Cost Uncertainty in Experimental Emissions Markets and Price Control

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FAERE Workshop
Brest 2017

Motivation

- Concerns about price level/ price volatility
- Uncertainty about abatement costs
- Need for cost containment measures

Source: sandbag.org.uk

Quantity based mechanisms (Cap-and-trade programs) vs. Price based mechanisms (Taxes)

↓

<u>Hybrid Mechanisms</u>

(Pizer, 2002; Fankhauser et al., 2010)

- Preserve allocative market efficiency
- Control for the price risk
- Strong price signal

Objectives

- Price Control Mechanisms – Induce more elasticity into the supply

  - Mitigate the effects of shocks in the cost of pollution

  - Maintain in the market the right carbon price

Experimental Tool – Laboratory Test Bed for the Market Institution (Chen and Ledyard, 2008)

- Test effectiveness of hybrid based policies

- Permit Transfer Mechanism (PT)
  Banking and Borrowing permits

- Permit Transfer Adjustable Supply Mechanism (PTAS)
  (Banking and Borrowing + Supply Rule (Newell et al. , 2005))

- Reduction of Price Volatility
- Convergence towards the target price
- Emissions Evolution

Theoretical Setting

Baseline

$$\max_{d_{i,t}} \sum_{t=0}^{T} (1+\mu)^{-1} E_t[\, \mathrm{p}_y \overline{y}_{i,t} - \bar{C}_i(\overline{y}_{i,t}) - \mathrm{C}_i(d_{i,t}, \theta_t) - pa_t(-g_i + \mathrm{F}_i(\overline{y}_{i,t}, \mathrm{d}_{i,t}))]$$

Permit Transfer (PT)

$$\mathrm{V}_t(\mathrm{B}_{i,t}, \Omega_{i,t}) = \max_{d_{i,t}, B_{i,t+1}} [\mathrm{p}_y \overline{y}_{i,t} - \mathrm{C}_i(\overline{y}_{i,t}) - \mathrm{C}_i(d_{i,t}, \theta_t) - pa_t(-g_i + \mathrm{F}_i(\overline{y}_{i,t}, \mathrm{d}_{i,t}) - \mathrm{B}_{i,t} + (\mathrm{B}_{i,t+1}/R_t))] + (1+\mu)^{-1} E_t[V_{t+1}(B_{i,t+1}, \Omega_{i,t+1})] + \lambda_t (\mathrm{B}_{i,t} + \mathrm{g}_i + \mathrm{a}_i - \mathrm{F}_i(\overline{y}_{i,t}, \mathrm{d}_{i,t}) - \alpha)$$

$$\longrightarrow \quad p_t = \lambda_t + (1+\mu)^{-1} R_t E_t(p_{t+1})$$

Permit Transfer with an Adjustable Supply (PTAS)

Supply Rule (Newell et al., 2005)

$$g_0 = g_0^*$$

$$g_{t+1} = g_{t+1}^* - R_t[d_t(pa_t^*; \theta_t) - d_t(pa_t^*; 0)],\ t \geq 0$$

Experimental Design and Procedures

- 24 sessions/ 8 per treatment / 15 periods / Groups of 6 players

- 144 subjects/ 48 subjects in each treatment:

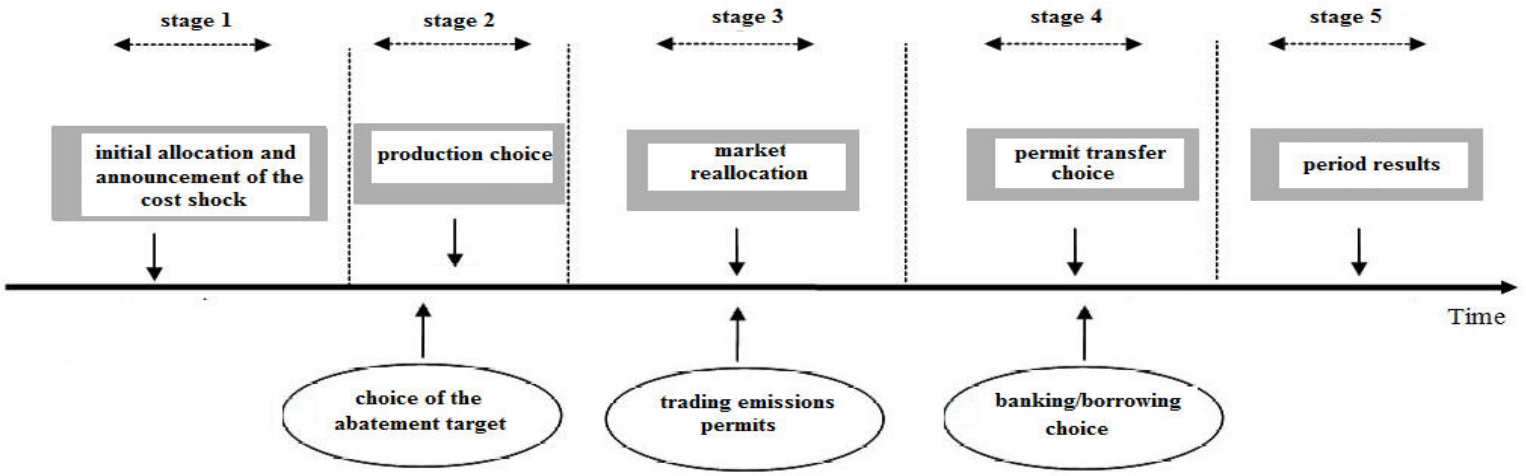
  - Baseline: fixed initial supply
  - Permit Transfer (PT): banking and borrowing + fixed initial supply
  - Permit Transfer Adjustable Supply (PTAS): banking and borrowing + variable initial supply

Game Intuition:

- Each player has to produce a certain amount of a good (abatement units)
- Initial provision of coupons (emissions permits) and cash
- Possibility to avoid production costs by holding coupons/profit maximization

Compliance Rule: Coupons + Production >= Production Target

Experimental Design



- Stage 1: Announcement
  - production target
  - initial cash
  - initial coupon provision
  - production cost level

Units	Production Costs
unit 1	68
unit 2	76
unit 3	84
unit 4	92
unit 5	100
unit 6	108
unit 7	116
unit 8	124
unit 9	132
unit 10	140
unit 11	148
unit 12	156
unit 13	164
unit 14	172
unit 15	180
unit 16	188
unit 17	196
unit 18	204
unit 19	212
unit 20	220

You have HIGH production costs in this period

Initial Cash Provision: 2200.
Initial coupon provision :5.
Production target : 20 .

OK

Experimental Design

- Stage 2: Production Choice

Units	Production Costs
unit 1	68
unit 2	76
unit 3	84
unit 4	92
unit 5	100
unit 6	108
unit 7	116
unit 8	124
unit 9	132
unit 10	140
unit 11	148
unit 12	156
unit 13	164
unit 14	172
unit 15	180
unit 16	188
unit 17	196
unit 18	204
unit 19	212
unit 20	220

