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The effect of Sanction Design on Investment Decision and Compliance Level in a Tradable Permit Market

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Motivation

- Sanction are an important element to ensure that the emission reduction target is achieved → environmental effectiveness of a tradable permit market or ETS
- Sanction types : Fixed Penalty Rate, Make-Good Provision, and Mix of both
- Existing literature
  - Different audit probabilities : Malik (1990), Stranlund (2007)
  - Dynamic/ targeted enforcement : Harrington 1988, Cason Gangadharan (2006)
  - Compliance incentives in Kyoto Protocol: Nentjes & Klaasen (2004)
- In theory, when the penalty rate is higher than the market price of permits and Marginal Abatement Costs firms will choose to be compliant by buying permits on the market or reducing emissions.
- Is that true? Design and level of penalty does not matter?

Method

- Existing emissions trading programs use different sanction forms, but very little information is known about their effects on market performance
- Carbon Pollution Reduction Scheme in Australia proposes the use of a fixed penalty rate (fine) plus a make-good provision. However, the design also includes a price cap of $40 (increased by a real rate of 5% annually) at the beginning
- In practice, it is difficult to know the true value of the equilibrium permit price; thus also more difficult in determining the appropriate level of penalty.
- Australia CPRS proposes link of penalty to average auction price which is rarely used in the existing ETS.
- No study on different sanction forms & their levels in ETS

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Research Question

- Focus of sanction design:
  - Sanction types : Fixed Penalty Rate (FPR), Make-Good Provision (MGP), and Mixed of both
  - Sanction level: low and high level
- Research questions:

  what are the effects of sanction type and level on market performance
  - Compliance strategy: Irreversible investment decision or permit holding(buying permits)
  - Auction and trading prices, standard deviation of prices
  - Compliance level
  - Efficiency

Experimental Design

Stages in Sanction Design Experiment

- Initial Allocation of permits: ascending clock auction
- Permit Trading: continuous double auction, posted offer
- Investment decision (in Sub Period 1 only) → automatic compliance, required number of permit is zero
- Compliance check: whether subject hold permits as required

Sanction enforcement

- Fixed Penalty Rate: Immediate deduction for violation at the end of each sub period
- Make-Good Provision:
  - Non-compliance in sub period 1: quantity compensation of the missing licenses
  - Non-compliance in sub period 2: loss of total revenue in that sub period

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Treatment overview

Sanction form	Sanction Level	
	Low Level	High Level
Fixed Penalty Rate (FPR)	1.2 Equilibrium Price **Treatment 1**	3 x Equilibrium Price **Treatment 2**
Make-Good Provision (MGP)	Ratio 1:1 **Treatment 3**	Ratio 3:1 **Treatment 4**
Mixed of FPR & MGP	Low Make-Good Provision and Penalty Rate Linked to Auction (1.2 x Auction Price) Treatment 5	

- Programming of the computer interface using University of Zurich's Z-Tree experimental software
- 2 experiment tasks in each session:
  - Risk preference assessment with Holt & Laury (2002) lottery choice decision
  - Sanction design experiment
- Control questions and one Practice round

