Can growth take place while reducing emissions? The role of energy mix.

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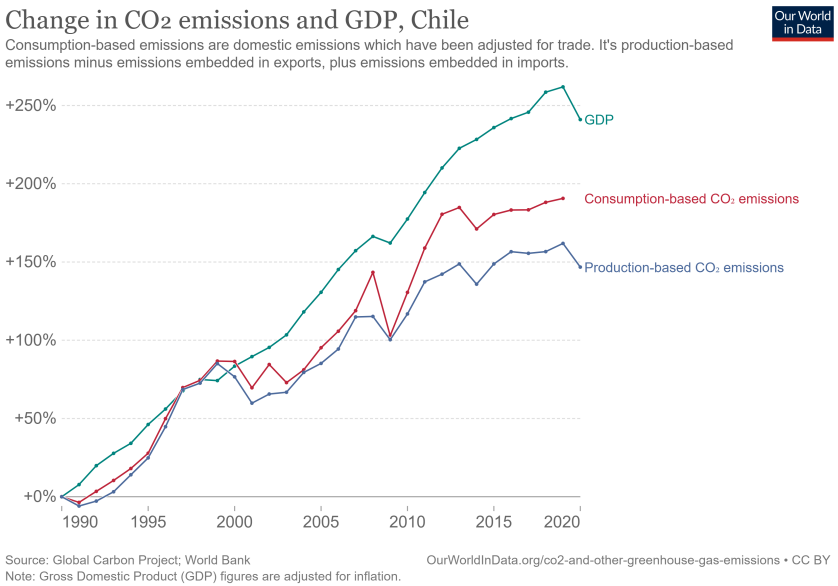
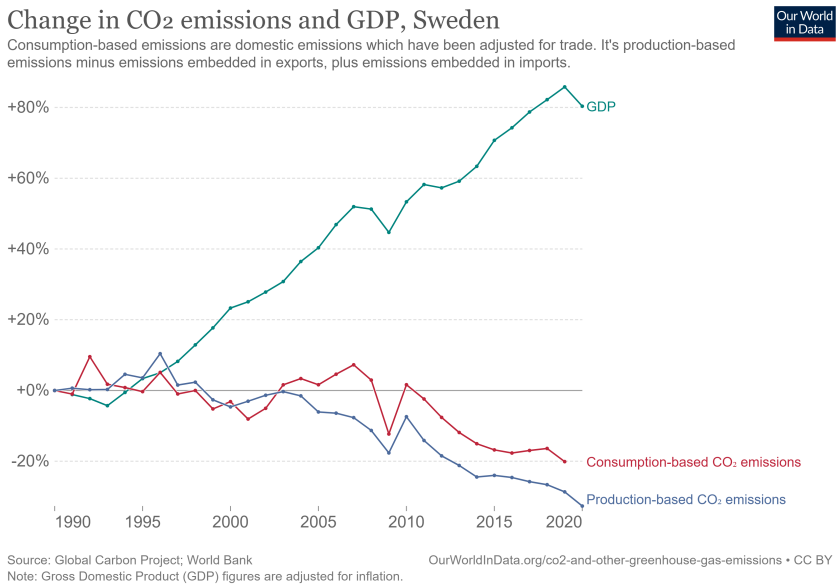
Agenda

Motivation: CO2 emissions, economic growth and energy mix

Many countries have decoupled economic growth from CO_2 emissions





Drivers of CO2 emissions

$$\text{Total } CO_2 \text{ emissions} = \text{Population} \times \text{Income} \times \text{Energy Intensity} \times \text{Carbon Intensity}$$

$$\text{Income} = \frac{GDP}{Population} \qquad \text{Energy Intensity} = \frac{Energy}{GDP} \qquad \text{Carbon Intensity} = \frac{CO_2}{Energy}$$

Disclaimer: GDP is widely used due to data availability, but it omits the social cost of emissions and ecosystem services.

In this paper...

I examine the effect of environmental policy on economic growth based on the energy mix.

How:

- Based on the model by Acemoglu et al. (2012)[1], I derive the effect of taxes and subsidies on aggregate production and growth rates.
- Empirical validation using an event study with sub-samples of countries. And robustness tests using Local Projection with sub samples and interaction terms.

Main results:

i Depending on the energy mix, the effect of environmental policies on growth can be negative initially,

ii This negative effect may decrease over time as the share of clean energy increases, and

iii the effect can become positive in the long run.

iv In countries with a cleaner energy mix, the effect can be positive from the beginning.

[1] Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous. 2012. "The Environment and Directed Technical Change." American Economic Review, 102 (1): 131-66.

Original framework: AABH model, 2012 in AER.

