Energy (and other Markets): Strategic Issues for the Tax System

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Outline

Motivation: Energy in the economy

- Energy products make up a large part of the tax revenue in European member states
- Complex of subsidies and taxes
  (Wind, coal, gas, nuclear, oil)
- Dependence question $\oplus$ environmental concerns
  (Green Paper): Does Europe have the means to change the international market and to respond to environmental issues?
- How to combine policies efficiently?
  - Competition policy in energy markets (Directives)
  - Environmental and climatic concerns (Kyoto)
  - Energetic independence

Ingredients

- Possibly non-competitive suppliers
  - monopolistic producers of fossil fuels can be foreign, domestic, or in between (i.e. partially owned by nationals)
    (in general low cost, high markup)
  - other fuels (e.g. renewables) are produced by competitive suppliers
    (cost may be high, markups are small a priori);
- Taxes
  - raise funds for public activities
  - serve to correct externalities due to pollution
  - have a strategic dimension as they take into account non-competitive supply

In short

- A Government, or the Community in the European context, may influence import prices by properly setting taxes and subsidies
- Competition between various forms of energies can be exploited by fiscal authorities
(windmills and nuclear plants for "energy independence")

- Literature
  - Optimal taxation
    (Ramsey, Samuelson, Mirrlees, Sandmo, Guesnerie)
  - General equilibrium with non-competitive markets
    (Gabszewicz-Vial 1972)
  - Both (Myles 1987, 1989, JPubEcon, Auerbach and Hines 2003, Handbook PubEcon, Reinhorn 2005, AdvEcoAn&Pol)
  - Also
    - Seade (1985) on effects of cost shifts—or taxes—
    - Newbery (2002) for overview on energy taxes
- Our contribution: Quasi-linear preferences, linear technologies
  - Neutralizes income effects (focus on leverage effects due to subst. or and comp. between commodities)
  - Considerably improves calculability of models and clarifies insights
  - Numéraire is "natural"

Main results

- Direct *and* indirect effects of taxation matter, strong argument against treating energy as a homogeneous commodity
- Consistent and comprehensive discouragement index (simple intuition for strategic effects)
- "Frontier effects": foreign and domestic firms should be treated differently
- Financing cost reductions (R&D) in domestically produced substitutes might also constitute "strategic" European energy policy
  (sometimes not desirable however)
- Calculable applications (algorithm)
  - An isoelastic model (non-intuitive results)
  - A fully quadratic linear version allows theoretical experiments

Notation

x_i	a fuel (vector $\mathbf{x}$)
$U[\mathbf{x}] + m$	quasi-linear consumer's utility function
p_i	price of commodity i (vector $\mathbf{p}$)
t_i	specific tax on commodity i (vector $\mathbf{t}$)
$q_i = p_i + t_i$	consumer's price (vector $\mathbf{q}$)
η_i	intensity of externality due to x_i (vector η)
λ	marginal cost of public funds

Game

1. Government sets taxes $\mathbf{t}$ to maximize domestic surplus
2. Firms plan production (taking taxes as given) to maximize profits (e.g. Cournot game): $\mathbf{p}[\mathbf{t}]$
3. Consumers consume in function of after-tax prices: $\mathbf{x}[\mathbf{p}+\mathbf{t}]$

We solve for subgame perfect equilibria

Social Welfare Function

$$SW[\mathbf{x}, \mathbf{p}, \mathbf{t}] \equiv U[\mathbf{x}] - \sum_i x_i \cdot q_i$$
$$- \sum_i x_i \cdot \eta_i + (1+\lambda) \sum_i x_i \cdot t_i + \sum_i \sigma_i \cdot \pi_i$$

$=$ net consumer's utility $\oplus$ three terms:

1. $\sum_i x_i \cdot \eta_i$: sum of external effects caused by various commodities
2. Value of fiscal revenue depends on (exogenous or endogenous) marginal cost of public funds λ
3. π_i profit earned by firm (or sector) i and σ_i is the share of this firm (or sector) that is owned by nationals of the country considered. ($\sigma_i = 1$ for purely domestic firms and $\sigma_i = 0$ for purely foreign firms)

Optimal tax policy

- Government maximizes SW subject to reaction functions of follower firms and follower consumers:

$$p_{ij} = \frac{\partial p_j}{\partial t_i} \text{ and } q_{ij} = \frac{\partial q_j}{\partial t_i}$$

with $q_{ii} = 1 + p_{ii}$ and $q_{ij} = p_{ij}$ $(i \neq j)$.

