Market Design in Cap and Trade Programs: Permit Validity and Compliance Timing

Stephen P. Holland – University of North Carolina at Greensboro

with

Michael R. Moore – University of Michigan

Two dimensions of cap & trade

- Flexibility in *permit validity* across time (or space) increases trading opportunities
  - Each permit is valid for a certain time (location and amount)
  - More trades lead to lower abatement costs, but marginal damages may not be equal across trades
- *Compliance timing*, i.e., "true-up," is when emissions are totaled and reconciled with permit holdings
  - Most programs (e.g., the SO_2 market) have quarterly emissions reporting and annual true-up
  - RECLAIM has annual true-up at two different times of the year
  - RGGI delays true-up by 3 (4?) years
- Is flexibility in compliance timing (true-up) a substitute for flexibility in permit validity?
  - Can delayed compliance smooth cost shocks?

Compliance timing and true-up in electricity (?!?)

- The electricity billing procedure
  - Each house has a (tamper-proof) meter \
  - Meter is read monthly / — Emissions reporting
  - Bills mailed monthly \
  - Payment due 30 days later / — True-up

- How apt is the analogy?
  - Electricity bills paid in dollars, but emissions trading "bill" paid in permits

Table 1. Compliance Timing and Permit Validity in Cap-and-Trade Programs

Program (pollutant)	Compliance Timing		Permit Banking		Permit Borrowing		Spatial Limits Within Program
	Emissions Reporting[1]	Permit True Up	Explicitly Allowed?[2]	Qualifications[3]	Explicitly Allowed?[2]	Qualifications[3]	
Acid Rain Program (ARP) (sulfur dioxide)	quarterly	annual	yes	unlimited	no	none	no
NOx Budget Program (NBP) (nitrogen oxides)	quarterly	annual	yes	quantity tax on use of banked permits above a specified threshold	no	none	no
Clean Air Interstate Rule (CAIR) (nitrogen oxides and sulfur dioxide)	quarterly	annual	yes	unlimited	no	none	two NO_x markets in eastern U.S.
Cross-State Rule (CSAPR) (nitrogen oxides and sulfur dioxide)	quarterly	annual	yes	unlimited	no	none	two NO_x markets; two SO_2 markets; variability limits on state emissions
RECLAIM (nitrogen oxides and sulfur dioxide)	quarterly	overlapping annual compliance cycles	no	limited ability to bank due to overlapping permit cycles	no	limited ability to borrow due to overlapping permit cycles	inland permits not valid in coastal zone
EU ETS (greenhouse gases)	annual	annual	yes	banking not allowed from first phase to second phase	no	unlimited borrowing from the next year's vintage of permits	no
Waxman-Markey (WM) (greenhouse gases)	quarterly	annual	yes	unlimited	yes	borrowing from the next year's vintage of permits; borrowing with interest from vintage years +2 to +5	no
RGGI (greenhouse gases)	quarterly	3-year period	yes	unlimited	no	unlimited borrowing within 3-year compliance period	no
California AB 32 (AB 32) (greenhouse gases)	annual	3-year period with 30% annual down payment	yes	unlimited	no	unlimited borrowing within 3-year compliance period	includes electricity imported to California

Modeling permit validity and compliance timing

- All permits in vintage j are perfect substitutes: p_{jt}
- Abatement costs: $c_{it}(e_{it}; \theta_{it})$ determine demand d_{ijt}
- Compliance time function: $\phi_i(t) \geq t$
  - e.g., RGGI $\phi_i(1) = 3, \phi_i(2) = 3, \phi_i(3) = 3$
- Compliance factor: α_{ijt} so $e_{it} \leq \sum_j \alpha_{ijt} d_{ijt}$

$$V_{it}(\bar{e}_{it}; \theta_{it})$$
$$= \min_{e_{it} d_{ijt}} c_{it}(e_{it}; \theta_{it}) + \sum_{t' \in \phi_i^{-1}(t)} \sum_j p_{jt} d_{ijt'} + \beta E_t V_{it+1}(\bar{e}_{it+1}; \theta_{it+1})$$