- *Households* derive utility from both consumption (C_t) and environmental quality (S_t).
- *Final good* production (Y_t) combines clean and dirty inputs using a CES function, with elasticity greater than 1, implying strong substitutability.
- Each clean and dirty sector produces *inputs* (Y_{jt}) à la Aghion and Howitt (1992), employing their workers (L_{jt}), and a continuum of sector-specific (machines) intermediate goods.
- *Intermediate goods* ($X_{i,j,t}$) are supplied by monopolistically competitive firms through innovation ($A_{j,t}$).
- The *quality of the environment* (S_t) is negatively impacted by the production of dirty inputs, but it also has the capacity to regenerate itself at rate ρ.

Original framework: AABH model, 2012 in AER.


$$Y_t = \left(Y_{ct}^{\frac{\epsilon-1}{\epsilon}} + Y_{dt}^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}, \quad \epsilon > 1$$


$$Y_{jt} = \alpha^{\frac{2\alpha}{1-\alpha}} A_{jt} L_{jt} P_{jt}^{\frac{\alpha}{1-\alpha}}, \quad j \in \{c, d\}$$


$$A_{j,i,t} = \begin{cases} \gamma A_{j,t-1} & \text{if successful } (\eta_j) \\ A_{j,t-1} & \text{if not successful } (1-\eta_j) \end{cases}$$

Without any environmental policy...

- Innovation primarily benefits the more advanced (dirty) sector, widening the gap with the clean sector.
- Global production degrades environmental quality, risking a climate catastrophe ($S = 0$).

Equilibrium with an optimal environmental policies.

A carbon tax τ on dirty inputs, with a subsidy[2] for clean inputs $\phi\tau$.

$$\frac{Y_{ct}}{Y_{dt}} = \left(\frac{P_{ct}}{P_{dt}}\right)^{\frac{\alpha}{1-\alpha}} \frac{A_{ct}}{A_{dt}} \frac{L_{ct}}{L_{dt}} = \left(\frac{P_{dt} \cdot (1+\tau)}{P_{ct} \cdot (1-\tau\phi)}\right)^{\epsilon} \tag{1}$$

- Raise the relative price of dirty inputs.
- High relative demand for clean inputs.

$$\frac{\eta_{ct}}{\eta_{dt}} = \left(\frac{1+\tau}{1-\phi\tau}\right)^{\epsilon} \left(\frac{A_{ct}}{A_{dt}}\right)^{\varphi-1} \tag{2}$$

- Increased green innovation.
- Higher wages in the clean sector, more workers in clean sector.
- Increases the relative share of the clean input.

[2] A fraction of the tax revenues allocated to lowering the prices of clean inputs

[2] Where $\varphi = (\epsilon - 1)(1 - \alpha)$.

