The Race for Polluting Permits

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Girona Workshop on Energy and the Environment
October 2, 2009

Motivation

- Kyoto protocol: worldwide market is emerging for greenhouse gases (2004)
- European Emission Trading Scheme (EU-ETS): trading for permits on carbon dioxide emissions among industrial firms within the EU (2006)
- Each country remains responsible for taxes on energy fuels responsible for carbon dioxide emissions
- Energy taxes are a substantial source of revenue for most countries
  - European (EU-15) average of 5.2% of total tax revenues= 2.4% of GDP
  - Ranging from 3.5% in the Netherlands and Belgium, to 6.3% in the UK, 7.7% in Italy and 8.4% in Portugal

What are the consequences of the interaction between TEP market and country-level energy taxation?

Related literature

Tradable Emission Permits (TEP) even when mentioning taxes, the literature mostly ignores the *strategic* tax setting. Exception: Santore *et al.* (2001)
Strategic behavior of state-level utility regulators in the context of the US federal trading system of sulfur oxide emissions.
State-level regulator impose pollution penalties on own utilities.
Emissions trading is not cost-efficient under fiscal competition.

Tax Competition some of our results are reminiscent of tax competition ones: race to the bottom, productive inefficiency, terms of trade effect

This paper

- Market for TEPs amongst industrial firms in N countries
- Total emission cap set by supra national institution
- Firms decide the quantity of polluting energy used for production
- Firms endowed with abatement technology and a given number of TEPs
- Countries are asymmetric due to: number of firms, firms' TEP endowment, firms' technology
- National governments are revenue maximizers (environmental damage fixed by TEP market!)

Energy cost in country c

For each unit of carbon dioxide emission, the firm

1. Buys a polluting permit in the international market at the price of ρ

2. Pays a tax t_c to the country where it locates

$$\underbrace{p_c}_{\text{cost of energy}} = \underbrace{\rho}_{\text{TEP price}} + \underbrace{t_c}_{\text{Energy tax}}$$

Outline of the talk

I have hopefully done

1. Motivation
2. Related literature
3. This paper: the setting

now moving to

4. This paper: the results
5. The model: firms, TEP market, national governments
6. Results
   - Cost inefficiency
   - Effect of TEP endowments
   - Resizing the market
   - Comparison with autarky
7. Conclusions

Our results

Cost inefficiency

- Usual argument for implementing TEP market: minimizes global abatement cost
- *However* TEP market in the presence of country-level energy taxation is not cost efficient

Effect of TEP endowments

- Usual textbook model argues that TEP endowments are neutral (i.e., do not influence market outcome)
- We show that country-level energy taxation eliminates neutrality: energy taxes and the cost of energy depend on firm's TEP endowment

Resizing the market we study how the total amount of permits and the number of participating countries change energy taxes and the cost of energy

Comparison with autarky we show what happens to energy taxes when market is introduced

The model: Firms

- Firms minimize total costs (production cost, energy tax bill and TEP net demand)
- By normalization, one unit of energy pollutes one ton of CO_2
- Trade-off of reducing emissions
  - decrease energy tax bill
  - save on polluting permits
  - increase production cost

Firm f in country c chooses emissions e_{fc} to minimize production cost

$$\mathcal{C}_{fc}(e_{fc}) = \underbrace{C_f(e_{fc})}_{\text{production cost}} + \underbrace{t_c e_{fc}}_{\text{energy tax bill}} + \underbrace{\rho(e_{fc} - \bar{e}_f)}_{\text{TEP (net) acquisition}} ,$$

Where

- t_c is the energy tax in country c,
- e_{fc} is energy consumption, which is equal to CO_2 emissions
- ρ is the TEP price
- $\bar{e}_f$ is the TEP endowment received by the firm
- $C_f(e_{fc})$ is the abatement technology, $C'_f < 0$ and $C''_f > 0$.