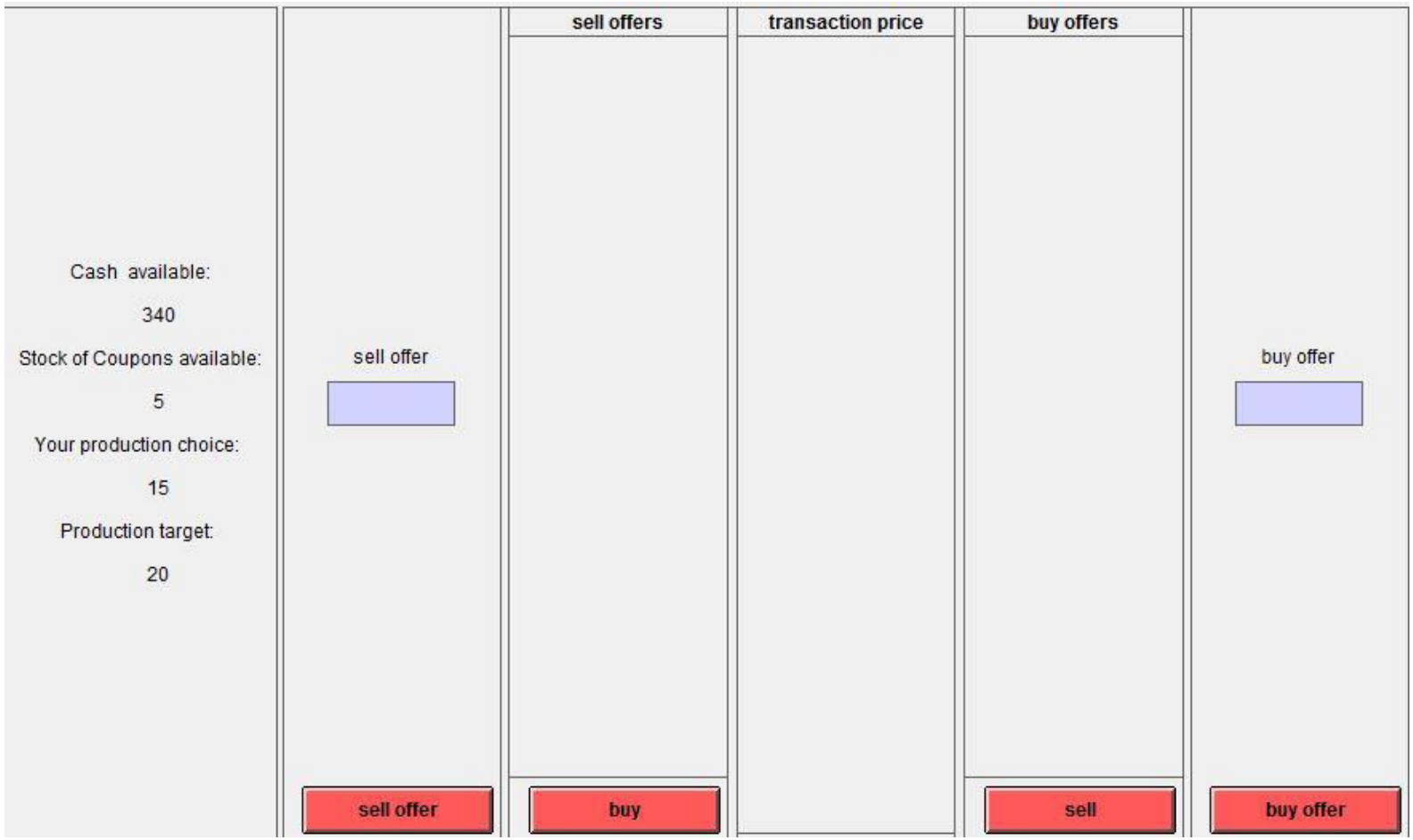
Initial Cash Provision : 2200.
Initial Coupon Provision : 5.
Production target : 20 .

Which is your production choice :

production choice

Experimental Design

- Stage 3: Coupon Market : - continuous double auction market structure



Experimental Design

- Stage 4: Permit Transfer Decision

Units	Production Costs
unit 1	68
unit 2	76
unit 3	84
unit 4	92
unit 5	100
unit 6	108
unit 7	116
unit 8	124
unit 9	132
unit 10	140
unit 11	148
unit 12	156
unit 13	164
unit 14	172
unit 15	180
unit 16	188
unit 17	196
unit 18	204
unit 19	212
unit 20	220

Initial Cash Provision: 2200
Initial coupon provision :5.
Production target : 20 .

How many coupons do you want to transfer :

borrow save

Experimental Design

- Stage 5: Period Results

Units	Production Costs
unit 1	68
unit 2	76
unit 3	84
unit 4	92
unit 5	100
unit 6	108
unit 7	116
unit 8	124
unit 9	132
unit 10	140
unit 11	148
unit 12	156
unit 13	164
unit 14	172
unit 15	180
unit 16	188
unit 17	196
unit 18	204
unit 19	212
unit 20	220

You are compliant to your production target

Stock of coupons available: 5
Production choice : 15
Production target: 20

Number of non-compliance periods : 0

Initial Cash Provision : 2200
Production Costs : 1860
Profit on the market : 0.

Profit of the period: 340.
Total Profit : 340.

OK

Main Predictions

Hypothesis 1: In the **Baseline** the relation between cost shocks and permit prices is stronger without permit transfer possibilities across periods, that would result into higher price volatility.

Hypothesis 2: In the **Permit Transfer (PT)** treatment, we should observe reduced price volatility and a more stable price path between and within periods with respect to the Baseline.

Hypothesis 3: In the **Permit Transfer Adjustable Supply (PTAS)** treatment we should observe an increased permit price control effectiveness. Besides stabilizing the price path, the mechanism induces convergence towards the targeted equilibrium price.

Results – Average Prices

Result 1: a) Average prices decrease over periods (no end of session redemption value).

b) Average prices are significantly different in the PT and the PTAS with respect to the Baseline.

c) In the Baseline and the PT treatment, prices are significantly different from the equilibrium target price. In the PTAS treatment prices significantly converge towards the equilibrium price target.

