Regulating Stock Externalities

Reyer Gerlagh and Roweno J.R.K. Heijmans

Tilburg University

June 26, 2020

Literature

Recent Literature Inspired Weitzman

- We give an overview of several recent contributions inspired by Weitzman's celebrated Prices vs. Quantities

Recent Literature Inspired Weitzman

- We give an overview of several recent contributions inspired by Weitzman's celebrated Prices vs. Quantities
- Point of departure: how can standard "Prices" and "Quantities" can be improved upon in dynamic markets?

Recent Literature Inspired Weitzman

- We give an overview of several recent contributions inspired by Weitzman's celebrated Prices vs. Quantities
- Point of departure: how can standard "Prices" and "Quantities" can be improved upon in dynamic markets?
- We link three papers:
  - **Bill Pizer & Brian Prest (2020)**: Prices versus Quantities With Policy Updating. (They also add policy noise)

Recent Literature Inspired Weitzman

- We give an overview of several recent contributions inspired by Weitzman's celebrated Prices vs. Quantities
- Point of departure: how can standard "Prices" and "Quantities" can be improved upon in dynamic markets?
- We link three papers:
  - **Bill Pizer & Brian Prest (2020)**: Prices versus Quantities With Policy Updating. (They also add policy noise)
  - **Garth Heutel (2020)**: Bankability and Information in Pollution Policy.

Recent Literature Inspired Weitzman

- We give an overview of several recent contributions inspired by Weitzman's celebrated Prices vs. Quantities
- Point of departure: how can standard "Prices" and "Quantities" can be improved upon in dynamic markets?
- We link three papers:
  - **Bill Pizer & Brian Prest (2020)**: Prices versus Quantities With Policy Updating. (They also add policy noise)
  - **Garth Heutel (2020)**: Bankability and Information in Pollution Policy.
  - **Reyer Gerlagh & Roweno J.R.K. Heijmans (2020)**: Regulating Stock Externalities.

Recent Literature Inspired Weitzman

- We give an overview of several recent contributions inspired by Weitzman's celebrated Prices vs. Quantities
- Point of departure: how can standard "Prices" and "Quantities" can be improved upon in dynamic markets?
- We link three papers:
  - **Bill Pizer & Brian Prest (2020)**: Prices versus Quantities With Policy Updating. (They also add policy noise)
  - **Garth Heutel (2020)**: Bankability and Information in Pollution Policy.
  - **Reyer Gerlagh & Roweno J.R.K. Heijmans (2020)**: Regulating Stock Externalities.
- Weitzman's famous criterion to favor "Prices" over "Quantities" extends to (some) dynamic markets.

Market conditions: an umbrella term

To avoid misunderstanding, first some semantics.

- We use the term *market conditions* throughout this presentation.
- This term is open to several interpretation:
  - The value of emissions for emitters, such as market demand for products
  - The costliness of cutting down on emissions
- Market conditions are the "information gap" Weitzman (1974) calls θ in his abatement cost function.
- They are a priori unobserved by the planner.

Pizer & Prest (2020): base model

Pizer & Prest (2020), base model: 2-period **pure flow** model

- Bankable quota with updated second-period quota can **implement the first best** if market conditions and damage shocks are **perfectly correlated** between periods.

Gerlagh & Heijmans (2020), base model: 2-period **pure stock** model

- Welfare losses with updated second-period quota **only depend on second-period innovations** in market conditions if these are **imperfectly correlated** between periods

Very similar mechanism at work (but different model)

Pizer & Prest (2020): climate change

PP2020: many periods + **constant** marginal damages + information about climate damages is partly **objective**, partly **political noise**.

1. Prices deals better with Policy Noise. Tradable Quantities deals better with objective information.
2. uncertain market conditions plays **no role** in selection of optimal climate change instrument

GH2020: many periods + marg. damages depend on **cumul. emissions** + AR1 for market conditions

- Volatile market conditions order instruments:
  Endogenous Taxes $\succ$ Responsive Quota $\succ$ Updated Prices $\succ$ Updated Quantities $\succ$ Banking $\succ$ Prices/Quantities.