Solving the model

$$V_{it}(\bar{e}_{it};\theta_{it})$$

$$= \min_{e_{it}d_{ijt}} c_{it}(e_{it};\theta_{it}) + \sum_{t'\in\phi_i^{-1}(t)} \sum_j p_{jt} d_{ijt'} + \beta E_t V_{it+1}(\bar{e}_{it+1};\theta_{it+1})$$

$$= \min_{e_{it}} c_{it}(e_{it};\theta_{it}) + \sum_{t'\in\phi_i^{-1}(t)} \left\{ \min_j \left\{ \frac{p_{jt}}{\alpha_{ijt'}} \right\} \bar{e}_{it+1}^{t'} \right\} + \beta E_t V_{it+1}(\cdot,\cdot)$$

FOCs:

$$-c'_{it}(e_{it};\theta_{it}) = \min_j \left\{ \frac{p_{jt}}{\alpha_{ijt}} \right\}$$

$$-c'_{it}(e_{it};\theta_{it}) = \beta^{\phi_i(t)-t} E_t \min_j \left\{ \frac{p_{j\phi(t)}}{\alpha_{ijt}} \right\}$$

Optimal abatement

- For prompt compliance:
  - $-c'_{it}(e_{it};\theta_{it}) = \min_j \left\{\frac{p_{jt}}{\alpha_{ijt}}\right\}$
  - marginal abatement cost equals cheapest current permit price
- For delayed compliance:
  - $-c'_{it}(e_{it};\theta_{it}) = \beta^{\phi_i(t)-t} E_t \min_j \left\{\frac{p_{j\phi(t)}}{\alpha_{ijt}}\right\}$
  - marginal abatement cost equals discounted, expected cheapest future permit price

Compliance Invariance

- Result 1: If $p_{jt} = \beta^{t'-t} E_t p_{jt'}$ and $E_t \min_j \left\{\frac{p_{jt'}}{\alpha_{ijt}}\right\} = \min_j \left\{\frac{E_t p_{jt'}}{\alpha_{ijt}}\right\}$, then abatement is invariant to delayed compliance.
- "Proof":
$$-c'_{it}(e_{it};\theta_{it}) = \beta^{\phi_i(t)-t} E_t \min_j \left\{\frac{p_{j\phi(t)}}{\alpha_{ijt}}\right\} = \min_j \left\{\frac{p_{jt}}{\alpha_{ijt}}\right\}$$
- Intuition:
  - Prompt compliance: marginal abatement cost equals current permit price
  - Delayed compliance: marginal abatement cost equals discounted, expected future permit price

Do sufficient conditions hold?

