Second-best Climate Policy

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Motivation

1st best climate policy:

- the price on carbon emissions equal to the social cost of carbon
- other instruments only to correct for other market and regulatory failures

But many countries have explicit or implicit substitutes of alternatives to fossil fuel that are not easily justified from the principles of 1st best climate policy.
This paper:

1. the carbon tax is for some reason lower than the value of emission reductions
2. although the carbon tax may be set optimally in the short run, governments cannot commit to the future carbon tax development
Model (simplest version)

Social welfare:

\[ W = F(x, y) - (p + v)x - b(y) \]

\( x \) is carbon energy with cost \( px \)
\( y \) is non-carbon energy with cost \( b(y) \)
\( F_{xy} < 0 \) (and \( F \) is increasing and strictly concave)
\( v \) is value of of emission reductions
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\( v \) is value of emission reductions

First-best:

\[ F_x(x, y) = p + v \]
\[ F_y(x, y) = b'(y) \]
Aggregate profits are

$$\pi = F(x, y) - (p + t)x - (b(y) - sy)$$

$t$ is a carbon tax
$s$ is a subsidy on non-carbon energy
Market

Aggregate profits are

\[ \pi = F(x, y) - (p + t)x - (b(y) - sy) \]

t is a carbon tax
s is a subsidy on non-carbon energy
Profit maximization gives

\[ F_x(x, y) = p + t \]
\[ F_y(x, y) = b'(y) - s \]

1st best achieved by \( t = v \) and \( s = 0 \)
Exogenous and "low" carbon tax

\[ F_x(x, y) = p + t \]
\[ F_y(x, y) = b'(y) - s \]

- \( t < v \)
- choosing \( s \) is the same as choosing \( y \)
- \( x = x(y, t) \) and \( x_y(y, t) = \frac{F_{xy}}{F_{xx}} < 0 \)
Modification: Increasing marginal costs of producing carbon energy

If \( c(x) \) instead of \( px \)

\[
-x_y = \frac{-F_{xy}}{-F_{xx} + C''} < \frac{-F_{xy}}{-F_{xx}}
\]

Implication (as we shall soon see):
The optimal subsidy is lower the higher is \( C'' \)
Social welfare:

\[ W = F(x(y, t), y) - (p + v)x(y, t) - b(y) \]

Maximizing \( W \) gives

\[ (F_y - b') + (F_x - p - v)x_y(y, t) = 0 \]
Social welfare:

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Maximizing \( W \) gives

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\]

or, using market equilibrium conditions

\[
s = (v - t)(-x_y(y, t))
\]
Extension 1: Many uses of carbon and non-carbon energy

We find

\[ s_j = \sum_i (v - t_i) \left[ -\frac{\partial x_i(y, t)}{\partial y_j} \right] \]
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\[ s_j = \sum_i (v - t_i) \left[ -\frac{\partial x_i(y, t)}{\partial y_j} \right] \]

or

\[ s_j = v \left[ -\frac{\partial \left[ \sum_i x_i(y, t) \right]}{\partial y_j} \right] - \sum_i t_i \left[ -\frac{\partial x_i(y, t)}{\partial y_j} \right] \]
Which substitutes should be subsidized?

Should all $y_j$ with $\frac{dx}{dy_j} < 0$ be subsidized?

- yes according to formal model
- but fixed administrative costs for each substitute that is subsidized
- and these costs will vary across substitutes
- therefore only some substitutes should be subsidized
Extension 2: Domestic versus foreign emissions

We find

\[ s_j = \sum_i (v_D - t_i) \left[ -\frac{\partial x_i(y, t)}{\partial y_j} \right] + v_F \left[ -\frac{\partial x_F(y, t)}{\partial y_j} \right] \]
Extension 3: Some emissions regulated by quotas

We find

\[ s_j = \sum_i (v_D - t_i) \left[ -\frac{\partial x_i(y, t)}{\partial y_j} \right] + v_F \left[ -\frac{\partial x_F(y, t)}{\partial y_j} \right] + (v_D - v_F) \left[ -\frac{\partial x_Q(y, t)}{\partial y_j} \right] \]
Second-best carbon taxes

Motivation:

- The tax on emissions from gasoline is exogenous; how should biofuels be treated?
- The tax on emissions from coal is exogenous; how should natural gas be treated?
Modified model

The units for $x$ and $y$ are chosen so both have same amount of carbon emissions per unit

Social welfare:

$$W = F(x, y) - px - b(y) - v(x + y)$$
First-best:

\[ F_x(x, y) = p + v \]
\[ F_y(x, y) = b'(y) + v \]

Market outcome:

\[ F_x(x, y) = p + t_x \]
\[ F_y(x, y) = b'(y) + t_y \]

1st best achieved by \( t_x = t_y = v \).
The optimal tax on $y$

- 1st best achieved by $t_x = t_y = v$.
- But what if $t_x$ is exogenous and $t_x < v$?
- should $t_y = v$?
- or $t_y = t_x$?
- or according so some other rule?
We find:

\[ t_y = v - (v - t_x)(-x_y(y, t)) \]

implying \( t_y < v \)

and

\[ t_y - t_x = (v - t_x)(1 + x_y(y, t)) \]