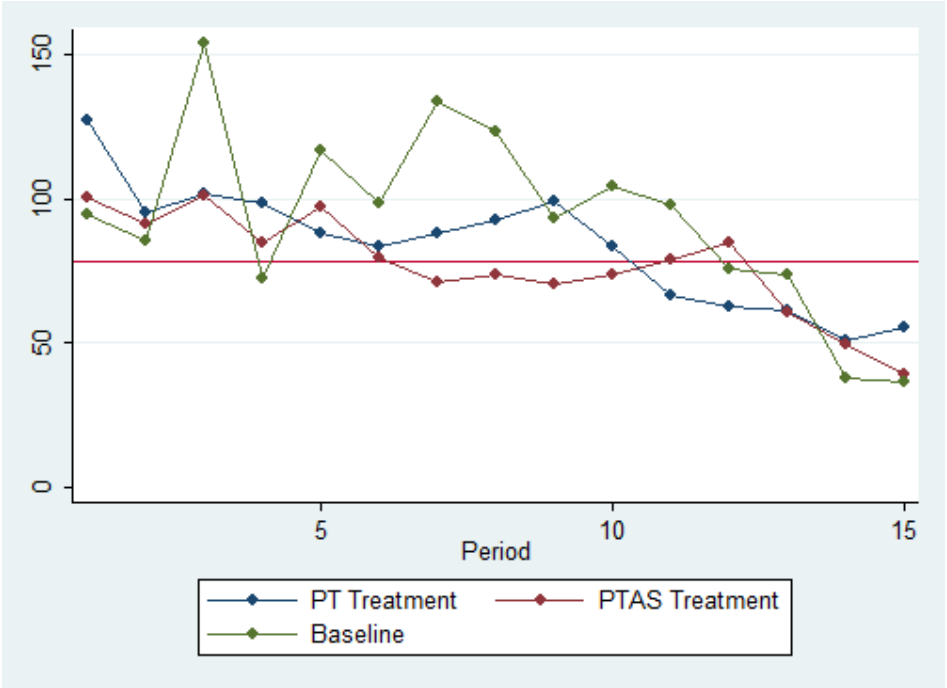


Figure. Mean permit prices evolution across all periods for all treatments

	Baseline			Permit Transfer Treatment			Permit Transfer with Adjustable Supply		
	Periods 1-2	Periods 3-12	Periods 12-15	Periods 1-2	Periods 3-12	Periods 12-15	Periods 1-2	Periods 3-12	Periods 12-15
Average Permit Price	107.98	89.27	50.63	107.51	83.32	55.67	99.74	80.30	50.92
	(46.13)	(41.65)	(44.32)	(53.93)	(27.89)	(19.34)	(28.34)	(9.83)	(17.19)

Results – Price Volatility/ Dispersion/ Volume Traded

Result 2. Volatility is significantly reduced in the PT and the PTAS treatments with respect to the Baseline condition. There is no significant difference between the two price control mechanisms.

Result 3. Dispersion is significantly reduced in the PT and the PTAS treatments with respect to the Baseline condition. There is no significant difference between the two price control mechanisms.

Result 4. Traded Volume is significantly increased in the PT and the PTAS treatments with respect to the Baseline condition. There is no significant difference between the two price control mechanisms.

Results – Price Analysis

Dependent variable	Permit price	Price Volatility	Price dispersion	Volume Traded
Constant	99.337***	73.316***	24.563***	4.087***
	(8.471)	(11.263)	(5.188)	(.635)
PT	-14.123	-55.898***	-14.628**	3.896***
	(11.711)	(12.164)	(6.041)	(1.496)
PTAS	-18.406*	-56.791***	-16.907***	5.559***
	(10.279)	(11.564)	(5.245)	(1.195)
Shock Magnitude	.646***	.203**	.029	-.029***
	(0.114)	(0.093)	(0.035)	(.011)
Periods 1-2 *Baseline	-2.05	-32.348**	-2.204	.210
	(16.691)	(12.694)	(8.511)	(.724)
Periods 1-2 *PT	35.752**	57.949**	1.789	-2.294**
	(17.819)	(26.563)	(4.089)	(1.022)
Periods 1-2 * PTAS	17.340**	23.971***	7.033***	-4.005***
	(8.201)	(8.469)	(2.506)	(1.278)
Periods 13-15 *Baseline	-48.044***	-27.252	-8.837**	-.388
	(7.609)	(21.861)	(3.53)	(.871)
Periods 13-15 *PT	-35.766***	-1.605	-4.537	1.931***
	(8.683)	(5.568)	(2.685)	(.735)
Periods 13-15 * PTAS	-19.831**	5.038	6.555***	1.928
	(9.989)	(4.048)	(2.262)	(1.601)
Observations	360	360	360	360
Groups	24	24	24	24

Results - Emissions

Result 5. **Mean Aggregate Emissions** are significantly higher in the PT and the PTAS treatment with respect to Baseline condition and increase across periods.

