A Comparative Analysis of Pigouvian Taxes and Cap-and-Trade Systems in Regulating Carbon Emissions

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RESEARCH FOCUS / ABSTRACT

This project provides a comparative analysis of two primary market–based environmental policy instruments, Pigouvian carbon taxes and cap– and – trade systems, in regulating carbon emissions. This study evaluates how price – based and quantity – based regulatory approaches internalize negative externalities and move markets toward socially efficient emission levels.

Integrating foundational economic theory, with an extensive review of empirical literature examining uncertainty, growth dynamics, institutional design, and policy implementation across countries.

MOTIVATION

Given the current political and economic climate of our world today, understanding pollution and carbon efficiency is extremely important for the future of our world.

A significant source of inspiration for this project came from my experience studying abroad in Switzerland and seeing how seriously environmental conservation was implemented throughout everyday life.

THEORY

- Carbon emissions create negative externalities (costs to society not paid by firms)
- **GOAL**: Reach a socially efficient emission level where:
  - Marginal Abatement Cost (MAC) = Marginal Damage (MD)
- Without regulation
  - Firms only consider private costs
  - Leading to an overproduction of emissions
- Two Main Policy Tools:
  - **Pigouvian Tax** (price – based)
    - Adds the cost per unit of pollution
    - Forces firms to internalize the social cost
  - **Cap and Trade** (quantity – based)
    - Sets a total emissions limit
    - Firms trade permits, leading to market efficiency

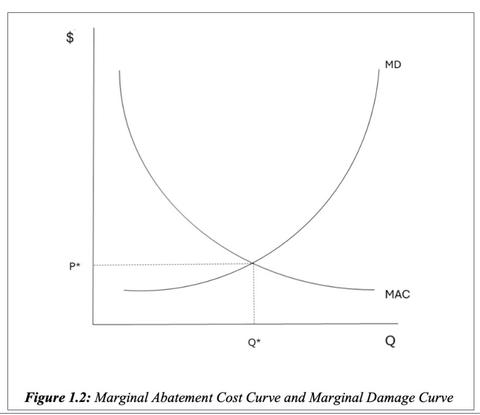

Figure 1.2: *Marginal Abatement Cost Curve and Marginal Damage Curve*

METHODS

Data Collection

- Panel data from multiple countries (1980-2019)
- Country Groupings:
  - No Policy (control)
  - Cap- and – Trade
  - Carbon Tax
  - Both Policies

Key Variables

- **Dependent:** Carbon Emissions (total, per capita, per 1M people)
- **Independent:** Policy type (dummy variables)
- **Controls:** GDP, Population, Trade Openness, Energy Intensity
- Models Used:
  - Basic Regression Model (No Controls)
  - Regression (With Controls)
  - Year Fixed Effects Model

    Controls for time – specific factors

Table 1.2: Summary Statistics of Control and Outcome Variables

Variables	(1) Mean	(2) Std. Dev.	(3) Min	(4) Max
CO_2 (Mt)	203.1	650.8	0.0146	5,929
GDP ($)	4.736e+11	1.566e+12	2.973e+07	2.138e+13
CO_2 Per Capita	8.06e-06	1.51e-05	1.05e-07	0.000203
GDP Per Capita	15,285	18,097	22.95	123,679
CO_2 Per 1M	8.063	15.10	0.105	202.9
GDP Per 1M	1.528e+10	1.810e+10	2.295e+07	1.237e+11
Population	2.501e+07	4.399e+07	12,271	3.302e+08
Trade (% of GDP)	82.46	56.28	0.0210	437.3

RESULTS

- Table 1.5 shows a measure of emissions relative to population size
- Results show:
  - Carbon pricing policies begin to show a negative relationship with emissions
  - Results are weaker and less consistent without the implementation of economic controls

Table 1.5: CO2 Per 1 Million People

Variables	(1) CO_2 Per 1 Million	(2) CO_2 Per 1 Million	(3) CO_2 Per 1 Million	(4) CO_2 Per 1 Million	(5) CO_2 Per 1 Million	(6) CO_2 Per 1 Million
Cap & Trade	0.289			-7.484***		
	(1.485)			(0.960)		
Tax		-3.513			-4.053***	
		(2.588)			(1.386)	
Both			-0.750			-10.52***
			(1.943)			(1.309)
GDP Per Capita				0.000253***	0.000309***	0.000213***
				(1.78e-05)	(2.21e-05)	(1.59e-05)
Trade				0.0351***	0.0192***	0.0407***
				(0.00504)	(0.00419)	(0.00593)
Constant	8.280***	7.512***	8.365***	1.616***	1.831***	1.206**
	(0.427)	(0.440)	(0.416)	(0.459)	(0.422)	(0.536)
Observations	1,920	1,800	1,920	1,785	1,676	1,796
R-squared	0.000	0.001	0.000	0.156	0.128	0.114

