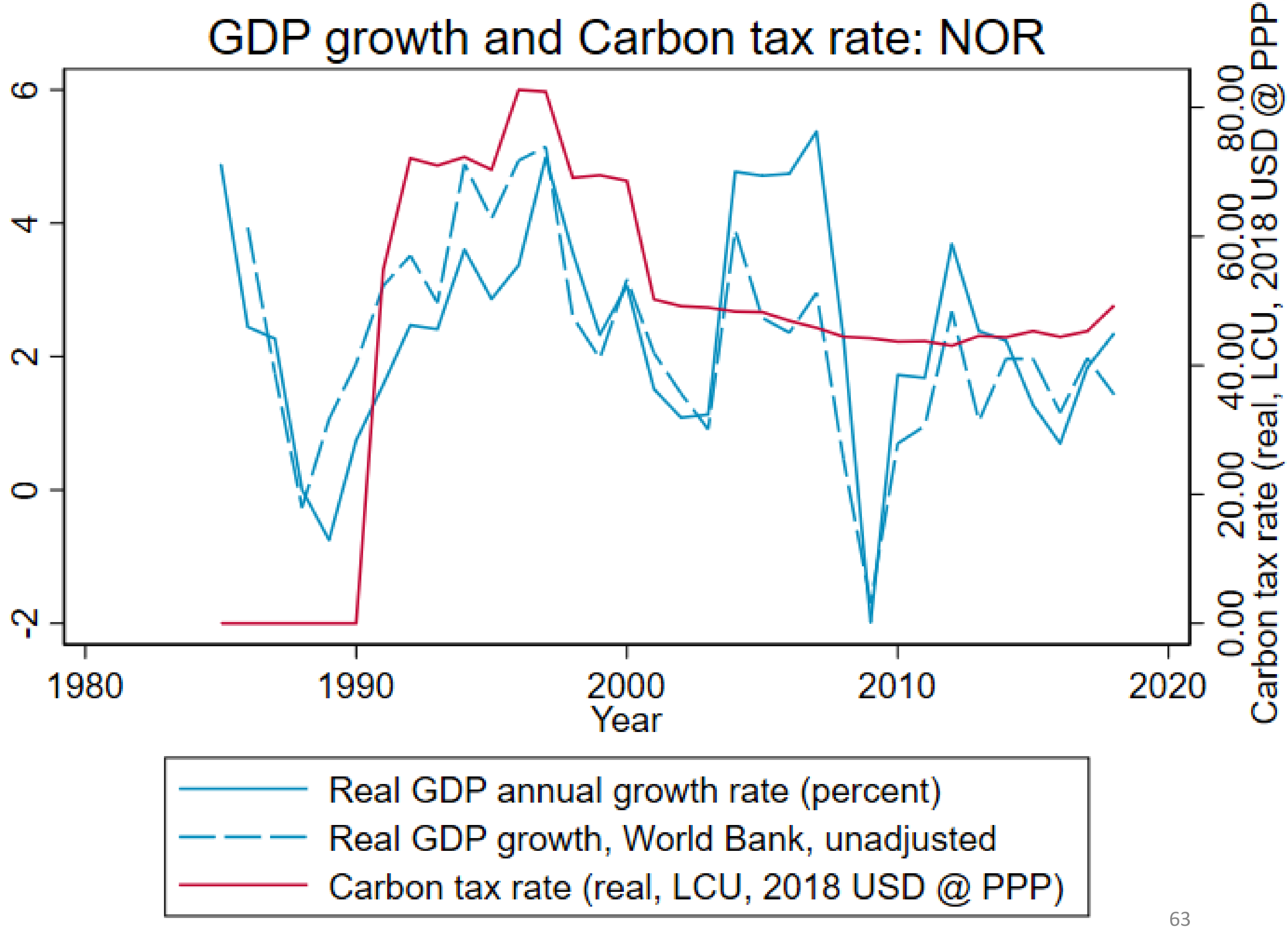
VAR IRF: Finland



VAR IRF: Finland

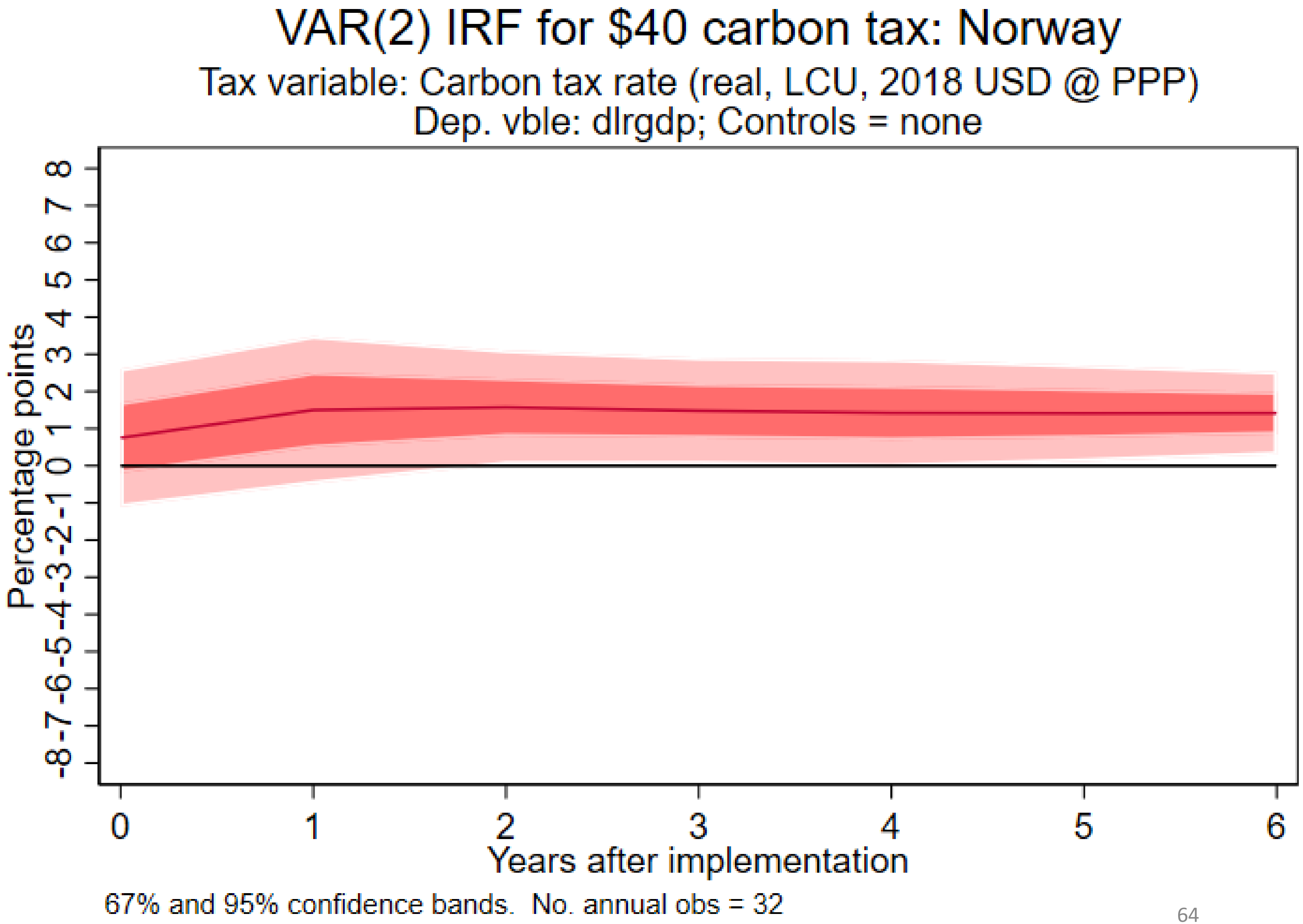


Norway