Climate damage structure determines optimal instrument

P2020 v GH2020: in words

(i) Similarity: banking signals private information to regulator: private information becomes public.

(ii) For constant marginal climate damages, changes in market conditions plays no role in updating regulation (PP2020). For increasing marginal climate damages, updating regulation based on (revealed) market conditions essential (GH2020).

(iii) GH2020 present a new regulatory instrument: "Endogenous Taxes". It outperforms all other instruments if marginal damages increase in cumulative emissions.

Are "Endogenous Taxes" simply Heutel's (2020) "Bankable Prices"?

Heutel (2020)

H2020 model: **flow pollutant** + imperfectly correlated market conditions

- New instrument: Bankable Prices (constant total quota)
- Finding 1: Bankable Prices always outperforms Non-Bankable Prices.
- Finding 2: With **constant** marginal damages, Bankable Prices outperforms all other instruments.

GH2020 model: **stock pollutant** + imperfectly correlated market conditions

- New instrument: Endogenous Taxes (endogenous total quota).
- Finding: With **non-constant** marginal damages: Endogenous Taxes $\succ$ Responsive Quota $\succ$ ... ($\succ$ Bankable Prices).

Climate damage structure determines optimal instrument

Summary of Comparisons = Our Contribution

(i) If *cumulative* emissions matter, innovations in market conditions should affect supply.

Summary of Comparisons = Our Contribution

(i) If *cumulative* emissions matter, innovations in market conditions should affect supply.

(ii) Ordering of instruments fundamentally different when marginal damages do, or do not, depend on *cumulative* emissions.

Summary of Comparisons = Our Contribution

(i) If *cumulative* emissions matter, innovations in market conditions should affect supply.

(ii) Ordering of instruments fundamentally different when marginal damages do, or do not, depend on *cumulative* emissions.

(iii) If *cumulative* emissions matter, flow models (even with constant marginal damage) cannot replicate the optimal regulation of stock models.

Summary of Comparisons = Our Contribution

(i) If *cumulative* emissions matter, innovations in market conditions should affect supply.

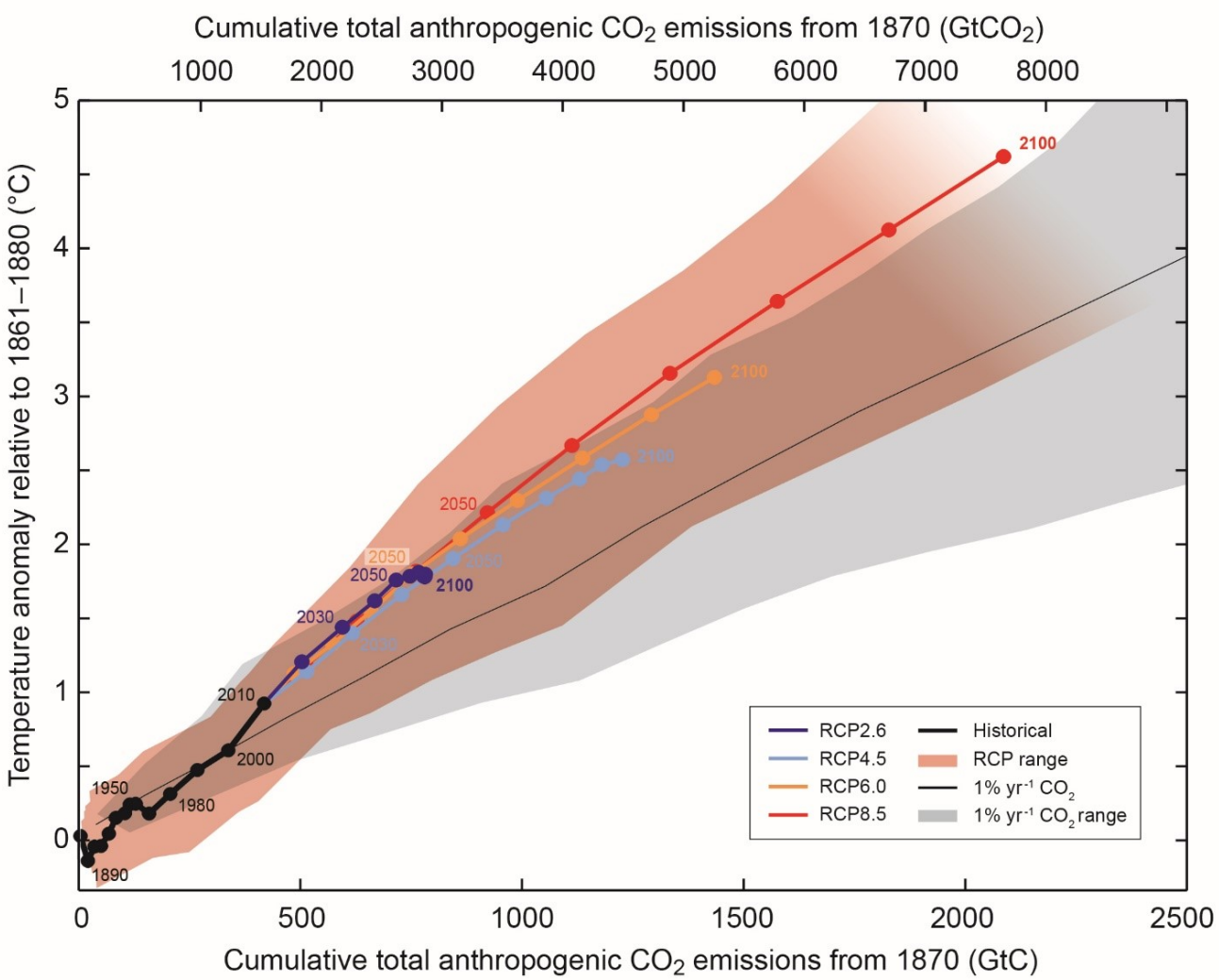
(ii) Ordering of instruments fundamentally different when marginal damages do, or do not, depend on *cumulative* emissions.