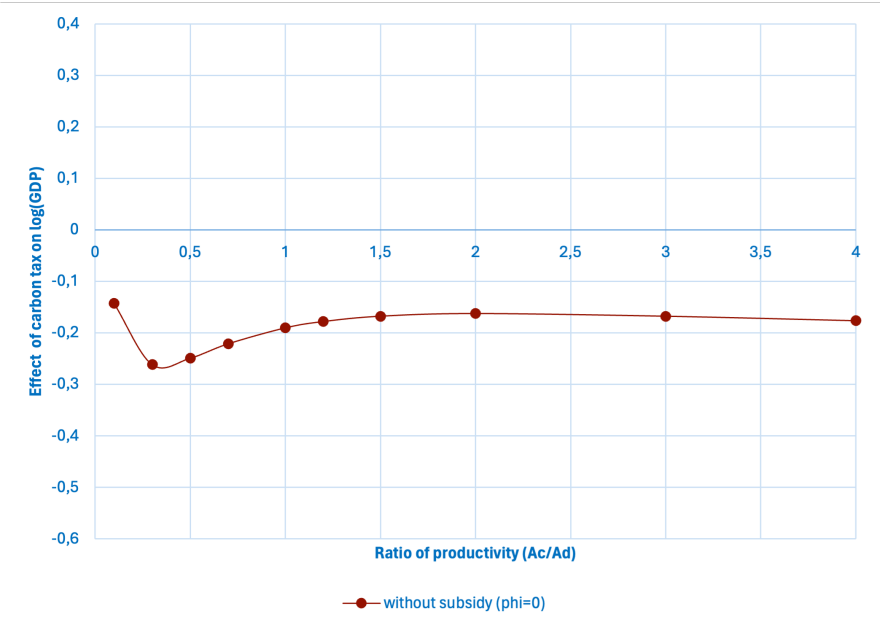
Income effect of environmental policy

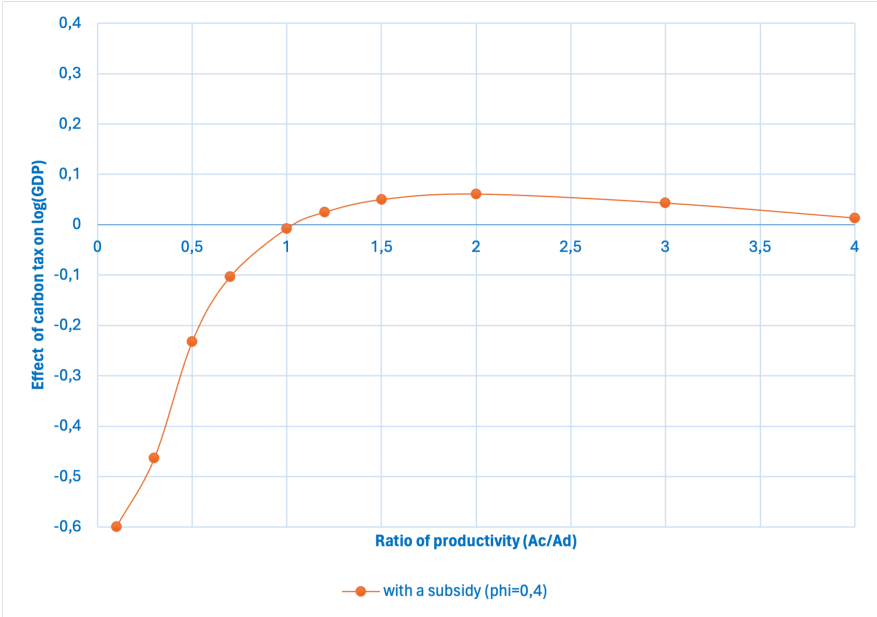
Proposition 1:

In the absence of subsidies, a tax on dirty production that promotes the energy transition has a negative effect on aggregate production. If $\phi = 0$ then $\frac{\partial \log(Y_t)}{\partial \tau} < 0$

Proposition 2:

If the elasticity of substitution is high enough, $\epsilon > \frac{\alpha}{1-\alpha}$, then along the energy transition ($Ac < Ad$), the negative effect of environmental policy on income levels is a decreasing function of the relative size of the clean sector, $\frac{\partial^2 \log(Y_t)}{\partial \tau \partial \left(\frac{A_{ct}}{A_{dt}}\right)^{\varphi}} > 0$.





Growth effect of environmental policy

The effect of a tax and a subsidy on the growth rate can be decomposed into:

- The effect on the sectoral composition of income,
- The effect on the growth rate of the two sectors.

$$\frac{\Delta Y_t}{Y_t} = \left(\frac{Y_{ct}}{Y_t}\right)^{\frac{\epsilon-1}{\epsilon}} \cdot \frac{\Delta Y_{ct}}{Y_{ct}} + \left(\frac{Y_{dt}}{Y_t}\right)^{\frac{\epsilon-1}{\epsilon}} \cdot \frac{\Delta Y_{dt}}{Y_{dt}} \tag{3}$$

Proposition 3:

If $\left(\frac{1+\tau}{1-\phi\tau}\right)^{\epsilon}\left(\frac{A_{ct}}{A_{dt}}\right)^{\varphi} > 1$ and $\varphi > 1$ then environmental policy has a positive effect on the aggregate growth rate.

Proof:

- If $\left(\frac{1+\tau}{1-\phi\tau}\right)^{\epsilon}\left(\frac{A_{ct}}{A_{dt}}\right)^{\varphi} > 1$ then $\frac{Y_{ct}}{Y_{dt}} > 1$.
- If $\left(\frac{1+\tau}{1-\phi\tau}\right)^{\epsilon}\left(\frac{A_{ct}}{A_{dt}}\right)^{\varphi-1} > 1$ then $\eta_{ct} > \eta_{dt}$.

Energy Mix and Carbon Tax

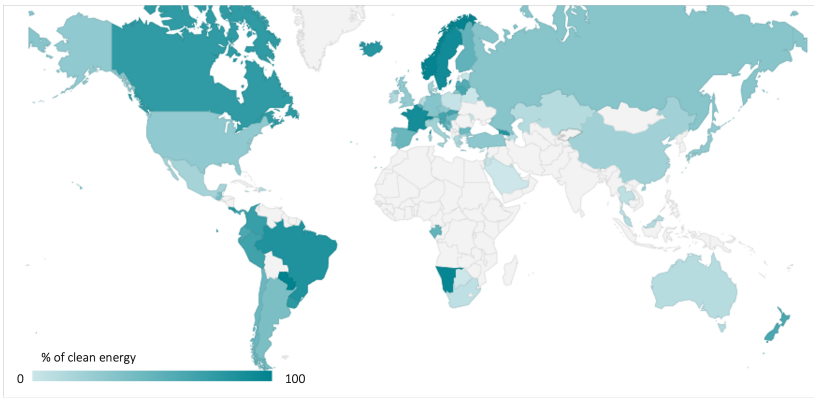


Figure: Clean energy share (%Primary Energy)