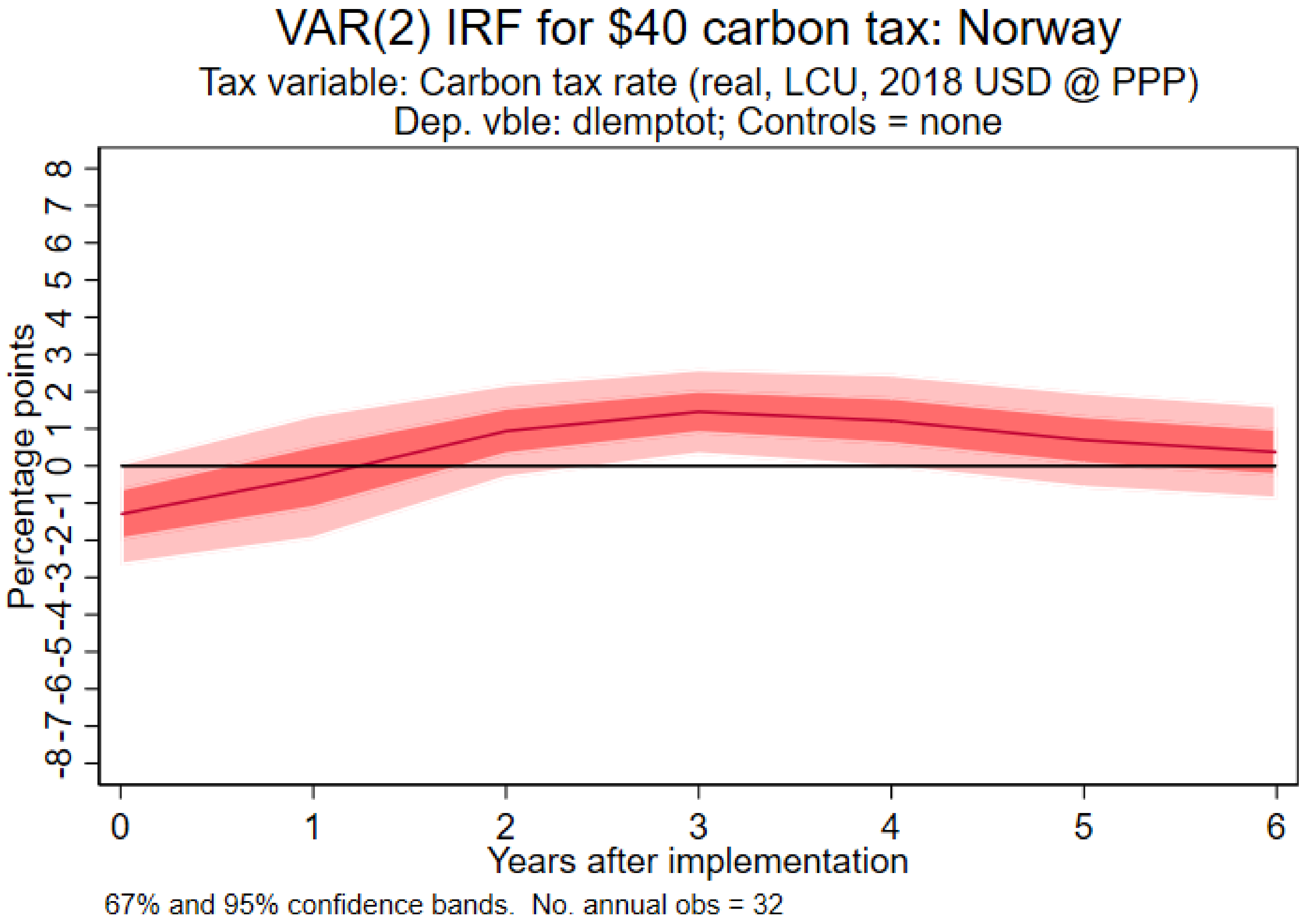


GDP growth and Carbon tax rate: NOR
6
4
2
0
-2
80.00
60.00
40.00
20.00
0.00
Carbon tax rate (real, LCU, 2018 USD @ PPP)
1980
1990
2000
2010
2020
Year
Real GDP annual growth rate (percent)
Real GDP growth, World Bank, unadjusted
Carbon tax rate (real, LCU, 2018 USD @ PPP)

