The Macroeconomic Impact of Europe’s Carbon Taxes

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The views expressed are the authors’ and do not necessarily reflect the views of the Federal Reserve Bank of San Francisco or the Federal Reserve System.
Climate change and the energy transition

Temperature and Fitted Values based on Radiative Forcings

Deviation from 1870-1890 mean

\[ Temp_t = \text{const} + 0.489RF_t^{\text{aggregate}} \]

(0.041)

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

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:

<table>
<thead>
<tr>
<th>Source</th>
<th>%, 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>38.4</td>
</tr>
<tr>
<td>Coal</td>
<td>23.5</td>
</tr>
<tr>
<td>Nuclear</td>
<td>19.7</td>
</tr>
<tr>
<td>Wind</td>
<td>7.3</td>
</tr>
<tr>
<td>Hydro</td>
<td>6.6</td>
</tr>
<tr>
<td>Solar</td>
<td>1.8</td>
</tr>
</tbody>
</table>

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

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

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 et al (2019) OECD environmental taxes
- Faucceglia 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
- 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: Recreated from World Bank (2019)

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

<table>
<thead>
<tr>
<th>Country</th>
<th>Year of Adoption</th>
<th>Rate in 2018 (USD)</th>
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<td>$70.65</td>
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<td>2015</td>
<td>11.54</td>
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Source: World Bank
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

Real GDP per capita, growth (annual %)

Before and after imposition of carbon tax

Year from first imposition of carbon tax

Deviation from country's pre-tax mean. Horizontal lines are pre/post means. Dots and bars denote mean and 90% confidence interval by year.
Total employment, growth (annual %)

Before and after imposition of carbon tax

Year from first imposition of carbon tax

Deviated from country's pre-tax mean. Horizontal lines are pre/post means. Dots and bars denote mean and 90% confidence interval by year.
CO2 emissions from fuel combustion per capita (log)

Before and after imposition of carbon tax

Year from first imposition of carbon tax

-5 -4 -3 -2 -1 0 1 2 3 4 5

-3 -2 -1 0 0.1 0.2

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)**

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

**Exogeneity condition:**

$$E(u_t | \tau_t, \tau_{t-1},...,W_t,W_{t-1},... ) = E(u_t | W_t,W_{t-1},... )$$

**Local projections (panel)**

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

**Exogeneity condition:**

$$E(u_t | \tau_t, \tau_{t-1},...,\Delta \ln(GDP_{t-1}),W_t,W_{t-1},... ) = E(u_t | \tau_{t-1},\tau_{t-2},...,\Delta \ln(GDP_{t-1}),W_t,W_{t-1},... )$$

**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)
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

<table>
<thead>
<tr>
<th></th>
<th>GDP</th>
<th>Employment</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LP</strong></td>
<td>0.33</td>
<td>-0.63</td>
<td>-2.09</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>0.53</td>
<td>0.04</td>
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<tr>
<td><strong>SVAR</strong></td>
<td>1.34</td>
<td>0.62</td>
<td>-1.26</td>
</tr>
<tr>
<td></td>
<td>0.18</td>
<td>0.53</td>
<td>0.21</td>
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Revenue Recycling Countries

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<thead>
<tr>
<th></th>
<th>GDP</th>
<th>Employment</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LP</strong></td>
<td>0.05</td>
<td>-0.72</td>
<td>-0.95</td>
</tr>
<tr>
<td></td>
<td>0.96</td>
<td>0.47</td>
<td>0.34</td>
</tr>
<tr>
<td><strong>SVAR</strong></td>
<td>1.39</td>
<td>0.17</td>
<td>-0.40</td>
</tr>
<tr>
<td></td>
<td>0.16</td>
<td>0.87</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Large Carbon Tax Countries

<table>
<thead>
<tr>
<th></th>
<th>GDP</th>
<th>Employment</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LP</strong></td>
<td>-0.41</td>
<td>0.14</td>
<td>-0.53</td>
</tr>
<tr>
<td></td>
<td>0.69</td>
<td>0.89</td>
<td>0.60</td>
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<tr>
<td><strong>SVAR</strong></td>
<td>1.00</td>
<td>1.23</td>
<td>-0.34</td>
</tr>
<tr>
<td></td>
<td>0.32</td>
<td>0.22</td>
<td>0.73</td>
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</table>

Scandinavian Countries

<table>
<thead>
<tr>
<th></th>
<th>GDP</th>
<th>Employment</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LP</strong></td>
<td>-0.44</td>
<td>0.80</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>0.66</td>
<td>0.42</td>
<td>0.85</td>
</tr>
<tr>
<td><strong>SVAR</strong></td>
<td>0.95</td>
<td>1.04</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>0.34</td>
<td>0.30</td>
<td>0.87</td>
</tr>
</tbody>
</table>

$t$-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
Sample: EU+

Method: Linear Projection
Unrestricted

Results: GDP growth
Results: GDP growth

Sample: EU+

Method: SVAR
Unrestricted

IRF for $40 carbon tax increase: SV4
Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δ1rgdp; Controls = YE; Sample = EU+

Percentage points

Years after implementation

67% and 95% confidence bands. Includes 4 lags of all regressors.
Sample: EU+

Method: Linear Projection Restricted

Results: GDP growth
Results: GDP growth

Sample: EU+

Method: SVAR Restricted
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 growth
Results: GDP growth