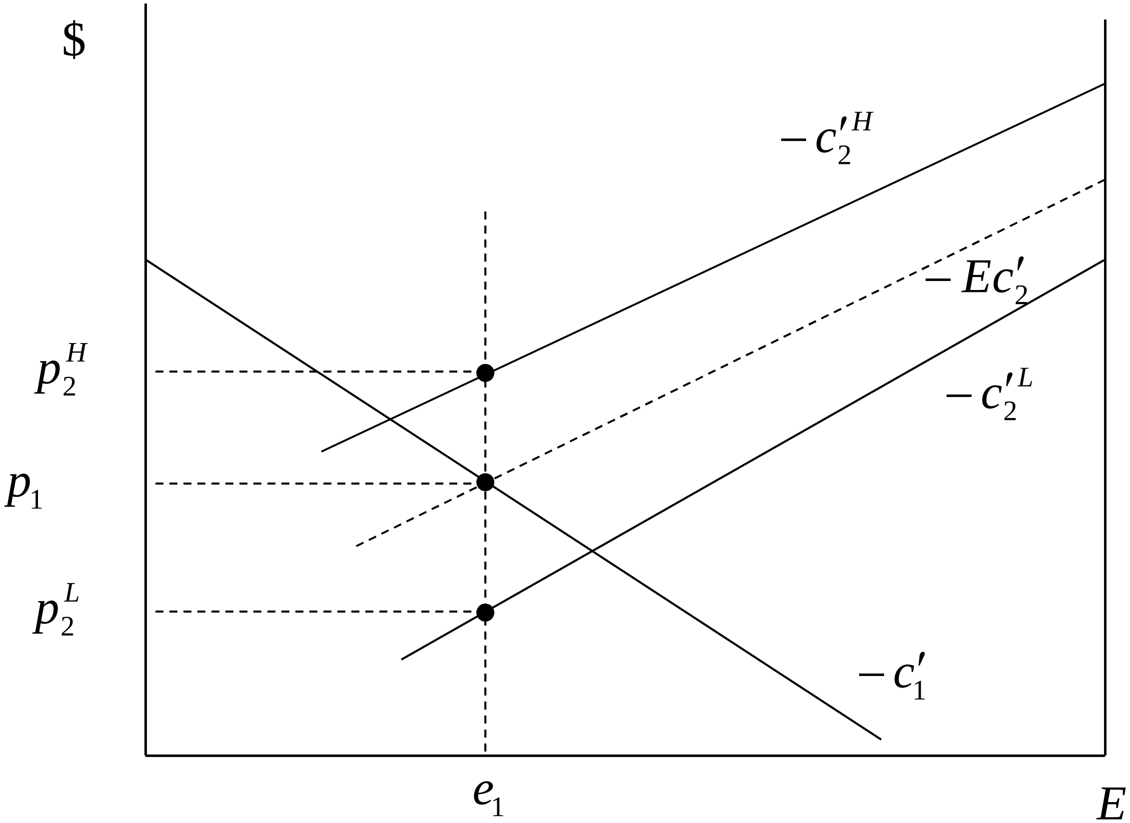
- First condition: $p_{jt} = \beta^{t'-t} E_t p_{jt'}$
  - This arbitrage condition holds if permits held and used in both periods
  - Might fail if *i*) delayed permit allocation or *ii*) price cap with reserve fund
- Second condition: $E_t \min_j \left\{ \frac{p_{jt'}}{\alpha_{ijt}} \right\} = \min_j \left\{ \frac{E_t p_{jt'}}{\alpha_{ijt}} \right\}$
  - Technical condition which holds in all relevant markets

Expected compliance costs and the variance of compliance costs

- Corollary 1: Under sufficient conditions, present value expected compliance costs are invariant to delayed compliance. The variance of compliance costs increases with delayed compliance.

- Intuition:
  - Current permit price equals expected future price, so expected compliance costs are equal. (in present value)
  - With delayed compliance, compliance price is current price plus "noise", i.e., variance increases.