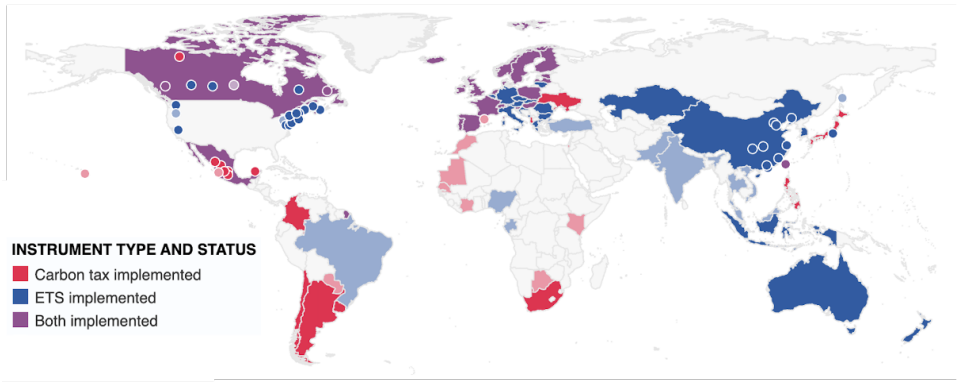


Figure: Countries with carbon pricing

Summary database Sample balance

Empirical strategy: Event study (staggered)

Effect of the carbon tax on growth rate:

$$GDP_{growth\,c,t} = \sum_{r=-S}^{-1} \beta_r \cdot D_{c,t}^r + \sum_{r=1}^{M} \beta_r \cdot D_{c,t}^r + \gamma_c + \gamma_t + \varepsilon_{c,t} \tag{4}$$

- $GDP_{growth\,c,t}$ is the annual GDP growth rate in country c, in year t.
- $D_{c,t}^r = 1$ if year t is r periods from the year of implementation of carbon tax.
- β_r the accumulative effect on the GDP growth relative to the year of implementation.
- γ_c country fixed effects.
- γ_t time fixed effects.

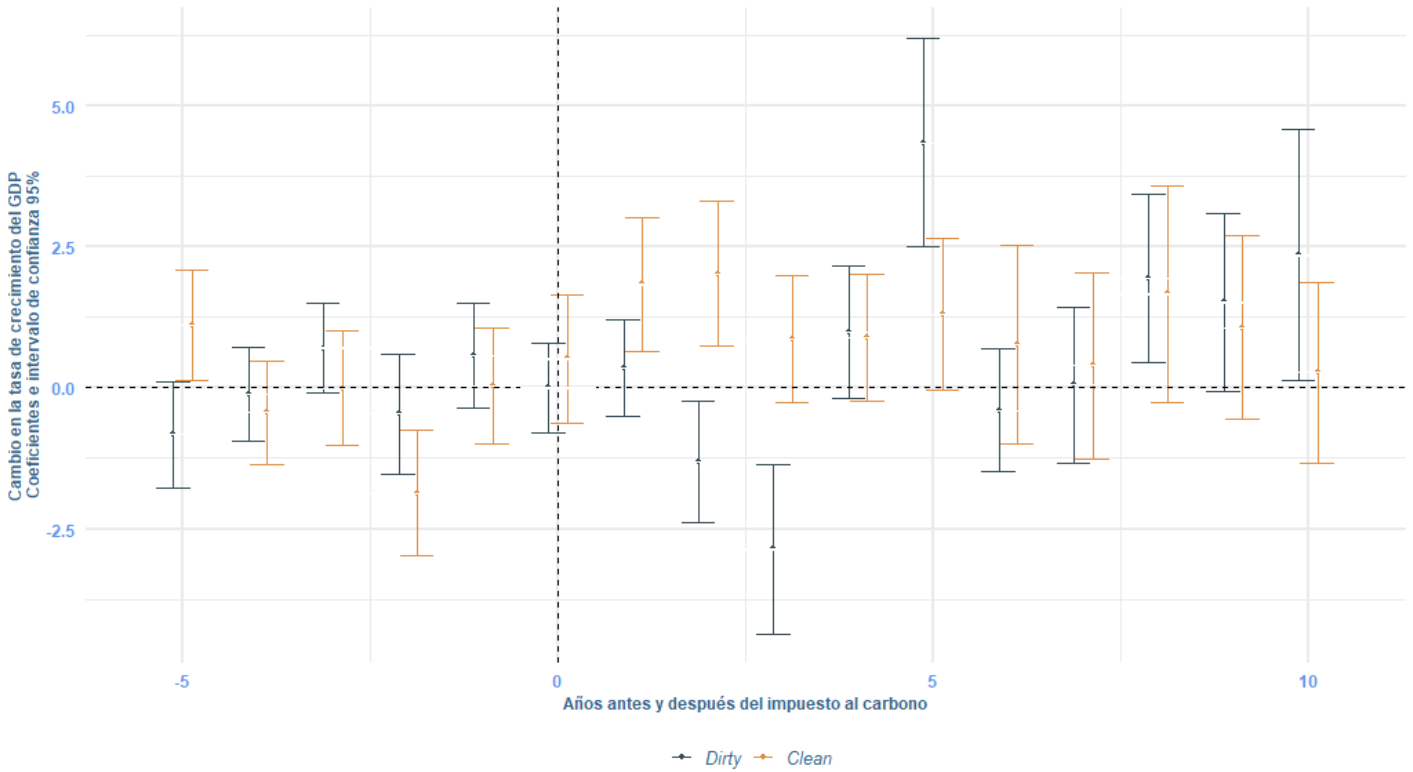
Two samples of countries with...