The model: Demand for TEPs

Demand for TEPs implicitly given by

$$-C'_f(e_{fc}) = \rho + t_c$$

Recall

$$\underbrace{p_c}_{\text{energy cost in country } c} = \underbrace{\rho}_{\text{TEP price}} + \underbrace{t_c}_{\text{tax rate in country } c}$$

TEP demand decreases with energy cost

$$\frac{de_{fc}}{dp_c} = e'_{fc} = -\frac{1}{C''_f(e_{fc})} < 0,$$

We assume that the demand is convex

$$\frac{d^2 e_{fc}}{dp_c^2} \geq 0$$

Convexity implies that when the cost of energy p_c increases

- the quantity e_{fc} decreases
- the absolute value of the slope e'_{fc} decreases too

We assume that the elasticity of the slope is smaller than the elasticity of the quantity (with respect to p_c)
This assumption ensures strategic complementarity (and stability of the Nash equilibrium)

The model: TEP market

- Total emission cap set by supra national institution

$$\bar{E} = \sum_{c=1}^{N} \sum_{f \in I_c} \bar{e}_{fc}$$

- Each firm f receives a TEP endowment of $\bar{e}_f$ (for free)
- Firms are price takers in the market
- ρ is the TEP price which clears the market, i.e. in equilibrium

$$\sum_{c=1}^{N} \sum_{f \in I_c} e_{fc}(p_c) = \sum_{f \in I} \bar{e}_f = \bar{E}$$

Equilibrium ρ exists because LHS decreasing in ρ

The model: Energy taxes and TEP market

When a country increases its tax rate

- the home demand for TEPs decreases
- hence, international demand for permits decreases
- since the supply is fixed, the TEP price decreases

What happens to the energy cost?

at home, it increases

$$\frac{dp_c}{dt_c} = 1 + \frac{d\rho}{dt_c} > 0$$

because

$$-1 < \frac{d\rho}{dt_c} < 0$$

abroad, it decreases

$$\frac{dp_j}{dt_c} = \frac{d\rho}{dt_c} < 0$$

Important to highlight that

- The TEP price absorbs part of the tax increase: energy cost varies less than one-to-one with tax rate
- The more ρ decreases with tax rate, the less sensible to the tax rate is the TEP demand

The model: National governments

- CO_2 is a global pollutant $\Rightarrow$ total pollution given by $\bar{E}$
- National governments do not need t_c to regulate emissions
- Fiscal revenue maximizers

$$U_c = \sum_{f \in I_c} \left\{ t_c e_{fc} + \gamma \left(-\mathcal{C}_{fc}(e_{fc}) \right) \right\},$$

  where $0 < \gamma < 1$ represents profit tax rate (or share of firms owned by national residents)

- The country chooses t_c to maximize U_c given by

$$\sum_{f \in I_c} \quad t_c e_{fc}(p_c) + \gamma \left[-C_f \left(e_{fc}(p_c) \right) - t_c e_{fc}(p_c) - \rho \left(e_{fc}(p_c) - \bar{e}_f \right) \right]$$

Tax setting by countries

The first order condition is

$$\underbrace{(1-\gamma)\sum_{f\in I_c} e_{fc}(p_c)}_{\text{Tax base effect}} + \underbrace{t_c \sum_{f\in I_c} \frac{de_{fc}(p_c)}{dt_c}}_{\text{Sensitivity effect}} - \underbrace{\gamma\rho_{t_c}\sum_{f\in I_c}(e_{fc}(p_c)-\bar{e}_f)}_{\text{Terms of trade effect}} = 0$$

Tax base effect Incentive to tax

Sensitivity effect Disincentive to tax (if positive tax rate)

Terms of trade effect Depends on net importing/exporting position

- Incentive to tax if net TEP-importer

$$\sum_{f\in I_c}(e_{fc}(p_c)-\bar{e}_f) > 0$$

- Disincentive to tax if net TEP-exporter

$$\sum_{f\in I_c}(e_{fc}(p_c)-\bar{e}_f) < 0$$

Results I: Cost inefficiency

Nash equilibrium tax rates are implicitly given by

$$\hat{t}_c = \frac{(1-\gamma)\sum_{f\in I_c} e_{fc}(p_c) - \gamma\rho_{t_c}\sum_{f\in I_c}(e_{fc}(p_c) - \bar{e}_f)}{(1+\rho_{t_c})\sum_{f\in I_c}|e'_{fc}(p_c)|}$$