Compliance timing in two periods



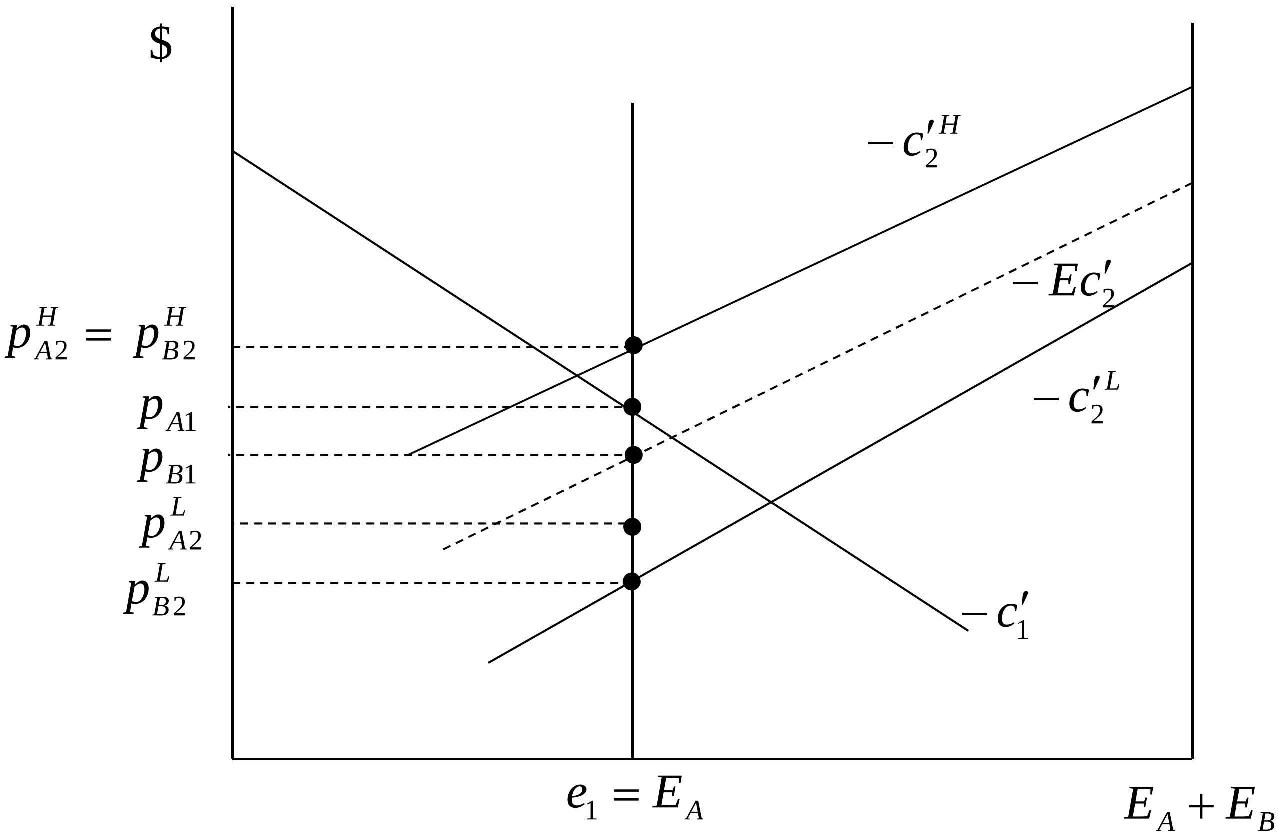
- Equilibrium invariant to compliance timing
  - Delayed compliance costs: $p_2^H E$ or $p_2^L E$
  - Prompt compliance costs: $p_1 e_1 + p_2^H e_2$ or $p_1 e_1 + p_2^L e_2$

Non-unique and degenerate prices

- Result 2: Equilibrium prices not unique and may require "degenerate" prices. Non-unique and degenerate prices are only relevant with delayed compliance.
  - "Degenerate" prices not determined by supply & demand

- Intuition from a single-period market (w/ 2 years)
  - p_1 equals marginal abatement cost at cap
  - p_2 can be p_1 plus "noise" (since supply & demand perfectly inelastic)
  - Note: p_2 only matters for delayed compliance