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

RESULTS

- Table 1.7 reflects a further controlled environment, utilizing year fixed effects
- A stronger more consistent negative relationship between policies and emissions
- **Cap and trade** shows the largest reduction effect
- Weaker results in basic regressions were because of hidden variables, not necessarily policy failure

Table 1.7: CO_2 Per 1 Million People Fixed Effects

Variables	(1) CO_2 Per 1 Million Fixed Effects	(2) CO_2 Per 1 Million Fixed Effects	(3) CO_2 Per 1 Million Fixed Effects
Cap & Trade	-0.960**		
	(0.475)		
Tax		0.109	
		(0.647)	
Both			-1.017*
			(0.576)
GDP Per Capita	-6.85e-05***	3.88e-06	-2.43e-05*
	(1.38e-05)	(1.84e-05)	(1.29e-05)
Trade	0.00367	0.0179***	0.0163***
	(0.00459)	(0.00500)	(0.00473)
Year	✓	✓	✓
Constant	6.658***	3.806***	5.782***
	(0.673)	(0.701)	(0.648)
Observations	1,785	1,676	1,796
R-squared	0.056	0.047	0.043
Number of Country ID	46	43	46

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

- Table 1.8 shows emissions on the scale of CO_2 per capita
- This display shows the inclusion of an added control variable, energy intensity
- Policy results remain negative and statistically significant, showing an even stronger relationship
- **Indicates:** Reductions are partly driven by shifts in energy use and improvements in efficiency
- **Dual policy** becomes the most effective policy

Table 1.8: CO_2 Per Capita with Energy Intensity Added to Controls

Variables	(1) CO_2 Per 1 Million People	(2) CO_2 Per 1 Million People	(3) CO_2 Per 1 Million People
Cap & Trade	-0.441***		
	(0.101)		
Tax		0.111	
		(0.123)	
Both			-1.194***
			(0.154)
Trade	-0.00621***	0.00118	-0.00359**
	(0.00125)	(0.00130)	(0.00174)
Energy	0.00244***	0.00192***	0.000803***
	(4.80e-05)	(4.81e-05)	(3.57e-05)
GDP Per Capita	-3.20e-05***	-2.45e-05***	-1.71e-05***
	(3.75e-06)	(4.36e-06)	(4.32e-06)
Year	✓	✓	✓
Constant	1.561***	1.481***	4.482***
	(0.187)	(0.165)	(0.206)
Observations	1,229	1,140	1,230
R-squared	0.752	0.636	0.392
Number of Country ID	41	38	41

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

CONCLUSION

Policy Effectiveness Depends on:

- Economic Conditions
- Model Specification

Key Insights:

- Policies alone may appear ineffective, controls matter
- Economic Factors (GDP, Trade, Population) strongly influence emissions

Cap and Trade:

- More effective due to strict emission limits

Carbon Tax:

- It works but is less consistent
- Firms can still pollute if they are willing to pay for it

Dual Policy:

- Shows strong potential (supporting hypothesis)

Both policies help in emission reduction but:

- Cap and trade is most effective overall

Theoretical equivalence does not necessarily mean the plan will work against real world circumstances

Key Takeaway: Policy effectiveness is dependent on the type of environment they are implemented in.

FUTURE WORK

- Utilize more refined identification strategies and considering more variables that may change the results
- Utilize an alternative indicator of policy implementation
- Test an alternative model for trend analysis, rather than basic regression models.
- Observing the allocation of funds
  - Including consideration of how the funds collected by the carbon tax are allocated throughout the economy and potential uses of funds acquired by firms that sell their carbon credits in the cap-and-trade system.
    - Tax revenue
      - green initiatives
      - recycling back into households
      - a general fund for the government
- In terms of funds acquired via permit selling, deeper analysis of where these funds go and how they are used by firms could pose an interesting perspective to find the "domino effect" these policies have in addition to the impact they have on the production of emissions alone.

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