- Measure tax incidence on prices, i.e. the extent to which producers shift forward tax burden to consumers
(No specific assumptions on game played between firms)
  - *Undershifting*: $p_{ii} < 0 \Leftrightarrow q_{ii} < 1$
  - *Overshifting*: $p_{ii} > 0 \Leftrightarrow q_{ii} > 1$
  - No name for cross effects

First Order Condition

$$\frac{1}{1+\lambda}\cdot(\mathbf{P}-\lambda\mathbf{I})\cdot\begin{bmatrix}x_1\\ \vdots\\ x_N\end{bmatrix}=(\mathbf{P}+\mathbf{I})\cdot\mathbf{S}\cdot\begin{bmatrix}t_1-\frac{\eta_1}{1+\lambda}\\ \vdots\\ t_N-\frac{\eta_N}{1+\lambda}\end{bmatrix}+\Pi\cdot\Sigma$$

$\mathbf{S}$ = consumer's Slutsky matrix
$\mathbf{P} = [p_{ij}]$
$\mathbf{P}+\mathbf{I}$ = tax incidence matrix $[q_{ij}]$
$\Sigma = [\sigma_i]$
$\Pi = [\pi_{ij}] = [\frac{\partial \pi_j}{\partial t_i}]$
Various situations, depending on specific hypotheses on $\mathbf{P}$ and $\mathbf{S}$
(Last term null when non-competitive firms are foreign)

Index of discouragement (Mirrlees 1976)

$d_i \simeq \frac{\Delta x_i}{x_i}$: change in compensated demand due to taxes (undistorted reference means taxes equal to $\frac{\eta}{1+\lambda}$)

$$\begin{bmatrix} d_1 \cdot x_1 \\ \vdots \\ d_N \cdot x_N \end{bmatrix} \underset{\text{def}}{=} \mathbf{S} \cdot \begin{bmatrix} t_1 - \frac{\eta_1}{1+\lambda} \\ \vdots \\ t_N - \frac{\eta_N}{1+\lambda} \end{bmatrix}$$

Impact of taxes on *prices* not considered (as if of second-order), which is not acceptable here

We approximate full impact adding

$$\mathbf{S} \cdot {}^{\mathbf{T}}\mathbf{P} \cdot \left(\mathbf{t} - \frac{\eta}{1+\lambda} \right)$$

Comprehensive discouragement d^C where

$$\begin{bmatrix} d_1^C \cdot x_1 \\ \vdots \\ d_N^C \cdot x_N \end{bmatrix} \underset{\text{def}}{=} \mathbf{S} \cdot ({}^{\mathbf{T}}\mathbf{P} + \mathbf{I}) \cdot \begin{bmatrix} t_1 - \frac{\eta_1}{1+\lambda} \\ \vdots \\ t_N - \frac{\eta_N}{1+\lambda} \end{bmatrix}$$

$d \approx d^C$ for small strategic impacts (small $\mathbf{P}$)

Special cases

- Pure competition
  $\mathbf{P} = 0$ and $d_i = d_i^C = -\frac{\lambda}{1+\lambda}$.
- Independent demands
  $\mathbf{S}$ diagonal $\Rightarrow$ $\mathbf{P}$ diagonal : no cross strategic effects

$$d_i^C = -\frac{\lambda}{1+\lambda} + \frac{p_{ii}}{1+\lambda}$$

If a firm reacts to tax increases by strongly decreasing its price, then discouragement effect should be large

In Europe (roughly) two types of fuels:

1. Domestic competitive
2. Foreign (maybe non-competitive)

If moreover $\mathbf{P}\cdot\mathbf{S}=\mathbf{S}\cdot{}^{\mathbf{T}}\mathbf{P}$ (quadratic-linear case)

$$d_i^C = -\frac{\lambda}{1+\lambda} + \frac{1}{1+\lambda}\cdot\sum_j \frac{x_j}{x_i}\cdot p_{ij}$$

Intuitive rule

Encourage consumption of commodities for which subsidies decrease prices of other commodities *on average*, effects being weighted by magnitude of consumption

Windmills

Good 1 produced non-competitively (fossil fuels)
Good 2 produced competitively (windmills) $\oplus$ CRS

$$\mathbf{P} = \begin{bmatrix} p_{11} & p_{12} \\ 0 & 0 \end{bmatrix}$$

Tax rates ($\lambda = 0$)

$$\begin{aligned} t_1 - \eta_1 &= \frac{x_1}{(1+p_{11})\,|\mathbf{S}|}(p_{11}S_{22} - p_{12}S_{12}) \\ t_2 - \eta_2 &= \frac{x_1}{(1+p_{11})\,|\mathbf{S}|}(p_{12}S_{11} - p_{11}S_{12}) \end{aligned}$$

Assume that $1 + p_{11} > 0$ and $p_{11} < 0$ (undershifting)
Assume that p_{12} and S_{12} have opposite signs
(e.g. if 1 and 2 are substitutes, then taxing 2 increases p_1)
Commodity 1 will be taxed and commodity 2 will subsidized (taxed) if and only if 1 and 2 are substitutes (complements)

Benefits of cost reduction policy

- Natural gas: production cost comprises extraction, transport, and distribution
- Does cost reduction (more competition downstream) benefit consumers?
- No if gains are recaptured by monopolists...
- Perhaps if avoids double marginalization...