- Clean energy $\frac{Renewableenergy}{Totalenergy} > mean$
- Dirty energy $\frac{Renewableenergy}{Totalenergy} < mean$

Correlation

Results: Long run effect of carbon tax on growth rate

Change of GDP growth in long run



Countries with a higher than average share of energy from dirty sources have initially a negative effect on the growth rate. This effect dissipates in the long run.

Results: Effect with different shares of clean energy.

Change in GDP growth

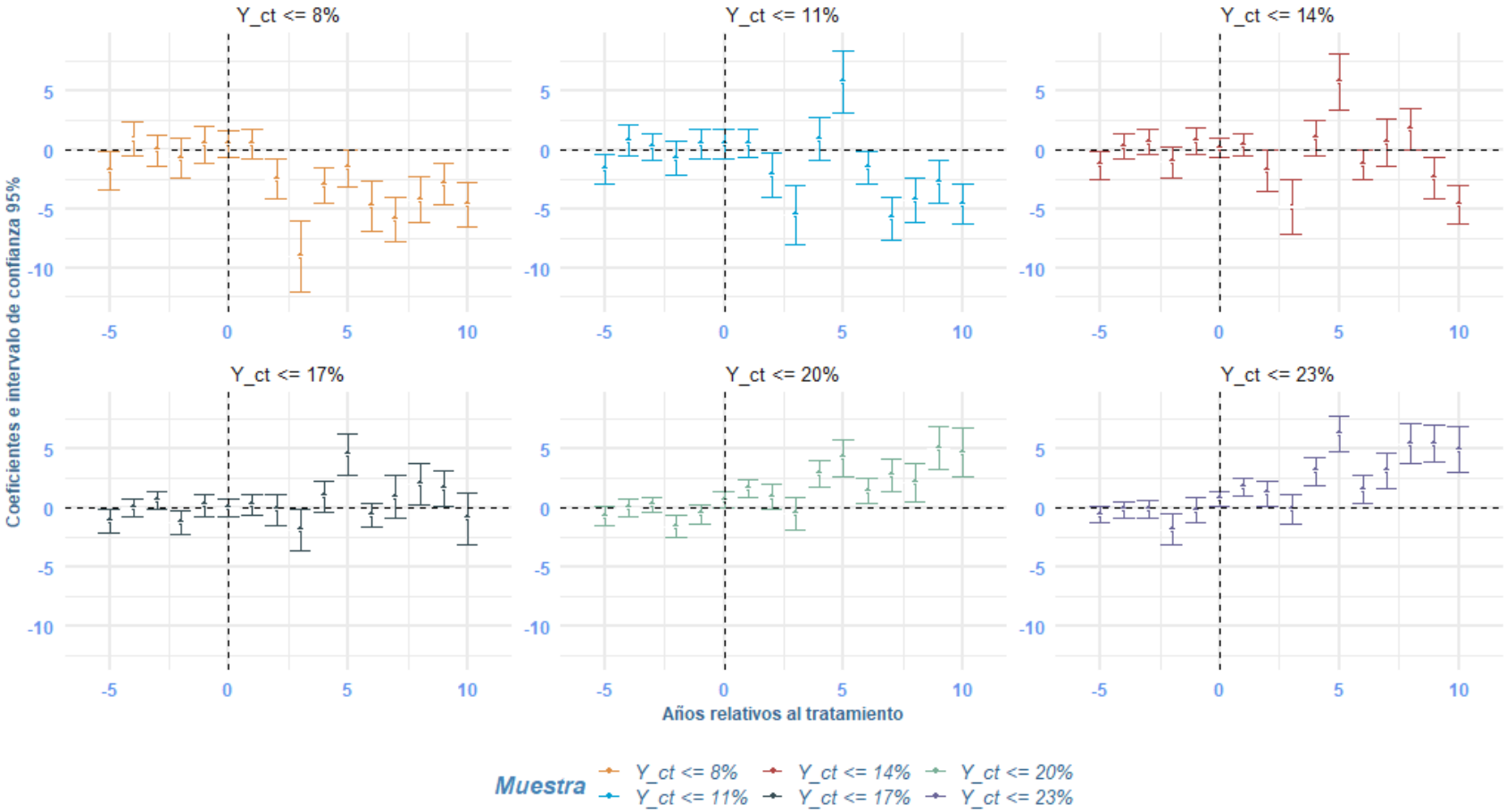


Figure: Effect of the carbon tax at different share of clean energy.

Conclusions

- The effect of the carbon tax on economic growth is an increasing function of the share of clean goods in total output.
- A carbon tax may result in a temporary GDP growth slowdown and a decrease in employment rates in countries that rely mainly on high-carbon energy sources.
- The destination of the tax revenue from the carbon tax is essential, as highlighted by the model's findings.

Primary energy sources can enhance or attenuate the adverse effects of introducing a carbon tax on economic growth.

- Energy mix composed of low-carbon sources $\Longrightarrow$ positive effect on economic growth.
- Energy mix composed of high-carbon sources $\Longrightarrow$ negative effect on economic growth.

Thank you!

Data

Variable	Mean	Median	Std. Dev.	Source
Real GDP (billion 2017US$)	1026.89	258.98	2511.96	Penn World Table
GDP Growth (annual %)	2.86%	2.99%	4.33%	Data WorldBank
GDP per capita (thousand US$)	9.384	9.532	1.143	Data WorldBank
Employment rate (% total labor)	92.30%	92.94%	4.56%	Data WorldBank
Population, total (Millions)	49,04	9,77	165,99	Data WorldBank
Primary energy consumption (TWh)	1589	324	4390	Our World in Data.
Clean energy fraction* (% total consumption)	14%	9%	16%	International Energy Agency.
Clean electricity fraction* (% total consumption)	37%	32%	31%	International Energy Agency.
Countries	66			
Observations	2511			