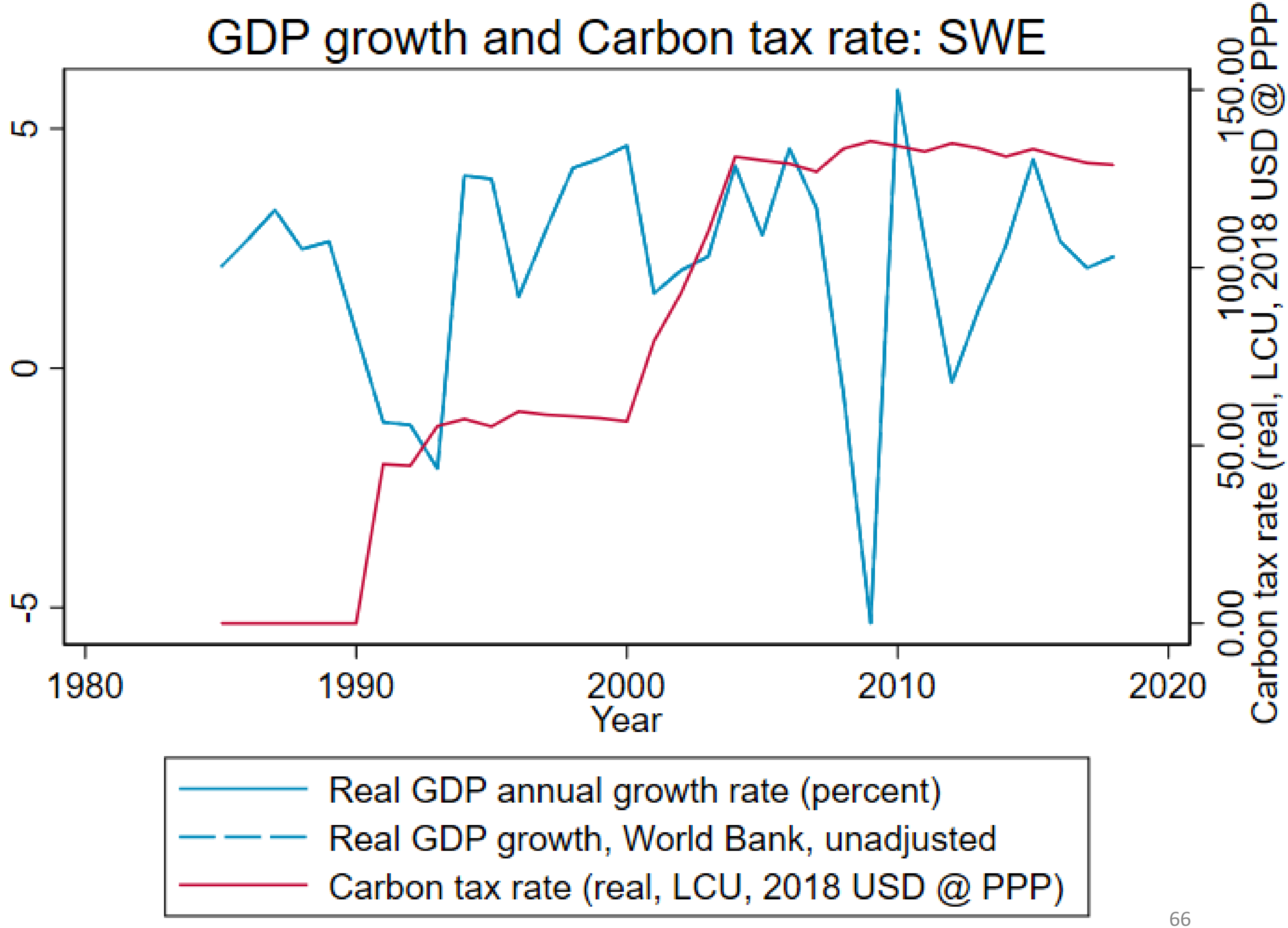
VAR IRF: Norway



VAR IRF: Norway

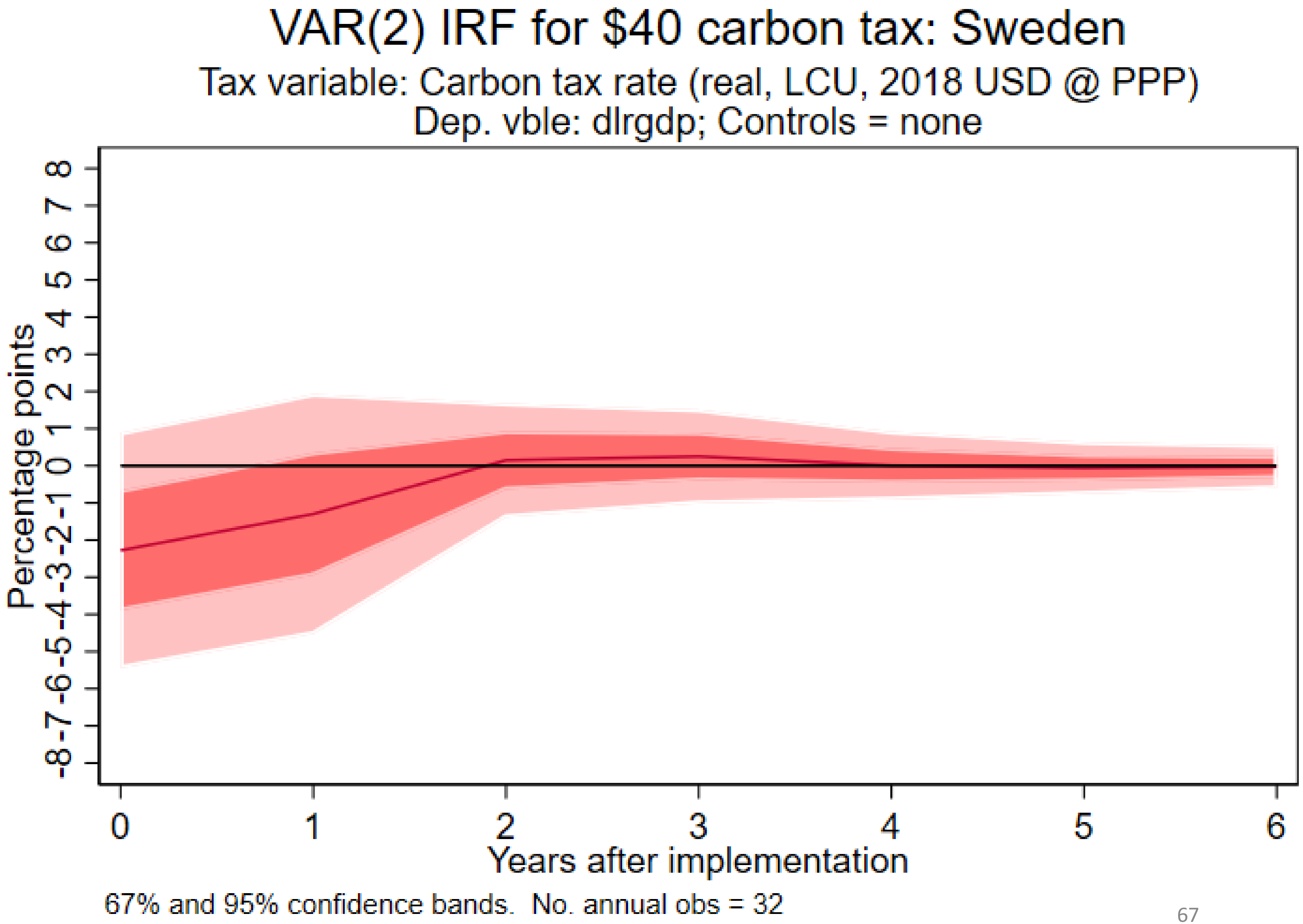


Sweden

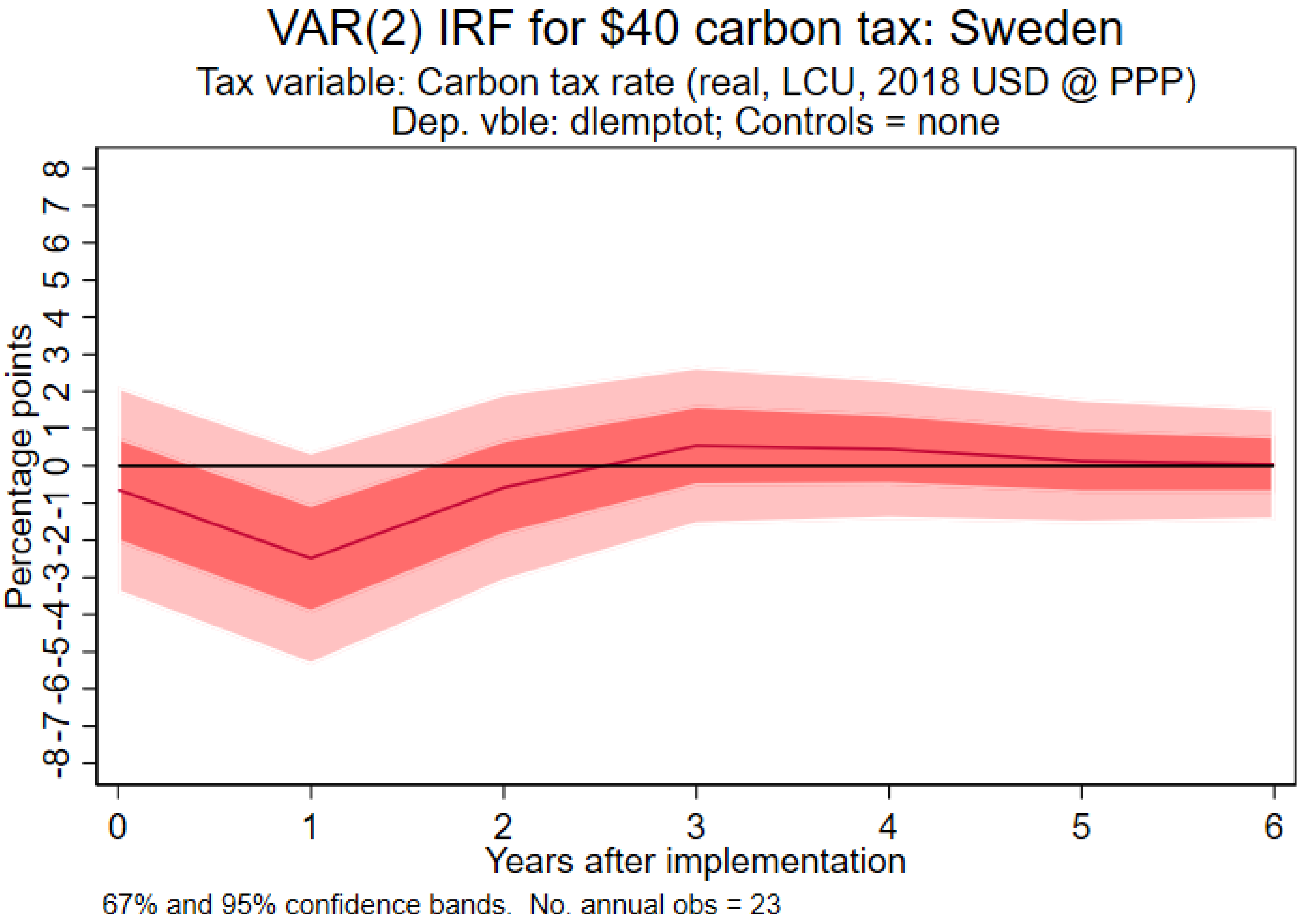


GDP growth and Carbon tax rate: SWE
5
0
-5
150.00
100.00
50.00
0.00
Carbon tax rate (real, LCU, 2018 USD @ PPP)
1980
1990
2000
2010
2020
Year
Real GDP annual growth rate (percent)
Real GDP growth, World Bank, unadjusted
Carbon tax rate (real, LCU, 2018 USD @ PPP)

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)