(iii) If *cumulative* emissions matter, flow models (even with constant marginal damage) cannot replicate the optimal regulation of stock models.

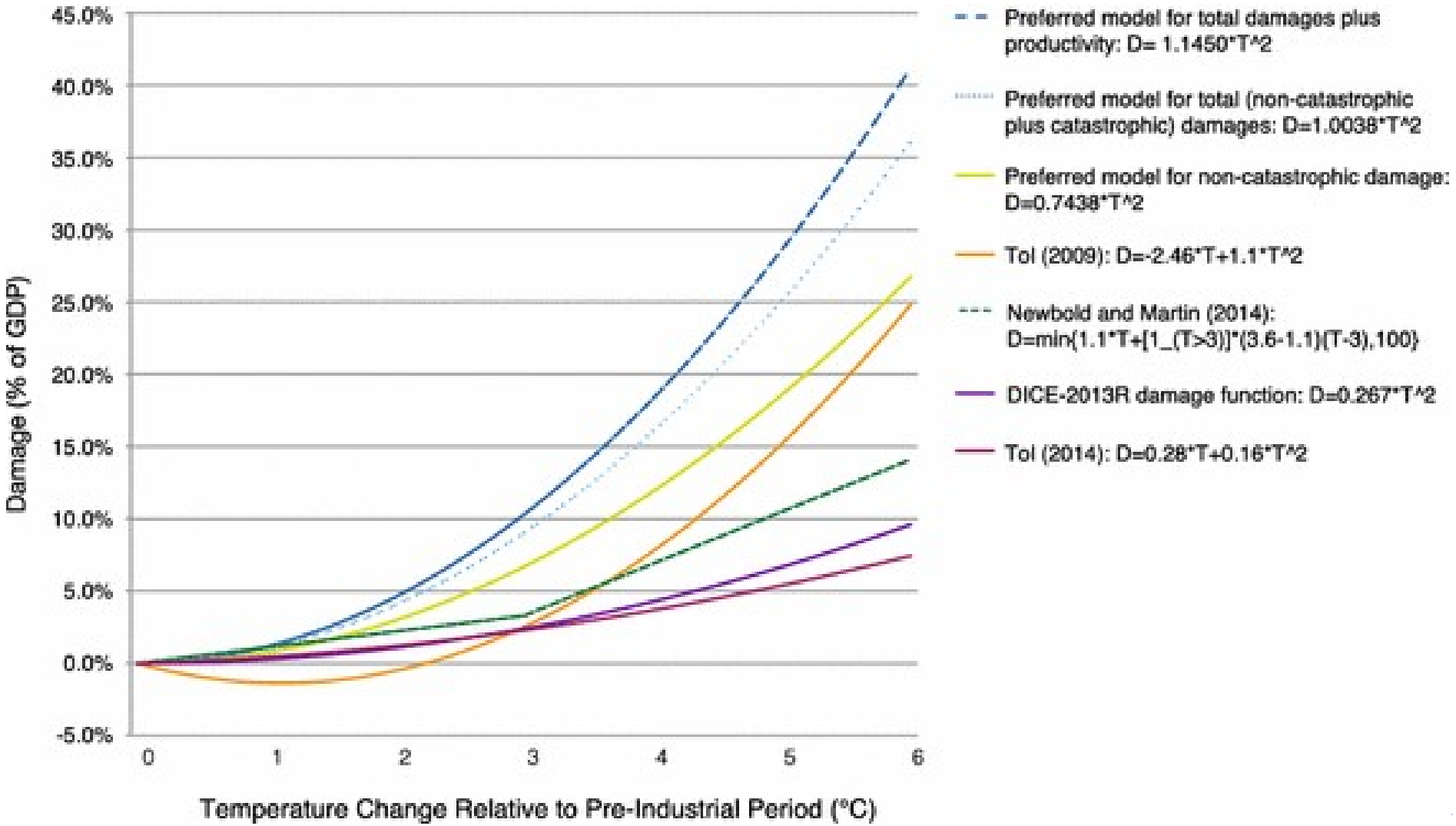
(iv) "Excessive formality" yields an altogether and strictly superior new instrument: Endogenous Taxes.