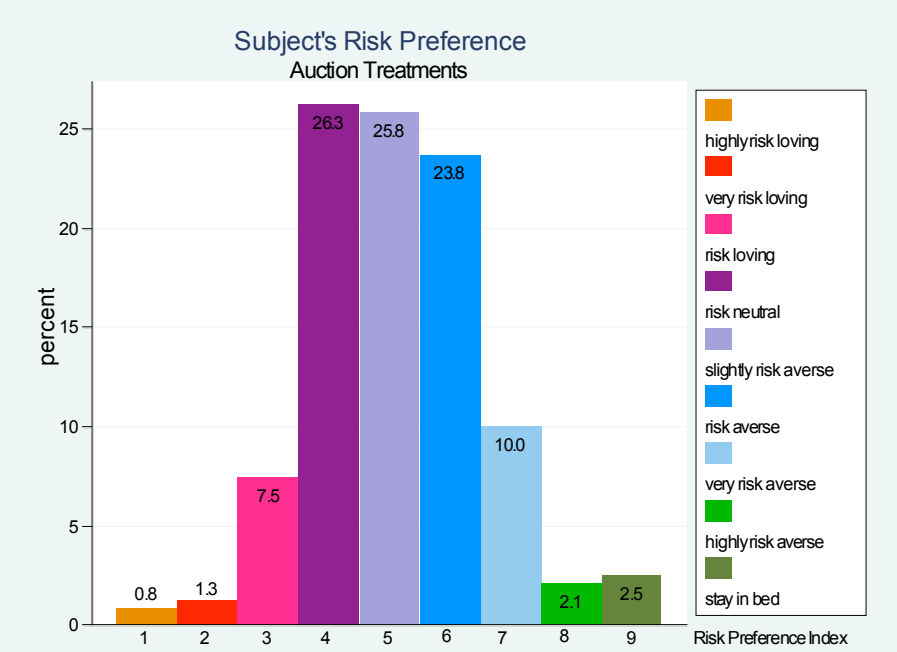
Key Market Design

- Period: 6 repeated rounds, each with 2 Sub Periods → 12 periods
- Players:
  - 8 identical firms which differ only in Marginal Abatement Cost (MAC) → 4 high MAC firms (net buyer) & 4 low MAC firms (net seller)
  - same structure of MAC in each round {20,55} for all, shuffled for each subject
  - Same endowment across players (same Total Revenue) and in each round
  - Fixed emission levels in each sub period (20 units)
- Information structure:
  - MAC, investment decision, compliance status are private information
  - Sanction design, permit supply, distribution of MAC, Total Revenue are common information
- Banking and borrowing are not allowed (permit expires at the end of a sub period)
- Compliance strategy:
  - By making investment decision (partial investment is not allowed)
  - By buying permits which match emissions level
- Language: neutral

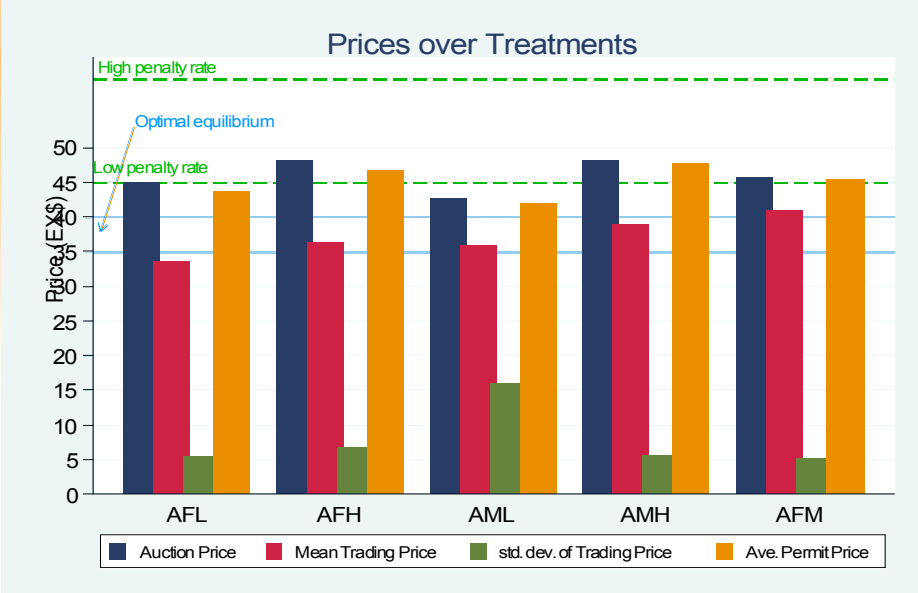
Dataset

- 6 observation groups for each treatment (2 groups of the same treatment in each session)
- Total of 240 subjects, self-select, from different disciplines at UNSW in ASB Experimental Research Lab
- Each session lasts 2-2.5 hours
- Demographic statistics
  - Balanced proportion of gender
  - Almost half from the faculty of business (47.5%)
  - 65.8 % is undergraduate student and the rest is post-graduate
- Results from Holt & Laury experiment
  - Normal distribution of risk preference