Sample: EU+

Method: SVAR 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

Cumulative IRF for $40 carbon tax increase: SV4

Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δlrgdp; Controls = YE; Sample = EU+

Percentage points

Years after implementation

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

Sample: EU+

Method: LP
Unrestricted

IRF for $40$ carbon tax increase: LP

Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δlemptot; Controls = YE; Sample = EU+

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

Sample: EU+

Method: SVAR
Unrestricted

IRF for $40$ carbon tax increase: SV4

Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δlemp tot; Controls = YE; Sample = EU+

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

Sample: EU+

Method: LP
   Restricted

IRF for $40 carbon tax increase: LP

Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δlemptot; Controls = YE; Sample = EU+

67% and 95% confidence bands. Includes 4 lags of all regressors.
Results: Manufacturing Employment

Sample: EU+

Method: LP
Restricted

IRF for $40 carbon tax increase: LP
Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δlempman; Controls = YE; Sample = EU+

67% and 95% confidence bands. Includes 4 lags of all regressors.
Sample: EU+

Method: LP
  Restricted
  Cumulative IRF

This cumulative IRF is the estimated effect of the tax increase on the level of \( \log(\text{emissions}) \), imposing the “parallel path” assumption.

Emissions series:
  Emissions in sectors exposed to the carbon tax

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
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

Results: Emissions

Cumulative IRF for $40 carbon tax increase: LP
Carbon tax rate (real, 2018 USD) wtd by coverage share Dep. vble: Δlemission6; Controls = YE; Sample = EU+

[Graph showing cumulative IRF with confidence bands]

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

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

IRF for $40 carbon tax increase: LP
Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δlrgdp; Controls = YE; Sample = EU+RR1

67% and 95% confidence bands. Includes 4 lags of all regressors.
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: Effect of revenue recycling

Sample: EU+
Revenue recycling

Dep vble: Empl. growth

Method: LP
Restricted

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Summary

GDP

IRF for $40 carbon tax increase: LP
Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δlgdp; Controls = YE; Sample = EU+

Employment

IRF for $40 carbon tax increase: LP
Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δemptot; Controls = YE; Sample = EU+

Emissions from transportation, commercial, & HH sectors

Cumulative IRF for $40 carbon tax increase: LP
Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δemission_ctsectors; Controls = YE; Sample = EU+

Emissions from fuel consumption

Cumulative IRF for $40 carbon tax increase: LP
Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δemission6; Controls = YE; Sample = EU+

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

Reference
Åslund and Dombrovskis (PIIE, 2011)
Focus on Scandinavia

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

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<td>Portugal</td>
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VAR IRF: Denmark

VAR(2) IRF for $40 carbon tax: Denmark
Tax variable: Carbon tax rate (real, LCU, 2018 USD @ PPP)
Dep. vble: dlrgdp; Controls = none

67% and 95% confidence bands. No. annual obs = 32
VAR(2) IRF for $40 carbon tax: Denmark

Tax variable: Carbon tax rate (real, LCU, 2018 USD @ PPP)
Dep. vble: dlempot; Controls = none

67% and 95% confidence bands. No. annual obs = 32
Finland
VAR(2) IRF for $40$ carbon tax: Finland

Tax variable: Carbon tax rate (real, LCU, 2018 USD @ PPP)
Dep. vble: dlrbgdp; Controls = none

67% and 95% confidence bands. No. annual obs = 32
VAR(2) IRF for $40 carbon tax: Finland

Tax variable: Carbon tax rate (real, LCU, 2018 USD @ PPP)
Dep. vble: dlempot; Controls = none

67% and 95% confidence bands. No. annual obs = 32
VAR IRF: Norway

VAR(2) IRF for $40 carbon tax: Norway

Tax variable: Carbon tax rate (real, LCU, 2018 USD @ PPP)
Dep. vble: dlnrgdp; Controls = none

Percentage points

67% and 95% confidence bands. No. annual obs = 32
VAR(2) IRF for $40 carbon tax: Norway

Tax variable: Carbon tax rate (real, LCU, 2018 USD @ PPP)
Dep. vble: dlempot; Controls = none

67% and 95% confidence bands. No. annual obs = 32
GDP growth and Carbon tax rate: SWE

- Real GDP annual growth rate (percent)
- Real GDP growth, World Bank, unadjusted
- Carbon tax rate (real, LCU, 2018 USD @ PPP)

Sweden
VAR(2) IRF for $40 carbon tax: Sweden

Tax variable: Carbon tax rate (real, LCU, 2018 USD @ PPP)
Dep. vble: dlrgrdp; Controls = none

67% and 95% confidence bands. No. annual obs = 32
VAR(2) IRF for $40 carbon tax: Sweden

Tax variable: Carbon tax rate (real, LCU, 2018 USD @ PPP)
Dep. vble: dlemp; Controls = none

67% and 95% confidence bands. No. annual obs = 23
Any tax anticipation effect?

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

<table>
<thead>
<tr>
<th>Dependent variable (growth rate)</th>
<th>Tax variable</th>
<th>Cumulative lead effect (@ $40 tax) 1 lead</th>
<th>Cumulative lead effect (@ $40 tax) 2 leads</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>Real tax rate</td>
<td>-0.40</td>
<td>-0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.28)</td>
<td>(1.33)</td>
</tr>
<tr>
<td>Total employment</td>
<td>Real tax rate</td>
<td>-0.89</td>
<td>-0.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.01)</td>
<td>(1.04)</td>
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</tbody>
</table>