Sign of \( t_y - t_x \) is ambiguous
The special case of perfect substitutes

Gross output $\tilde{F}(\tilde{x} + \tilde{y})$; carbon emissions are $x = a_x \tilde{x}$ and $y = a_y \tilde{y}$

$$\tilde{F}(\tilde{x} + \tilde{y}) = \tilde{F}(\frac{x}{a_x} + \frac{y}{a_y}) = F(x, y)$$

Example: $x$ is coal and $y$ is natural gas; $a_x > a_y$, implying $t_y < t_x$

The optimal tax per unit of carbon from natural gas is hence lower than the exogenous tax per unit of carbon for coal.
The special case of perfect substitutes

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$$\tilde{F}(\tilde{x} + \tilde{y}) = \tilde{F}\left(\frac{x}{a_x} + \frac{y}{a_y}\right) = F(x, y)$$

It follows that

$$-x_y = \frac{a_x}{a_y} \text{ and hence}$$

$$t_y - t_x = (v - t_x) \left(1 - \frac{a_x}{a_y}\right)$$
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Example:

$x$ is coal and $y$ is natural gas; $a_x > a_y$, implying $t_y < t_x$

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Modification: Increasing marginal costs of producing carbon energy

If \( c(x) \) instead of \( px \)

\[-x_y < \frac{a_x}{a_y}\]

Hence, \( a_y < a_x \) is necessary but not sufficient for optimal \( t_y < t_x \)
Uncertain future carbon tax

- 2-period model
- government set $t = \nu$ in period 1
- but cannot commit to a tax rate for period 2
- with no uncertainty market agents would know that $t = \nu$ also in the future
- but what if the future value of $\nu$ is uncertain?
  - scientific uncertainty
  - political uncertainty
2-period model

Social welfare:

\[ W = \left\{ F(x, y) - (p + v)x \right\} - b(y) \]

period 2  period 1
2-period model

Social welfare:

\[ W = \left\{ F(x, y) - (p + v)x \right\} - b(y) \]

period 2

period 1

Market:

\[ E\pi = E \left\{ \max_x \left[ F(x, y) - (p + t)x \right] \right\} - (b(y) - sy) \]

period 2

period 1
2-period model

Social welfare:

\[ W = \left\{ F(x, y) - (p + v)x \right\} - b(y) \]

\[ = \begin{cases} \text{period 2} & \text{period 1} \end{cases} \]

Market:

\[ E\pi = E \left\{ \max_x [F(x, y) - (p + t)x] \right\} - (b(y) - sy) \]

\[ = \begin{cases} \text{period 2} & \text{period 1} \end{cases} \]

maximizing \( E\pi \) gives

\[ EF_y(x(y, t), y) = b'(y) - s \]
Scientific uncertainty

\[ EW = E \left\{ \max_x \left[ F(x, y) - (p + v)x \right] \right\} - b(y) \]

period 2

period 1
Scientific uncertainty

\[ EW = E \left\{ \max_x [F(x, y) - (p + v)x] \right\} - (b(y)) \]

Maximization of \( EW \) (where \( v \) is stochastic):

\[ EF_y(x(y, v), y) = b'(y) \]

Since \( t = v \) whatever \( v \) turns out to be, this outcome is identical to the market outcome provided \( s = 0 \).
Political uncertainty

- Current government’s valuation of future emissions is \( \nu \).
- Future government’s valuation of future emissions is \( \tilde{\nu} \), uncertain in period 1.
- Hence, the future carbon tax is \( t = \tilde{\nu} \) (uncertain in period 1).

The current government maximizes

\[
EW = E \left\{ F(x(y, t), y) - (p + \nu)x(y, t) \right\} - b(y)
\]

period 2

where \( \nu \) is known with certainty, while \( t \) is uncertain.
Maximization of $EW$ with respect to $y$ gives

$$E(v - t) \cdot E(-x_y) - \text{covar}(t, -x_y) + EF_y = b'(y)$$

The market outcome coincides with the social optimum if

$$s = E(v - t) \cdot E(-x_y) - \text{covar}(t, -x_y)$$

So $s > 0$ if

- $Et < v$ and/or
- $\text{covar}(t, -x_y) < 0.$
What do we know about \( \text{covar}(t, x_y) \)?

- generally its sign is ambiguous
- \( \text{covar}(t, -x_y) = 0 \) if \( x \) and \( y \) are perfect substitutes (and interior solution for all relevant \( \tilde{\nu} \))
- \( \text{covar}(t, -x_y) < 0 \) in the figure below

*Figure 1*
Main conclusions
Is it optimal to subsidize non-carbon energy, and if yes, by how much?

1. a subsidy is optimal if carbon energy is taxed at a rate that is too low

2. the size of the subsidy on a specific type of non-carbon energy is proportional to the difference between the value of the reduction of total carbon emissions and the loss in tax revenue due to this reduction

3. uncertainty about the future carbon tax is not necessarily an argument for subsidizing non-carbon energy, although a subsidy may be justified for some types of uncertainty