Result from Holt & Laury experiment



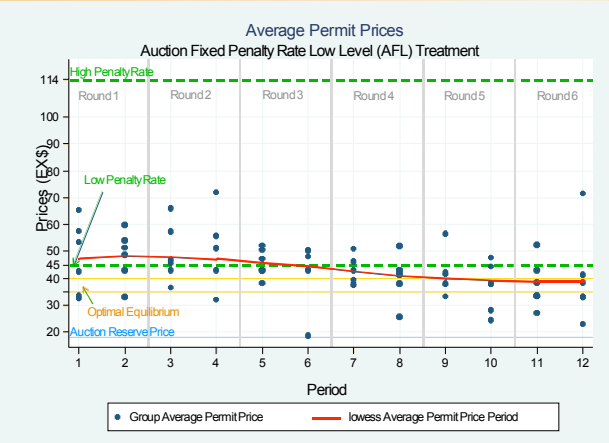
Mean prices over treatments

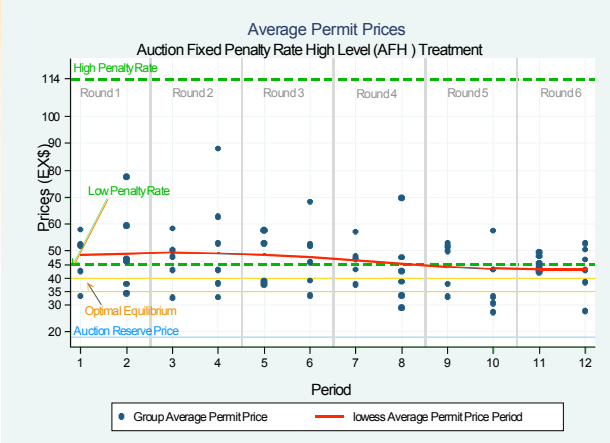


Notes: AFL= Auction Fixed Penalty Rate Low Level
AFH= Auction Fixed Penalty Rate high Level
AML= Auction Make-Good Provision Low Level
AMH= Auction Make-Good Provision High Level
AFM =Auction Mix of FPR & MGP