Climate Damages

Do Cumulative Emissions Matter?
Emissions → (linear) Temperature



Do Cumulative Emissions Matter?
Temperature → (convex) Damages



A Simple Model

The previous figures suggest two things:

1. Temperatures rise $\approx$ **linearly** in cumulative emissions.
2. Damages **convex** in temperatures

Karp & Traeger (2018, 2019) assess instruments for such damage structures.

There are two intuitive and convenient simplifications of this model...

Two Simplifications

- A **pure flow model** (Weitzman (2019), Pizer & Prest (2020), Heutel (2020)) neglects effects of current (past) emissions on future (current) marginal damages :

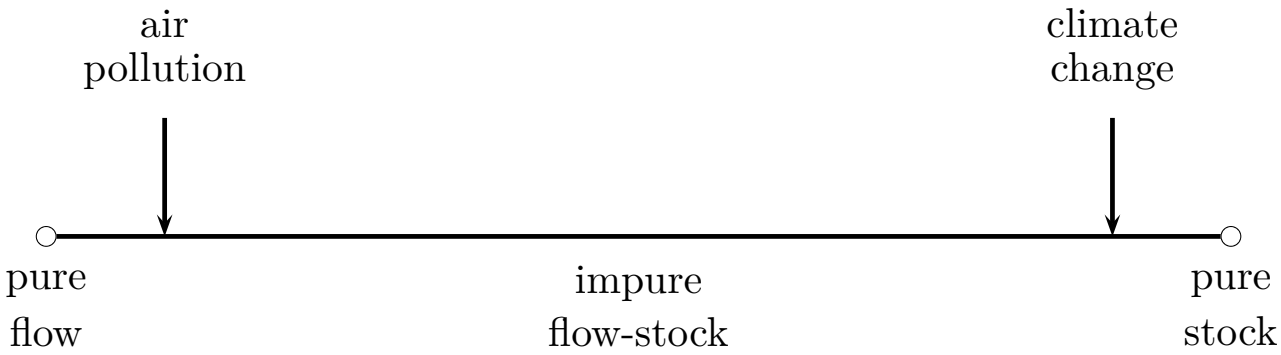
$$\sum_t \beta^t D_t^F \approx \frac{\gamma^F}{2}(E_0^2 + \beta E_1^2 + \beta^2 E_2^2 + ...)$$

- A **pure stock model** neglects effects of current emissions on current marginal damages:

$$\sum_t \beta^t D_t^S \approx \frac{\gamma^S}{2}(E_0 + E_1 + E_2 + ...)^2.$$

- Both are approximations with different optimal instruments. We believe the pure stock case is appropriate for climate change.