Non-unique and degenerate prices: banking without borrowing



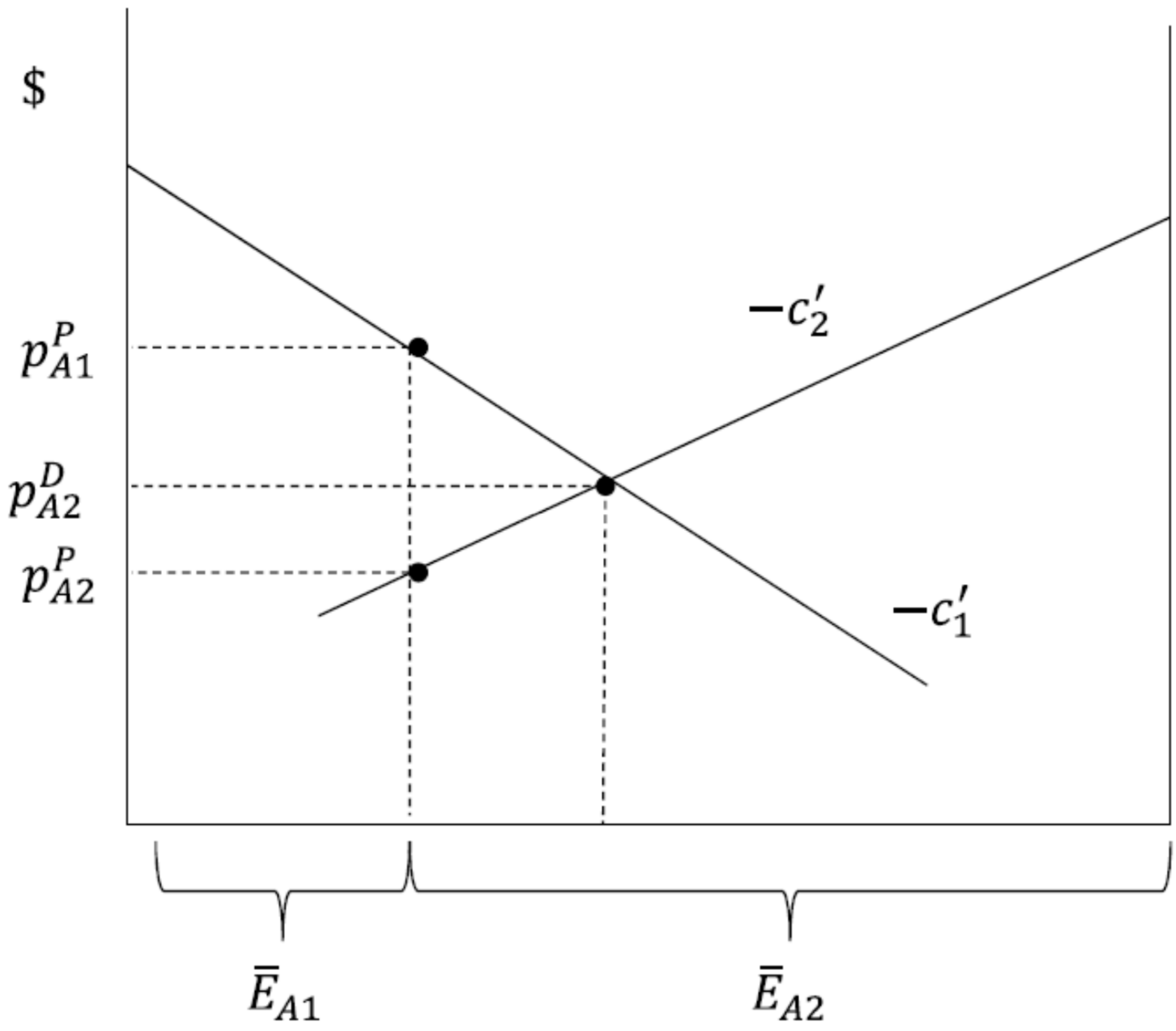
Invariance fails: Compliance timing and delayed permit allocations

- Intuition: Consider 2-year program with one permit vintage and most permits allocated in second year

- With prompt compliance, facilities would like to use "unallocated" permits in first year but cannot.
  - $p_1 > \beta p_2$

- With delayed compliance, facilities can use any permits for first- or second-year obligation
  - $p_1 = \beta p_2$