Average permit price convergence path

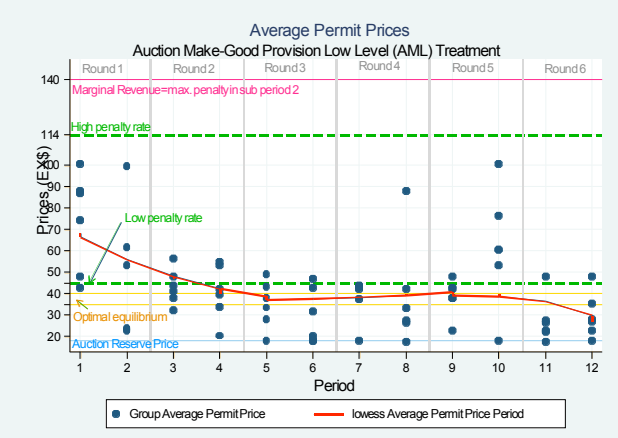
Fixed Penalty Rate Treatments

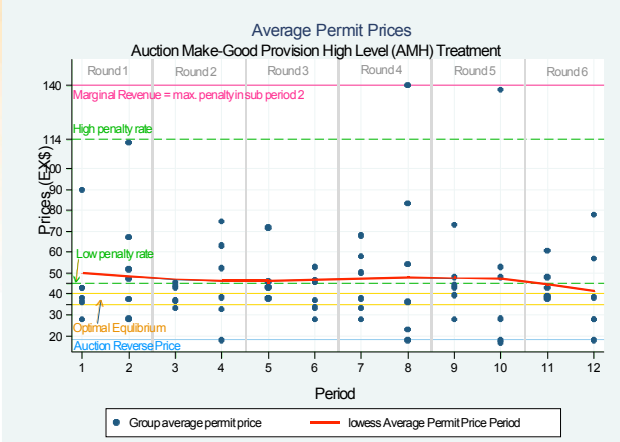




Average permit price convergence path

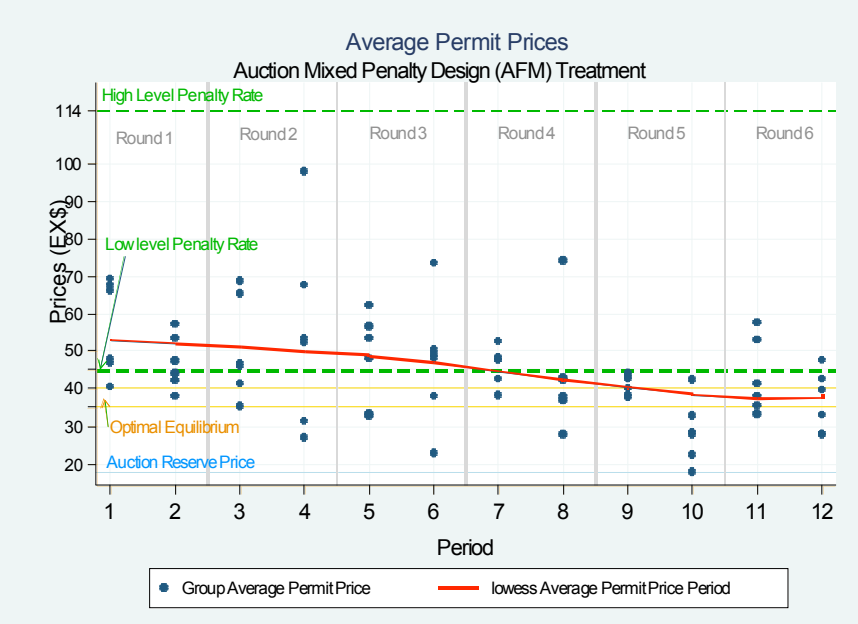
Make-good Provision Treatments



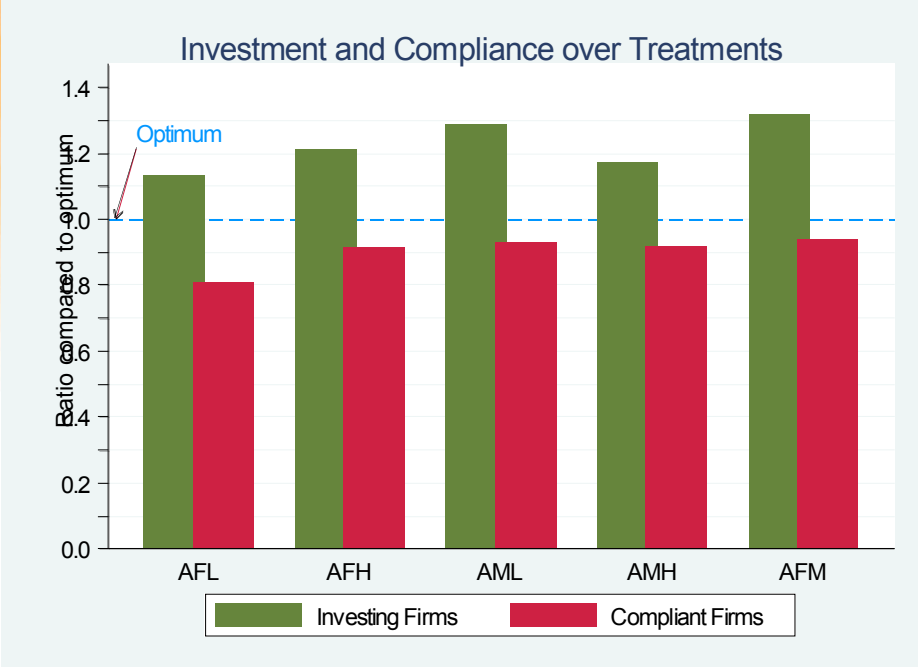


Average permit price convergence path

Mixed Penalty Treatment



Investment and Compliance Level across Treatments

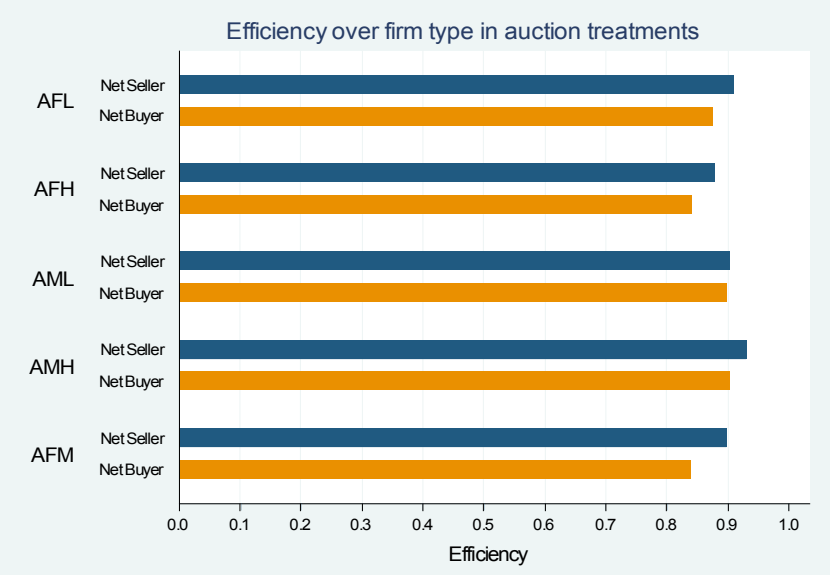


Treatment Effects for all treatment cells

Treatment	Mean of Eff.	Auction price	Mean of Trading price	Std. Dev. Of Trading price	Average Permit Price	Total invest-ment[a]	Total com-pliance[a]
FPR Low (AFL)	0.890	45.01	33.63	5.36	43.66	1.130	0.810
FPR High (AFH)	0.861	48.21	36.25	6.70	46.80	1.215	0.913
MGP Low (AML)	0.853	42.58	35.91	15.82	41.94	1.292	0.927
MGP High (AMH)	0.832	48.28	38.85	5.63	47.77	1.174	0.917