Benefits of cost reduction policy (cont'd)

Social welfare in reduced form $SW = SW[\mathbf{t}, \mathbf{c}]$
$\mathbf{c}$ = vector of parameters c_i affecting firm i's production cost.
We find

$$\frac{\partial SW^*}{\partial c_i} = \sum_j \frac{\partial SW}{\partial p_i} \cdot \frac{\partial p_j}{\partial c_i} + \frac{\partial SW}{\partial c_i}$$

- Sufficient condition: all $\frac{\partial p_j}{\partial c_i} \geq 0$
- Decreasing (increasing) production costs in competitive sectors is welfare improving (degrading) ("As If" argument)

But

- May be false with non-competitive economies...
- ...or if $\mathbf{t}$ is not reoptimized

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QL model

- Still calculable with large dimension

$$\text{Demand: } \mathbf{x} = \mathbf{a} + \mathbf{S} \cdot (\mathbf{p} + \mathbf{t})$$

- Producers face constant marginal costs $\mathbf{c}$
- Oligopoly size n_i for x_i (Cournot-Nash)

$$\text{Producers' FOC: } x_i/n_i + (p_i - c_i)/A_{ii} = 0$$

(SOC $(1 + 1/n_i)/A_{ii} < 0$ always true) with $\mathbf{A} = \mathbf{S}^{-1}$

- Change of variable (physical units are arbitrary) to have only -1s on the diagonal of $\mathbf{A}$
(we keep $\mathbf{x}$, $\mathbf{p}$, $\mathbf{t}$, $\mathbf{c}$, $\mathbf{a}$ to denote consumption, prices, taxes, costs, and constants in the new base)

- The two equations of interest are now

$$\begin{aligned}\mathbf{p}+\mathbf{t} &= \mathbf{A}\cdot(\mathbf{x}-\mathbf{a}),\\ \mathbf{x} &= \mathbf{p}-\mathbf{c}.\end{aligned}$$

- Gives the NE of subgame played by producers, parameterized by taxes chosen by Government

$$\mathbf{p}[\mathbf{t}] = (\mathbf{A}-\mathbf{I})^{-1}\cdot(\mathbf{A}\cdot(\mathbf{a}+\mathbf{c})+\mathbf{t}).$$

- The reaction matrix is therefore

$$\mathbf{P} = (\mathbf{A}-\mathbf{I})^{-1}.$$

$\mathbf{A}$ being negative definite, so is $\mathbf{A}-\mathbf{I}$: NE exists and unique

- Gvt FOC

$$(\mathbf{P} - \lambda \mathbf{I}) \cdot \mathbf{x} = (1 + \lambda)(\mathbf{P} + \mathbf{I}) \cdot \mathbf{S} \cdot \mathbf{t}$$

- We find immediately

$$\Gamma \cdot \mathbf{t} = \Gamma_a \cdot \mathbf{a} + \Gamma_{\mathbf{c}} \cdot \mathbf{c} + \Gamma_\eta \cdot \eta$$

  where Γ, Γ_a, $\Gamma_{\mathbf{c}}$ and Γ_η are rational fractions of $\mathbf{A}$ and λ only
- Γ definite negative $\Leftrightarrow$ Solution $\mathbf{t}$ maximizes welfare

Proposition

Matrix Γ is definite negative if $\lambda > -\frac{1}{2}$ where λ is the marginal cost of public funds.

Effects of costs on welfare

We find, for $\lambda = 0$

$$\frac{dSW}{d\mathbf{c}} = -\mathbf{x}$$

So to find economies in which decreasing certain costs has adverse welfare effects, we need either:

- $\lambda \neq 0$
- there are domestic sectors
- taxes are not reoptimized

For example, for $\lambda = 0$

$$\left.\frac{dSW}{d\mathbf{c}}\right|_{\mathbf{t}} = (\mathbf{A} - 2\mathbf{I})^{-1}(\mathbf{A} - \mathbf{I})\mathbf{A}^{-1}(\mathbf{I} - \mathbf{A})(\mathbf{A} - 2\mathbf{I})^{-1}(\mathbf{A} \cdot \mathbf{a} + \mathbf{c})$$

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For example, for $\lambda = 0$

$$\left.\frac{dSW}{d\mathbf{c}}\right|_{\mathbf{t}} = (\mathbf{A} - \mathbf{2I})^{-1}(\mathbf{A} - \mathbf{I})\mathbf{A}^{-1}(\mathbf{I} - \mathbf{A})(\mathbf{A} - \mathbf{2I})^{-1}(\mathbf{A} \cdot \mathbf{a} + \mathbf{c})$$

Conclusion

- Tax policy useful against market power
- Different fiscal treatment of domestically produced energy and foreign monopolistic supplies
- Taxing/subsidizing one source of energy requires consideration of complementarity/substitutability
- Whether two fuels are substitutes or complements is not always obvious
- Applied QL versions rich enough to provide a variety of calculable scenarios