Pure Stock Externality (=Hotelling rule)



supported by some literature:

- Dietz and Venmans (2019, JEEM): "simple Hotelling rule is in fact appropriate [to support optimal abatement along a dynamic path]"
- Mattauch et al. (2020, AER): "The least-cost policy path [. . .] implies that the carbon price [. . .] increases at the interest rate."
- Howard and Sterner (2017, ERE): marginal damages increase by about 22 euro/tCO2 for each 1000 GtCO2 of global emissions [our calculation based on their data]

Model

Regulating Stock Externalities: Model

- 2 periods t
- Production by firms source of concave economic benefits
- Cumulative production (stock) carries convex external costs
- Regulator aims at maximizing welfare:

$$W = \underbrace{B_1(q_1;\theta_1)}_{\text{Benefits in period 1}} + \underbrace{B_2(q_2;\theta_2)}_{\text{Benefits in period 2}} - \underbrace{C(q_1+q_2)}_{\text{Costs}},$$

q_t Production/emissions in period $t \in \{1,2\}$.

θ_t Market conditions in period t, unobserved by the regulator.

Stages of the Game

1. Regulator sets its policy instrument $(t = 0)$.
2. Firms observe first-period market conditions θ_1 $(t = 1)$.
3. First-period prices p_1 and/or quantities q_1 are determined, subject to policy, such that markets clear and firms maximize expected profits $(t = 1)$.
4. Regulator implements chosen instrument rule
5. Firms observe second-period market conditions θ_2 $(t = 2)$.
6. Second-period prices p_2 and/or quantities q_2 are determined, subject to policy, such that markets clear and firms maximize profits $(t = 2)$.
7. Damages due to the stock of emissions are realized $(t = 2)$.

Regulation Characterization

We characterize regulation rules by the information available $\{\varnothing, \{\theta_1\}, \{\theta_1, \theta_2\}\}$ when choosing quantities or prices $x_1, x_2 \in \{q, p\}$:

$$\max_{x_1} \quad \mathbb{E}_{t_1}\left[\max_{x_2} \mathbb{E}_{t_2} W(q_1, q_2; \theta_1, \theta_2)\right] \tag{1}$$

$$\text{s.t.} \quad p_t = MB_t(q_t; \theta_t) \tag{2}$$

where $0 \leq t_1 \leq t_2 \leq 2$, is the timing: $(t = 0, 1, 2) \equiv \{\varnothing, \{\theta_1\}, \{\theta_1, \theta_2\}\}$

- Characterization: (x, t_1, t_2)
- Condition (2) $=$ competitive markets

Overview of Policy Instruments

- Our lens: timing (t_1, t_2) of regulation decisions vis-a-vis market information (revealing demand shocks)
- Better instruments delay decisions and/or leave these to markets

Instrument Type	Quantity-based	Price-based
Static $(x, 0, 0)$	"Quantities"	"Prices"
Dynamic $(x, 0, 1)$	"Banking"	Dynamic Taxes
Optimal Dynamic $(x, 1, 1)$	Responsive Quotas	Endogenous Taxes

Results

Responsive Quotas (q,1,1)

- The allocation is the solution to

$$\max_{q_1,q_2} \quad \mathbb{E}_1 W(q_1, q_2; \theta_1, \theta_2) \tag{3}$$

- In words: only after first-period market conditions (θ_1) are realized do you choose q_2... **and** q_1
- Our maximization problem (3) implies the following FOCs:

$$MB_1 = \mathbb{E}_1 MB_2 \tag{4}$$
$$MB_1 = MC \tag{5}$$

- Implementation? Regulator adapts second-period quotas to emissions in the first period:

$$q_2^{RQ}(\theta_1) = R(q_1^{RQ}(\theta_1)). \tag{6}$$

First Main Result – Responsive Quotas

Our first main result is that the instrument we call Responsive Quotas can, in fact, be implemented.