Mixed Penalty (AFM)	0.834	45.57	40.85	5.23	45.30	1.319	0.941
Optimum	1.000	35-40	35-40	0	35-40	1.000	1.000
ANOVA test	Not sig.	Not sig.	Not sig.	Not sig.	Not sig.	Sig. 1%	Sig. 1%
Kruskal Wallis test	Not sig.	Sig. 5%	Sig. 1%	Not sig.	Sig 5%	Sig. 1%	Sig. 1%

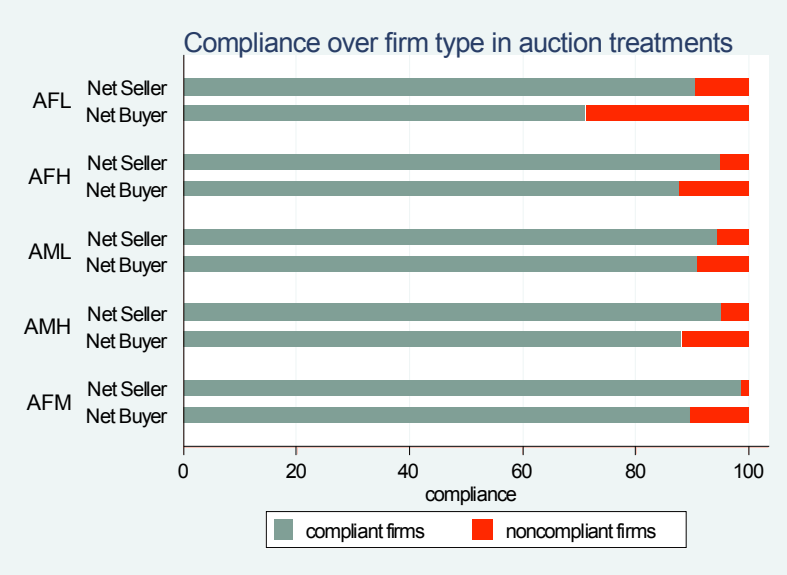
- **Significant differences in variables related to compliance strategy both with parametric and non-parametric tests**
- **No significant differences in variables related to prices with parametric tests**
- **Significant differences Auction and Average permit prices with non parametric tests**

Efficiency over firm type across treatments



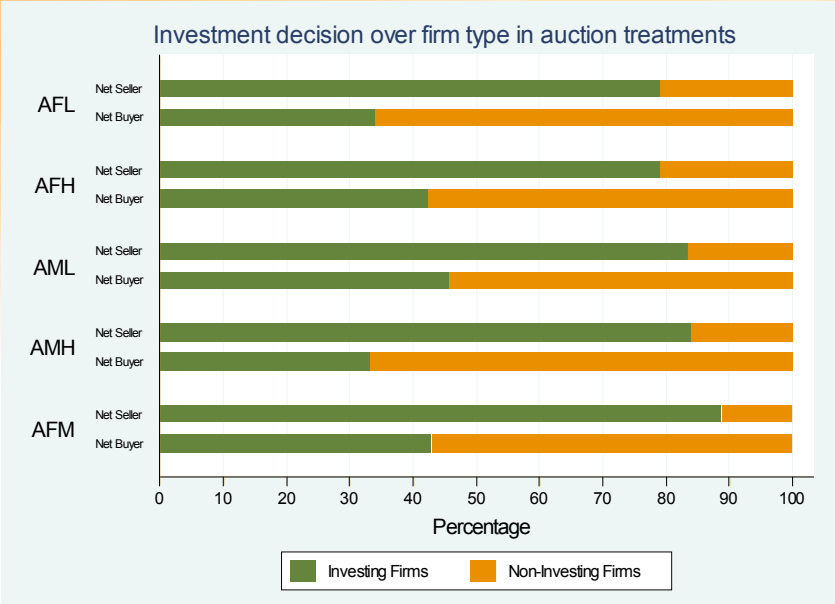
- **Significant differences (p<0.000) with parametric and non-parametric tests in efficiency across treatments for each net buyer and net seller group**
- **No significant difference between netbuyer and netseller in general across treatments**