The TEP market is *cost-efficient* if, given $\bar{E}$, the total abatement cost is minimized

$$C'(e_{fc}) \quad \text{is constant} \quad \forall f, \forall c$$

In our case firms' optimization requires

$$-C'_f(e_{fc}) = \rho + t_c - \delta$$

Since countries are asymmetric, t_c differs across countries and the TEP market is cost inefficient

Results II: neutralizing effects

The *tax base* and *sensitivity* effects depend on firms' technology
The *terms of trade effect* depends also on firms' endowments

In order to further characterize equilibrium taxes,

- We neutralize technology differences (study effect of TEPs' endowments)

  Technology-comparable countries
  Two countries a and b are technology-comparable if, for each firm in I_a, there is one and only one firm in I_b with the same technology.

- Then, we neutralize the effect of TEPs' endowments

  Quasi-symmetric countries
  Two countries a and b are quasi-symmetric if they are technology comparable and the total permits endowment of firms in country a is the same as in country b, *i.e.*, $\sum_{f\in I_a}\overline{e}_f = \sum_{f\in I_b}\overline{e}_f$.

Let

- $E_c = \sum_{f \in I_c} e_{fc}$,
- $\bar{E}_c = \sum_{f \in I_c} \bar{e}_f$, and
- $\mathcal{E}_c = \sum_{f \in I_c} e'_{fc}$

Then the first order condition is

$$(1-\gamma)E_c + t_c\mathcal{E}_c - \gamma\rho_{t_c}\left(E_c - \bar{E}_c\right) = 0$$

And the equilibrium tax rate

$$t_c = \frac{(1-\gamma)E_c - \gamma\rho_{t_c}\left(E_c - \bar{E}_c\right)}{|\mathcal{E}_c|}$$

Results III: TEPs' endowments

When countries are technology comparable

- if the total permit endowment of firms in country a is lower than in country b, country a sets a higher energy tax than country b;
- a permit-importing country sets a higher energy tax than a permit-exporting one.

Intuition: terms of trade effect

When countries are quasi-symmetric the equilibrium tax rate is

$$t_c = \frac{(1-\gamma)E_c}{|\mathcal{E}_c|}$$

Results IV: Resizing the market

When countries are quasi-symmetric

- All countries set same tax rate in equilibrium.
  However, there is TEP trade amongst firms!

- When $\bar{E}$ decreases, p_c increases, ρ increases and t_c decreases

  Intuition: tax base decreases, disincentive to tax

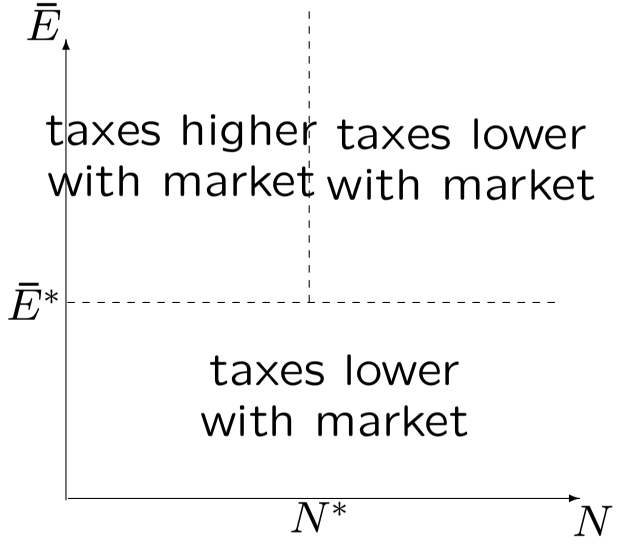
- Suppose N increases with the average TEP endowment per firm kept constant. Then
  p_c does not change, ρ increases and t_c decreases

  Intuition: tax base more sensitive to tax variations

Results V: Comparison with autarky

Non-constraining market taxes go up because the tax base becomes less sensitive to tax rate variations

Letting the restrictiveness of emission cap vary



Conclusions and future research

- We show that market for TEPs is not cost-efficient when energy taxation is set at the national level
- We characterize the energy tax equilibrium in terms of
  - Firms TEP endowment
  - Market size (emissions cap, number of countries)
- We show how energy tax rates change with the introduction of the TEP market

Future research: firm mobility, strategic interaction between TEP endowment allocation and taxation

Thank you!