**clean energy sources are hydro, nuclear, solar and wind power.*

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Anexo: Sampling balance

Variable	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
			Panel all data			
		With carbon tax			Without carbon tax	
Real GDP (billion 2017US$)	850.69	393.49	1082.45	1121.27	166.13	3006.62
GDP per capita (thousand US$)	9.89	10.10	0.94	9.11	9.15	1.15
GDP growth (annual %)	2.48%	2.68%	3.69%	3.05%	3.25%	4.63%
Employment rate (% total labor)	92.07%	92.85%	4.75%	92.43%	93.02%	4.45%
Primary energy consumption (TWh)	1094.63	474.96	1379.31	1855.63	254.93	5334.58
Clean electricity share (% total consumption)	47%	46%	33%	31%	24%	29%
Clean energy share (% total consumption)	23%	18%	20%	9%	4%	11%
Countries	23			51		
			Panel - Countries with relatively 'clean' energy matrix			
		With carbon tax			Without carbon tax	
Real GDP (billion 2017US$)	609.24	322.00	721.71	654.03	161.62	1096.71
GDP per capita (thousand US$)	10.02	10.17	0.91	9.26	9.44	1.04
GDP growth (annual %)	2.17%	2.57%	3.28%	2.35%	2.67%	3.47%
Employment rate (% total labor)	92.14%	92.70%	4.51%	90.99%	91.68%	4.23%
Primary energy consumption (TWh)	841.80	351.14	1103.98	748.81	232.82	1166.34
Clean energy share (% total consumption)	70%	71%	21%	60%	60%	16%
Clean electricity share (% total consumption)	36%	32%	17%	23%	23%	8%
Countries	13			12		
			Panel - Countries with relatively 'dirty' energy matrix			
		With carbon tax			Without carbon tax	
Real GDP (billion 2017US$)	1164.57	579.57	1359.16	1302.52	168.37	3459.27
GDP per capita (thousand US$)	9.72	9.86	0.95	9.06	9.07	1.19
GDP growth (annual %)	2.89%	2.83%	4.14%	3.33%	3.57%	4.98%
Employment rate (% total labor)	91.97%	93.96%	5.06%	93.06%	93.67%	4.39%
Primary energy consumption (TWh)	1423.29	1010.65	1614.45	2289.49	277.86	6198.64
Clean energy share (% total consumption)	16%	12%	15%	19%	10%	24%
Clean electricity share (% total consumption)	6%	5%	6%	3%	1%	5%
Countries	10			49		