Result 6. **Emissions Volatility** is significantly higher in the PT and the PTAS treatment with respect to Baseline condition.

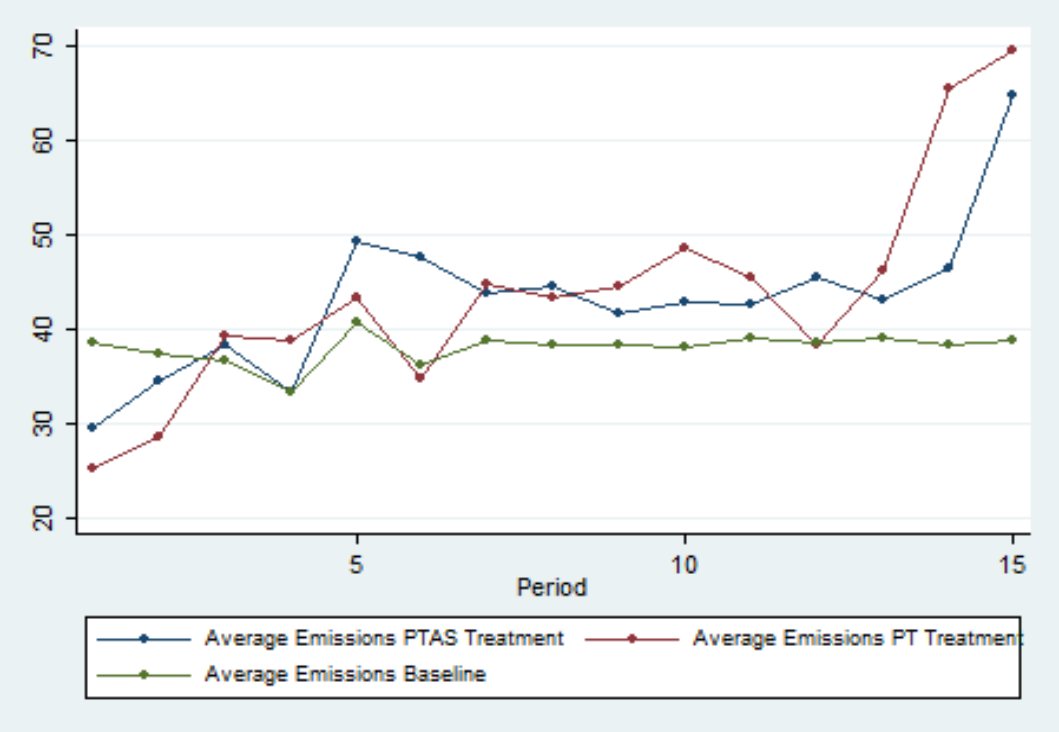


Figure. Mean aggregate emissions evolution

Results – Emissions Analysis

Dependent variable	Aggregate Emissions		Emissions Volatility	
	Coefficient	St. error	Coefficient	St. error
Constant	38.012***	1.489	2.837***	.529
PT	4.881	7.148	7.487***	1.432
PTAS	4.056	2.037	16.450***	1.765
Shock Magnitude	.041	0.032	-.017	.028
Periods 1-2 *Baseline	.952	.743	-.218	.736
Periods 1-2 *PT	-10.149*	4.969	12.479***	3.638
Periods 1-2 * PTAS	-14.976**	3.868	8.147*	4.578
Periods 13-15 *Baseline	1.005	.862	-1.257*	.671
Periods 13-15 *PT	8.068	5.678	5.387**	1.797
Periods 13-15 * PTAS	18.987**	2.745	-.796	2.519
Observations	360		360	
Groups	24		24	

Table. Linear Random Effects Models of Emissions and Emissions Volatility

Conclusions

- Experimental emissions trading markets – Price control mechanisms

Permit Transfer (PT) mechanism allowing for banking/borrowing permits stabilizes the price path between and within periods.

Permit Transfer with an Adjustable Supply Rule (PTAS) also settles the price path around the targeted price level.

- Limitations - banking/borrowing restrictions

- target price/ equilibrium prediction efficiency trade-off