The Macroeconomic Impact of Europe’s Carbon Taxes

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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.

Lots of policy proposals! .. but the economists love 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/](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)
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.

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)
Runt 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
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 in road transport, commercial & institutional, and household sectors
  - Alternatively, emissions from fuel consumption
## Carbon taxes in 2018

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

Source: World Bank

https://carbonpricingdashboard.worldbank.org/
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 GDP per capita, growth (annual %)
Before and after 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.
Total employment, 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.
**Data description**

**CO2 emissions from fuel combustion per capita (log)**

Before and after imposition of carbon tax

- **Y-axis:** CO2 emissions (log scale)
- **X-axis:** Year from first imposition of carbon tax

Legend:
- CHE, DNK, ESP, EST, FIN, FRA, GBR, IRL, ISL, LVA, NOR, POL, PRT

Deviation 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)

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

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)

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

<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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</table>

<table>
<thead>
<tr>
<th>Revenue Recycling Countries</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>

<table>
<thead>
<tr>
<th>Large Carbon Tax Countries</th>
<th>GDP</th>
<th>Employment</th>
<th>Emissions</th>
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</thead>
<tbody>
<tr>
<td><strong>LP</strong></td>
<td>-0.41</td>
<td>0.14</td>
<td>-0.53</td>
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<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>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scandinavian Countries</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>
Results: GDP growth

Sample: EU+

Method: Linear Projection
Restricted
Results: GDP growth

Sample: EU+

Method: SVAR
    Restricted

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

Percentage points
0 1 2 3 4
Years after implementation
0 1 2 3 4 5 6

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

Sample: EU+

Method: LP
Restricted

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

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

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(emissions), imposing the “parallel path” assumption

Emissions series:
Emissions in sectors exposed to the carbon tax

Results: Emissions log level

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+

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
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

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

IRF for $40 carbon tax increase: LP
Carbon tax rate (real, 2018 USD) wtd by coverage share
Dep. vble: Δlgdp; Controls = YE; Sample = EU+RR0

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
Results: Effect of revenue recycling

Sample: EU+
No revenue recycling

Dep vble: Empl. growth

Method: LP
Restricted

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

GDP
No effect

Employment
No effect
• initial positive bump?

Emissions from covered sectors
4-6% reduction

Emissions from fuel consumption
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
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
Sample: EU+

Method: SVAR
Unrestricted

Results: GDP growth

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

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: Δlempot; 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: Δlemptot; Controls = YE; Sample = EU+

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

Results: Emissions
More details on carbon pricing schemes internationally

Summary map of regional, national and subnational carbon pricing initiatives

- ETS implemented or scheduled for implementation
- ETS or carbon tax under consideration
- ETS implemented or scheduled, tax under consideration
- Carbon tax implemented or scheduled for implementation
- ETS and carbon tax implemented or scheduled
- Carbon tax implemented or scheduled, ETS under consideration