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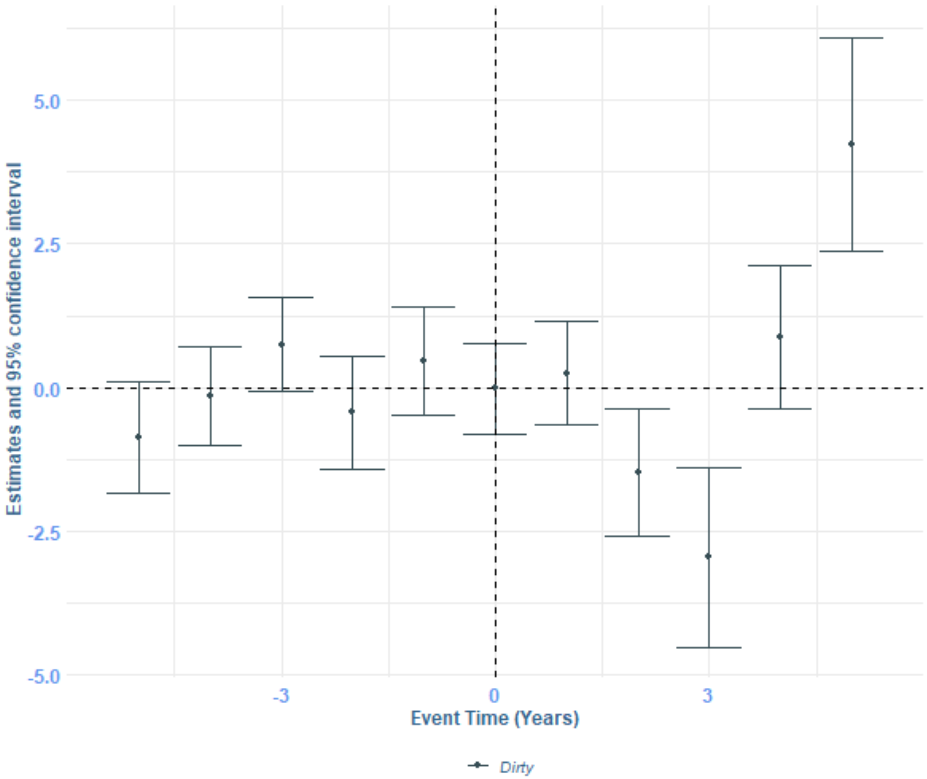
Effect of carbon tax on growth rate according electricity mix

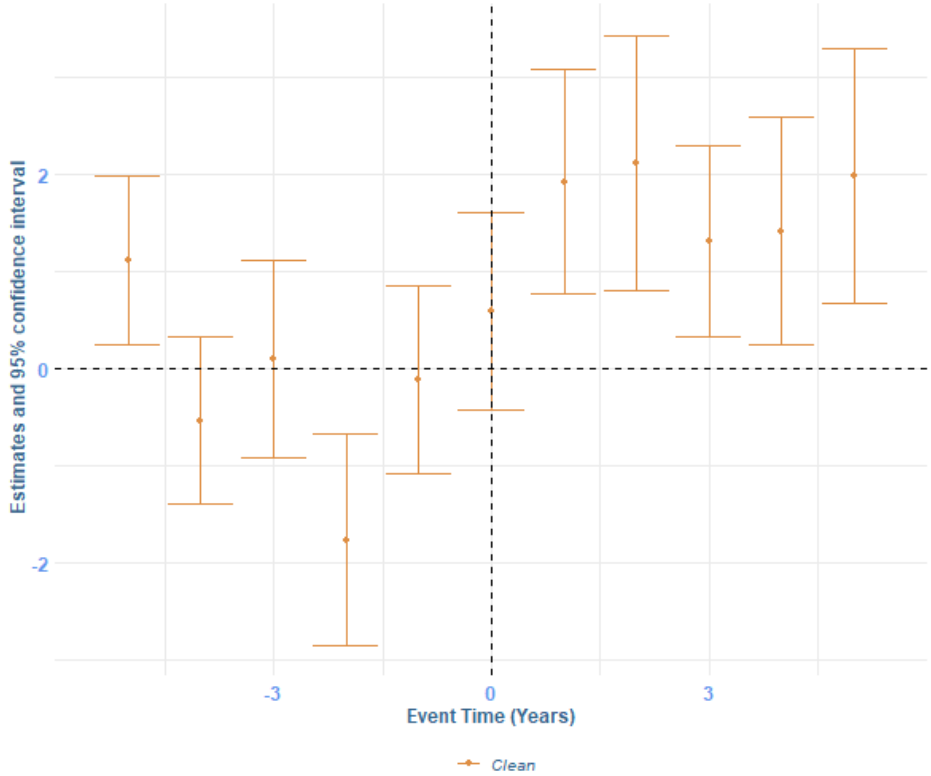
Countries with polluting electricity sources.