Theorem

Given concave benefits and convex costs, there exists a pure quantity instrument that implements the solution to maximization program (3) [$\max_{q_1,q_2} \mathbb{E}_1 W(q_1, q_2; \theta_1, \theta_2)$]. This instrument – by virtue of its timing – is strictly welfare superior among the class of pure quantity instruments. Only demand innovations ('shocks') that neither regulated nor regulating parties can foresee cause welfare losses.

Endogenous Taxes

- We label a new policy Endogenous Taxes, mathematically defined as the instrument that solves:

$$\max_{p_1,p_2} \quad \mathbb{E}_1 W(q_1, q_2; \theta_1, \theta_2) \tag{7}$$

$$\text{s.t.} \quad p_t = B_t'(q_t; \theta_t). \tag{8}$$

- Implementation? Bankable quota where regulator sets second-period auction-price in response to banking/quantities in the first period.
- Endogenous price (Note: $p_1 = p_2$):

$$p_2^{ET}(\theta_1) = H(q_1^{ET}(\theta_1)). \tag{9}$$

- Isn't that simply Heutel's Bankable Prices?

Intermezzo: Endogenous Taxes = Bankable Prices?

	Bankable Prices (Heutel)	Endogenous Taxes
Prices	$p_1 \neq p_2$	$p_1 = p_2$
Cumulative Quantities	Exogenous (fixed)	Endogenous (variable)

Second Main Result – Endogenous Taxes

Our second main result is that the instrument we call Endogenous Taxes can, in fact, be implemented.

Theorem

Given concave benefits and convex costs, there exists an instrument that implements the solution to maximization program (9) $[\max_{p_1,p_2} \mathbb{E}_1 W(q_1(p_1;\theta_1), q_2(p_2;\theta_2);\theta_1,\theta_2)]$*. This instrument – by virtue of its timing – is strictly welfare superior among the class of pure price instruments. Only demand innovations ('shocks') that neither regulated nor regulating parties can foresee cause welfare losses.*

Third Main Result – Ordering in N-period Model

Theorem

For sufficiently many number of periods, N, and marginal damages increasing in cumulative emissions, $\gamma > 0$, polices are strictly ordered $OR \succ ET \succ RQ \succ PT \succ PQ \succ CQ$. The welfare gap between the best possible allocation OR and the policies decreases with N according to

$$\mathbb{E}W^{OR} - \mathbb{E}W^{ET} = O(N^{-4}), \tag{10}$$

$$\mathbb{E}W^{OR} - \mathbb{E}W^{RQ} = O(N^{-2}), \tag{11}$$

$$\mathbb{E}W^{OR} - \mathbb{E}W^{PT} = O(N^{-1}), \tag{12}$$

$$\mathbb{E}W^{OR} - \mathbb{E}W^{PQ} = O(N^{-1}), \tag{13}$$

$$\mathbb{E}W^{OR} - \mathbb{E}W^{CQ} = O(1). \tag{14}$$

Optimal Dynamic Prices vs. Quantities

Proposition (Weitzman Extended)

In a model with linear marginal benefits β and costs γ, let there be N regulatory periods. Then

$$\mathbb{E}W^{ET} \geq \mathbb{E}W^{RQ} \iff \beta \geq \frac{\gamma}{N}. \tag{15}$$

Implication: If an ETS regulates emissions with many ('short') periods (large N), Endogenous Taxes is the best possible instrument:

(i) Price instruments strictly outperforms quantity instruments

(ii) Endogenous Taxes strictly outperform all possible price instruments

Summary

Conditional on

1. the social costs of carbon rises with cumulative emissions, and
2. many regulatory periods available, and
3. the demand for allowances (value of emissions) as the main source of uncertainty **that is resolved** within the regulatory time-frame,

Endogenous Taxes is the best instrument.