Compliance over firm type across treatments



- **Significant differences (p<0.001) with parametric and non-parametric tests in efficiency across treatments for each net buyer and net seller group**
- **Across treatments, net seller has higher compliance level than net seller at 0.1%**

Investment Decision over firm type across treatments



Pairwise Comparison of treatment effects

Variable	AFL vs AFH	AML vs AMH	Mix vs Low MGP	Mix vs AFL
Auction Price	AFL < AFH	AML > AMH	AFM < AML^	AFM > AFL
Mean trading price	AFL < AFH	AML < AMH ^^	AFM < AML^^	AFM > AFL
Std. dev. Trading price	AFL < AFH	AML > AMH	AFM ≈ AML	AFM ≈ AFL
Average Permit Price	AFL < AFH	AML < AMH	AFM < AML^	AFM > AFL
Investment level	AFL < AFH *	AML > AMH **	AFM > AML	AFM > AFL ** ^^
Compliant firms	AFL < AFH ** ^^	AML > AMH	AFM ≈ AML	AFM > AFL ** ^^
Compliance level	AFL <AFH **	AML > AMH**^	AFM >AML	AFM > AFL ** ^^
Mean efficiency	AFL > AFH * ^	AML > AMH	AFM ≈ AML	AFM < AFL **^

Note: * significant with parametric test, ^ significant with parametric test

- **For FPR, efficiency & variables related to compliance strategy are better in AFL compared to AFH**
- **For MGP, mean trading price, investment and compliance level are better in AML compared to AMH**
- **Mixed penalty performs better than MGP in prices variable and better than AFL in compliance strategy.**

Results: estimation models

1. Model of Auction Price

- **We compare models with Auction Price and Log of Auction Price as the dependent variable.**
- **Models are estimates with cluster-robust OLS, robust random effects model, and robust population average model.**
- **The signs of the coefficients across models are consistent, except for dummy for sub period 2, which is also the source of heteroskedasticity. There are differences in Auction prices in sub period 1 and sub period 2 but statisticaly insignificant.**
- **Round is highly statistically & economically significant and this suggests learning effect**
- **Level of penalty rate is statistically significant at 5 % level.**
- **Subject's risk preference is significant in Log Auction Price model but the inconsistent choice of risk preference is the significant regressor for Auction price model**
- **The suction price gives an early price signal which is a highly significant regressor for the following investment and compliance decision models**
- **A higher auction price increases the probability of making an investment decision, and conversely reduces the likelihood of firms being compliant for those firms who do not invest.**

Auction Price

Regressor	Regression Model for AucPr			Regression Model for lnAucPr		
	OLS cluster	RE rob theta	PA robust	OLS cluster	RE rob theta	PA robust
fpr	2.5045	2.1277	2.2812	0.1278	0.1201	0.1225
	-3.1916	-4.1754	-3.0975	-0.0745	-0.1018	-0.0728
PRate	0.0654	0.0783*	0.0731*	0.0015	0.0018*	0.0017*
	-0.0376	-0.0319	-0.0362	-0.0008	-0.0007	-0.0007
mgp	3.2869	3.9586	3.685	0.0708	0.0845	0.0801
	-3.7254	-2.4722	-3.676	-0.0732	-0.0566	-0.0719
himgp	6.7011	6.6708	6.6831	0.142	0.1414	0.1416
	-4.1989	-5.8163	-4.1504	-0.0908	-0.1139	-0.0896
Round	-2.3802**	-2.3757***	-2.3775 ***	-0.0526***	-0.0525***	-0.0526***
	-0.6727	-0.5205	-0.6648	-0.0134	-0.0102	-0.0132
sp2	0.395	0.5449	0.4839	-0.0493	-0.0462	-0.0472
	-1.8848	-1.9074	-1.8856	-0.0399	-0.0365	-0.04
totrisk	-0.3494	-0.358	-0.3545	-0.0119*	-0.0121*	-0.0121*
	-0.2037	-0.2458	-0.2005	-0.0053	-0.0059	-0.0052
totincons	2.4792*	2.43	2.4501*	0.0393	0.0383	0.0386
	-1.0841	-1.6055	-1.0712	-0.0233	-0.0294	-0.023
_cons	57.6217***	57.2964***	57.4289***	4.1972***	4.1905***	4.1927***
	-10.9711	-11.2258	-10.8463	-0.2811	-0.2465	-0.2777
Statistics						
N	360	360	360	360	360	360
r2	0.0965			0.146		
r2_a	0.0759			0.126		
F	5.253			6.346		
rmse	17.8	17.28		0.344	0.3297	
r2_w		0.0658			0.0937	
r2_b		0.2719			0.3637	
r2_o		0.0962			0.1454	
chi2		2992.4563	44.8814		37644.95	54.4235