Figure: GDP growth (% annual)



Countries with clean electricity sources.

Figure: GDP growth (% annual)



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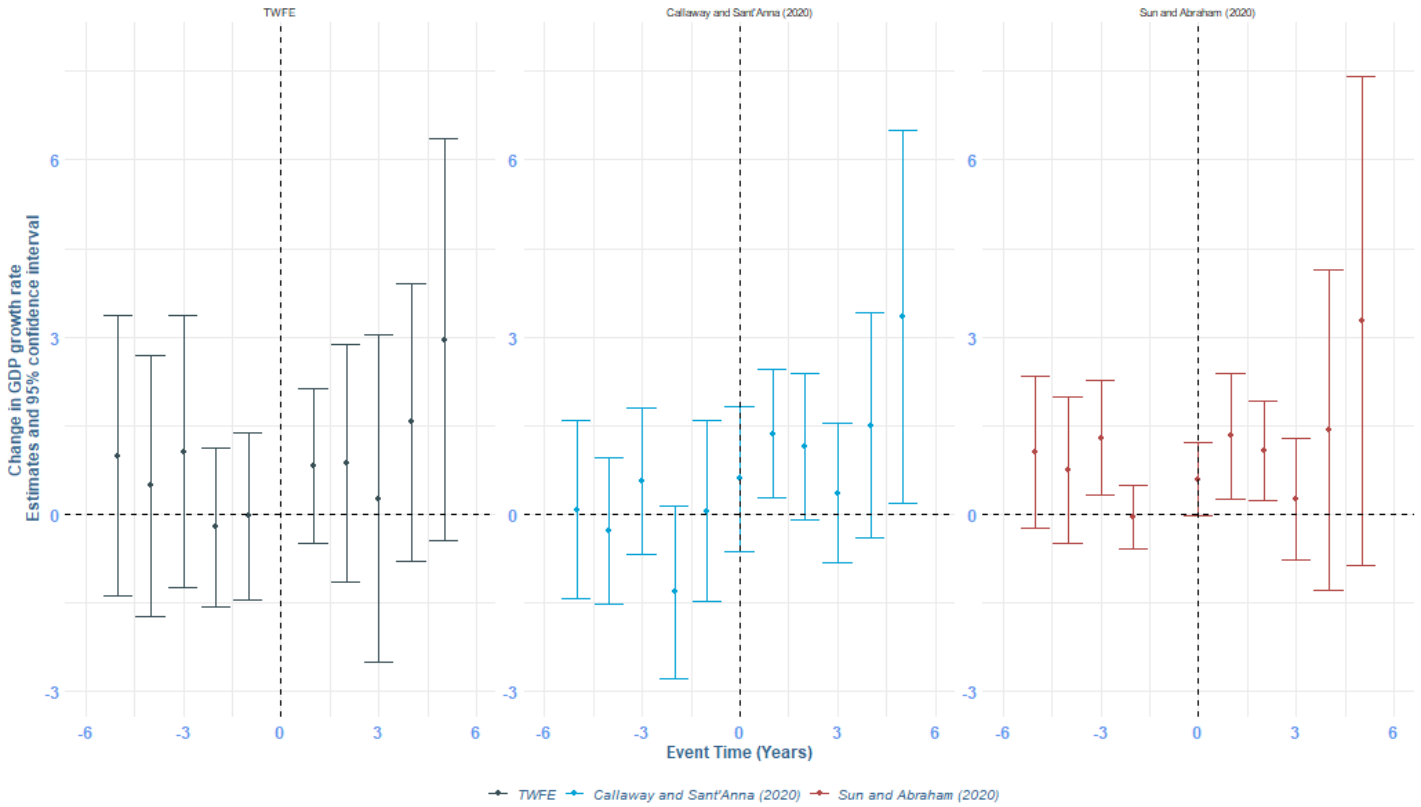
Results on GDP growth using others estimators

Effect of carbon tax on GDP growth rate.



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