Delayed compliance can smooth "shock" from delayed allocations



Invariance fails: Compliance timing and price caps with a reserve fund

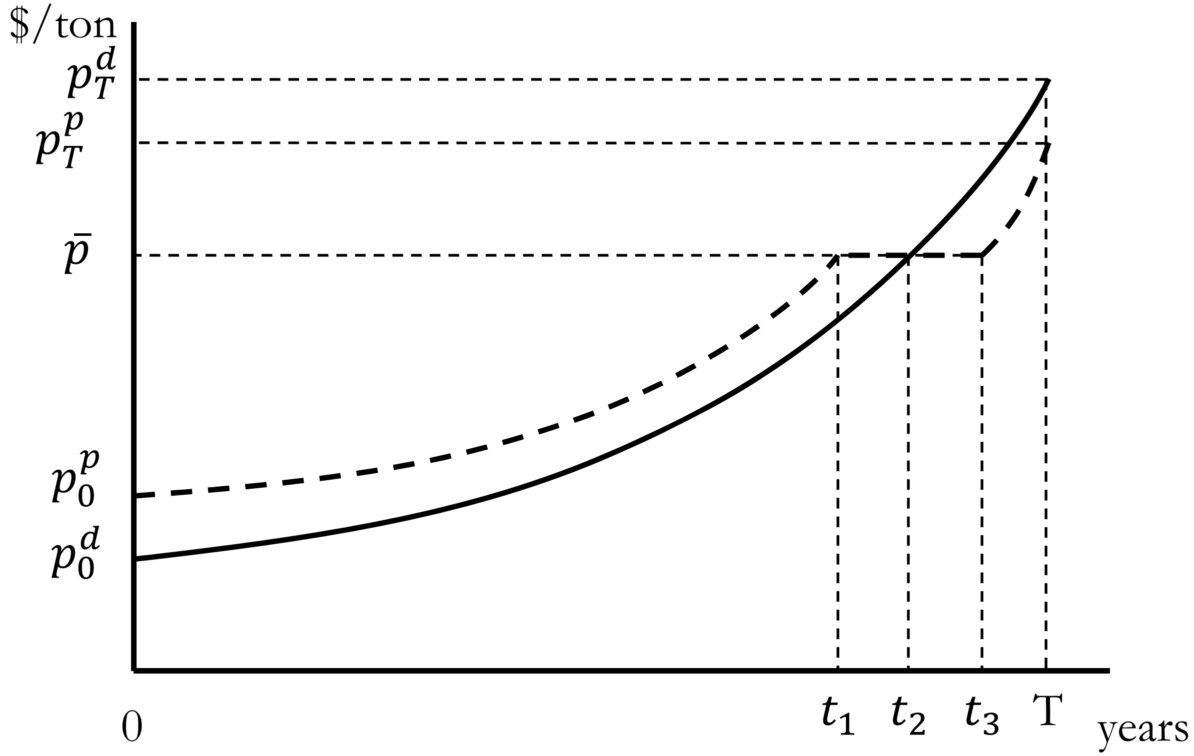
- Suppose \$100 price cap is supported by a reserve fund and most permits in reserve fund

- With prompt compliance, facilities set marginal abatement costs equal to \$100

- With delayed compliance, facilities set marginal abatement costs equal to β\$100
  - Emissions higher with delayed compliance

Delayed compliance invites a "speculative attack" on reserve fund

- Hasegawa & Salant show compliance variance where a price cap is supported by a reserve fund



Summary

- Under sufficient conditions, delayed compliance
  - doesn't affect abatement,
  - doesn't affect expected compliance costs,
  - increases variance of compliance costs, and
  - may rely on non-unique or "degenerate" permit prices.

- Delayed compliance can affect abatement if
  - permit allocation is delayed or
  - a price cap is implemented with a reserve fund.

How should we think about compliance timing?

- Delayed compliance does not smooth cost shocks

- Balancing costs and benefits of frequent compliance
  - Costs: more frequent bill payment
  - Benefits: i) avoids bankruptcy complications, ii)builds administrative capacity, iii) keeps costs salient, iv) resolves disputes early, v) regulated cost recovery unambiguous, vi) reduces variance of compliance costs, and vii) avoids non-unique and "degenerate" prices