Results: estimation models

2. Model of Investment decision

- To assess the effects of our treatment variables, we use dummies for MGP, FPR, high FPR, and the rate of FPR as regressors. Additional dummy of net buyer.
- Models are estimated with cluster robust Probit/Logit model, RE probit/logit model, and robust probit/logit model
- Other regressors: long position (permits), Auction Price, Mean trading price
- The significant variables across model are very consistent.
- MGP treatment & Auction Price increase the probability of subjects' compliance , while netbuyer & long position have negative effects on investment decision.
- Netbuyer and MGP treatment have the largest marginal effects.

Investment Decision Model

	Logit cluster	Logit RE	Logit RE bootstr	Probit cluster	Probit RE	Probit RE bootstr
Dummy FPR	-0.0442	-0.0534	-0.0534	-0.045	-0.0746	-0.0746
	(0.468)	(0.4992)	(0.5008)	(0.2573)	(0.2711)	(0.2573)
Penalty Rate	0.0054	0.0064	0.0064	0.0023	0.0031	0.0031
	(0.0051)	(0.0054)	(0.0056)	(0.0026)	(0.0029)	(0.0029)
Dummy MGP	0.9258*	1.0922**	1.0922**	0.5013*	0.5857**	0.5857**
	(0.3614)	(0.3619)	(0.3596)	(0.197)	(0.1951)	(0.2037)
Dummy High MGP	-0.4299	-0.5245	-0.5245	-0.3369	-0.3787	-0.3787
	(0.3284)	(0.3974)	(0.34)	(0.1775)	(0.2142)	(0.2152)
Dummy Net buyer	-1.5147***	-1.6401***	-1.6401***	-0.8266***	-0.9084***	-0.9084***
	(0.1838)	(0.2083)	(0.2509)	(0.097)	(0.1112)	(0.1296)
Auction Price	0.0202***	0.0247**	0.0247***	0.0121***	0.0142**	0.0142***
	(0.0059)	(0.008)	(0.0063)	(0.0034)	(0.0044)	(0.0032)
Mean trading price	0.0004	0.0000	0.0000	0	-0.0002	-0.0002
	(0.0024)	(0.0032)	(0.0036)	(0.0014)	(0.0018)	(0.0019)
Long position of permits	-0.2224***	-0.2623***	-0.2623***	-0.1191***	-0.1393***	-0.1393***
	(0.0153)	(0.0162)	(0.0194)	(0.008)	(0.0076)	(0.0113)
_cons	-1.9933***	-2.5122***	-2.5122***	-1.0329***	-1.2810***	-1.2810***
	(0.5591)	(0.5971)	(0.5691)	(0.3073)	(0.3167)	(0.2813)
N	1440	1440	1440	1440	1440	1440
ll	-438.88	-422.93	-422.93	-448.63	-431.01	-431.01
'r2'	0.5331			0.5433		
chi2	259.9135	307.9514	229.7005	303.1957	1013.7609	227.3476
% Corr. pred.	88.47			88.75		

Results: estimation models

3. Model of compliance decision by holding permits

- We use the same regressors as in Investment model plus dummy sub period 2, but we remove net buyer and permits shortfall.
- Significant regressors remain the same across our probit and logit models.
- High fixed penalty rate and MGP treatment increase the probability of subjects' compliance , while higher Auction Price has negative effects on compliance status.
- Learning curve for compliance decision is apparent as Round is a significant variable.
- MGP generates the largest marginal effect.
- For Mixed penalty design, we observe the highest compliance levels compared to other treatments -→mixed penalty serves as a double penalty mechanism which increases compliance level.

Compliance Decision Model

Regressors for compliance	1 Probit cluster robust	2 Probit RE bootstrap	3 Probit RE bootstrap	4 Logit cluster robust	5 Logit RE bootstrap	6 Logit RE bootstrap
Dummy FPR	-0.0872 (0.1653)	-0.1416 (0.1911)	-0.1397 (0.2206)	-0.1357 (0.2869)	-0.2640 (0.3404)	-0.2593 (0.3500)
Penalty Rate	0.0087*** (0.0021)	0.0089** (0.0028)	0.0088*** (0.0024)	0.0148*** (0.0035)	0.0153*** (0.0039)	0.0152*** (0.0046)
Dummy MGP	0.9548*** (0.2019)	0.9796*** (0.2354)	0.9776*** (0.2383)	1.6195*** (0.3464)	1.6872*** (0.4300)	1.6834*** (0.4696)
Dummy High MGP	0.0779 (0.1801)	0.1307 (0.1870)	0.1306 (0.1796)	0.1320 (0.3160)	0.1959 (0.3246)	0.1954 (0.3814)
Round	0.051 (0.0291)	0.0749* (0.0334)	0.0750* (0.0331)	0.0837 (0.0494)	0.1262* (0.0553)	0.1263* (0.0514)
Auction Price	-0.0088*** (0.0025)	-0.0103*** (0.0028)	-0.0102*** (0.0026)	-0.0147*** (0.0044)	-0.0176** (0.0061)	-0.0175*** (0.0043)
Dummy Sub Period 2			-0.0094 (0.0762)			-0.0225 (0.1396)
_cons	0.0802 (0.2639)	0.1508 (0.3028)	0.1559 (0.2984)	0.1002 (0.4535)	0.2700 (0.4953)	0.2811 (0.5910)
Statistics						
N	1114	1114	1114	1114	1114	1114
ll	-592.4348	-572.8482	-572.8431	-592.5244	-572.3567	-572.347
ll_0	-632.4116	-600.5278	-600.5278	-632.4116	-599.6696	-599.6696
r2	0.0632	0.0461^	0.0461^	0.0631	0.0455^	0.0456^
chi2	41.7655	45.5528	62.4192	40.8994	38.0885	60.0678

Conclusions

- In general, the sanction type and level have an significant effect on the compliance strategy for both investing firms and permit buying firms
- With pair-wise comparison, the sanction level has significant effect on either efficiency (FPR) or trading prices (MGP)
- A firm of the Net-seller type has more advantage than a Net Buyer when prices are higher than the optimal equilibrium in terms of making investment and compliance decision, and thus the resulting efficiency
- We observe a trade-off between efficiency and compliance level in the FPR treatment but not in the MGP treatment
- Higher sanction levels induce higher Auction prices, investment and compliance.
- A Mixed Penalty design yields an Auction Price almost as low as AFL but with much higher compliance level, confirming the effect of double-penalty. More consistent price signals are also observed in Mixed Penalty.
- A learning effect is shown with regard to the Auction Price and Compliance decision by permit buying firms in regression models

Thank you

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Results: Statistics summary

Treatm.	Mean Eff	Auction price	Mean Trading price (EX$)	Std. dev. Of price (EX$)	Ave. Permit Price^ (EX$)	Total Invest. (firms)	Total compl. (firms)	Total Viola-tion (permit)	Total Invest. Cost (EX$)	Pen. Cost (EX$)	Total Compl. Cost (EX$)
AFL	0.890	45.01	33.63	5.36	43.66	1.130	0.810	-10.56	2961.11	560.00	3521.11
AFH	0.861	48.21	36.25	6.70	46.80	1.215	0.913	-17.22	3316.67	432.25	3748.92
AML	0.853	48.28	35.91	15.82	41.94	1.292	0.927	-21.39	3472.22	855.56	4327.78
AMH	0.832	42.58	38.85	5.63	47.77	1.174	0.917	-7.71	3033.33	1166.67	4200.00
AFM	0.834	45.57	40.85	5.23	45.30	1.319	0.941	-24.83	3547.22	857.47	4404.69
Optimum	1.000	35-40	35-40		35-40	1.000	1.000	0	2200	0	2200

Notes: ^ Average permit price is the average between Auction price and Trading price

- AFL= Auction Fixed Penalty Rate Low Level
- AFH= Auction Fixed Penalty Rate high Level
- AML= Auction Make-Good Provision Low Level
- AMH= Auction Make-Good Provision High Level
- AFM =Auction Mix of FPR & MGP

Lowest value

Highest value