Centre for Energy and Environmental Markets

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA



Market Performance under Different Penalty Design: experimental evidence on emissions trading scheme with auctioned permits

International Energy Workshop
KTH - Royal Institute of Technology, Stockholm, 21-23 June 2010

Phillia Restiani & Regina Betz

Outline

- Motivation
- Research questions
- Hypotheses
- Experimental design
- Descriptive statistics of the results
- Test of Treatment effects
- Estimation models
- Conclusion

Motivation

- Penalty is an important element to ensure that the emission reduction target is achieved → environmental effectiveness of an ETS
- Penalty 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 practice, there is a tendency to set penalty level very high in order to encourage higher compliance rates.
- In theory, when penalty rate is higher than permit price, firms will choose to be compliant by buying permits on the market or by reducing emissions.
- Questions:
  - How high should the penalty level be set?
  - Do penalty level and type really matter?

Research Question

What are the effects of penalty type and penalty level on market performance in terms of:

a. **Auction price**
b. **Compliance rate and the choice of compliance strategy:**
    1. **Irreversible investment decision, or**
    2. **Permit holding (buying permits)**
c. **Efficiency**

Hypotheses

- ***Hypothesis 1***: Auction price should remain the same in all treatments as the supply and demand structure remains the same.
- ***Hypothesis 2***: In Fixed Penalty Rate treatments, investment levels and compliance rates should be the same at 100% regardless of the penalty level since the penalty rate is set higher than the theoretical equilibrium permit price.
- ***Hypothesis 3***: The make-good ratio should not affect investment levels and compliance rates in the Make-Good Provision treatments as long as it is set equal to or higher than one, under the assumption that prices remain the same in both sub periods.
- ***Hypothesis 4***: Penalty type should not effect investment level and compliance rates regardless of penalty level as long as the level is set at the optimal level.
- ***Hypothesis 5***: The Mixed Penalty design should yield the same compliance rates as in the Fixed Penalty Rate and Make-Good Provision treatments.

Experimental design: overview

Penalty type	Penalty 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**	

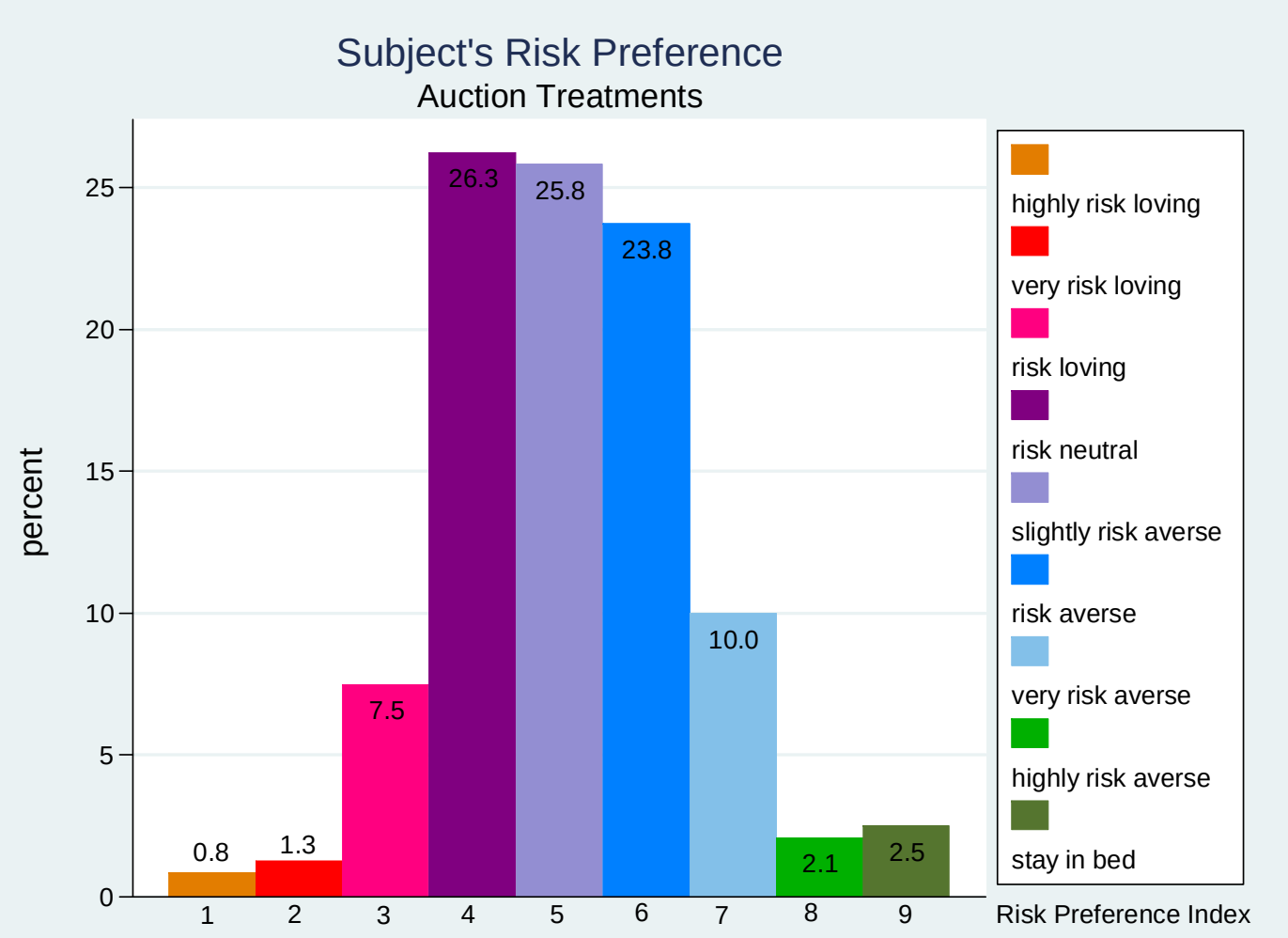
Implementation:

- **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**
  - **Market game**
- **Control questions and one Practice round**
- **6 observation groups for each treatment (2 groups of the same treatment in each session)**
- **Total of 240 subjects, self-select, from various disciplines at UNSW**
- **Each session lasts 2-2.5 hours**

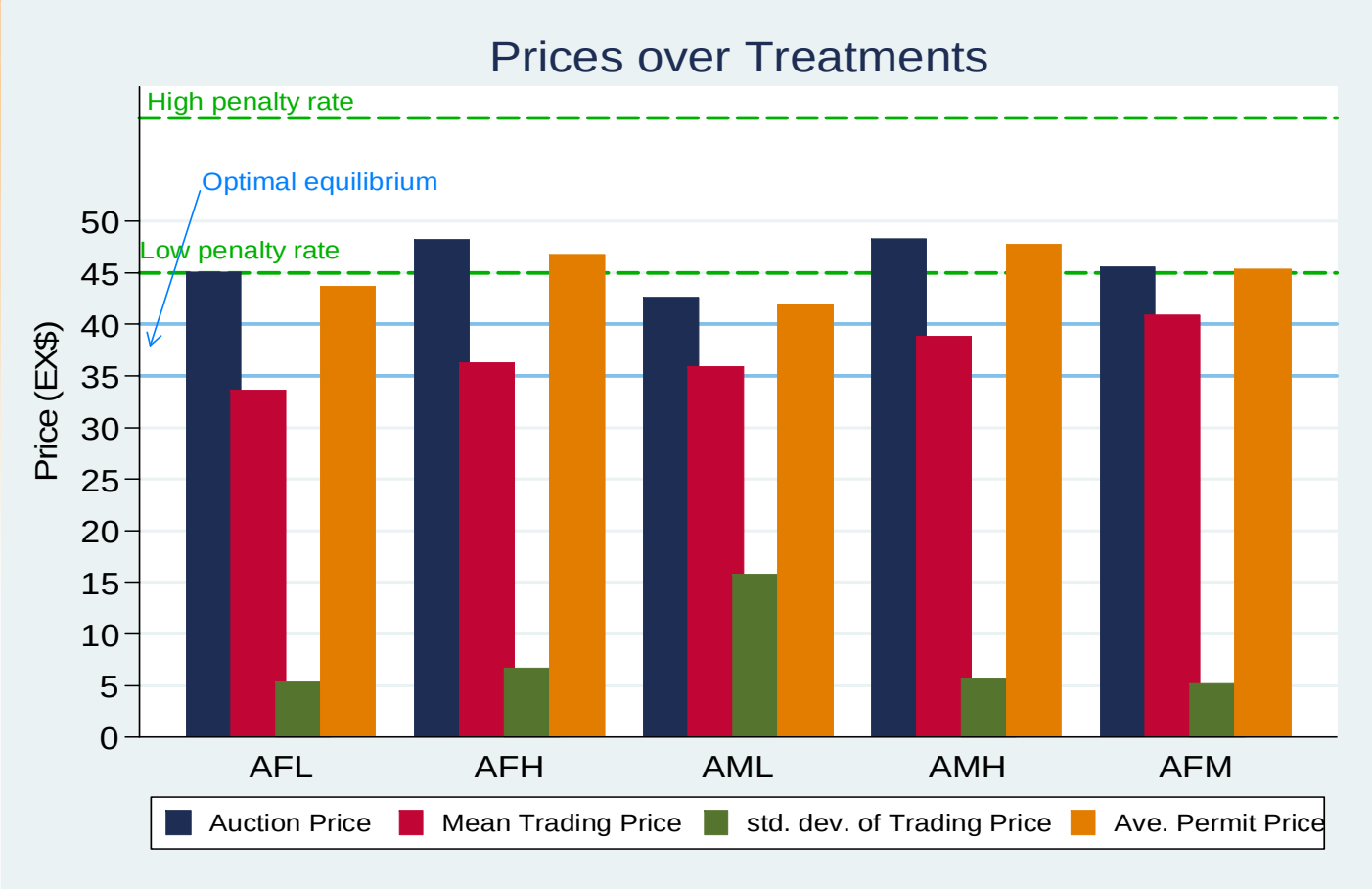
Experimental design: key market features

- **Stages in market game experiment**
  1. **Initial Allocation of permits: ascending clock auction**
  2. **Permit Trading: continuous double auction, posted offer**
  3. **Investment decision (Sub Period 1 only) → automatic compliance, no permit required**
  4. **Compliance check and penalty enforcement**
- **6 repeated rounds, each with 2 Sub Periods → 12 periods**
- **Players characters :**
  - **8 identical firms → 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)**
- **Banking and borrowing are not allowed (permit expires in each sub period)**
- **Enforcement of penalty**
  - **Fixed Penalty Rate: Immediate deduction at the end of each sub period**
  - **Make-Good Provision:**
    - **Sub period 1: quantity compensation of the missing licenses**
    - **Sub period 2: loss of total revenue in that sub period**
- **Language: neutral**

Result from Holt & Laury experiment

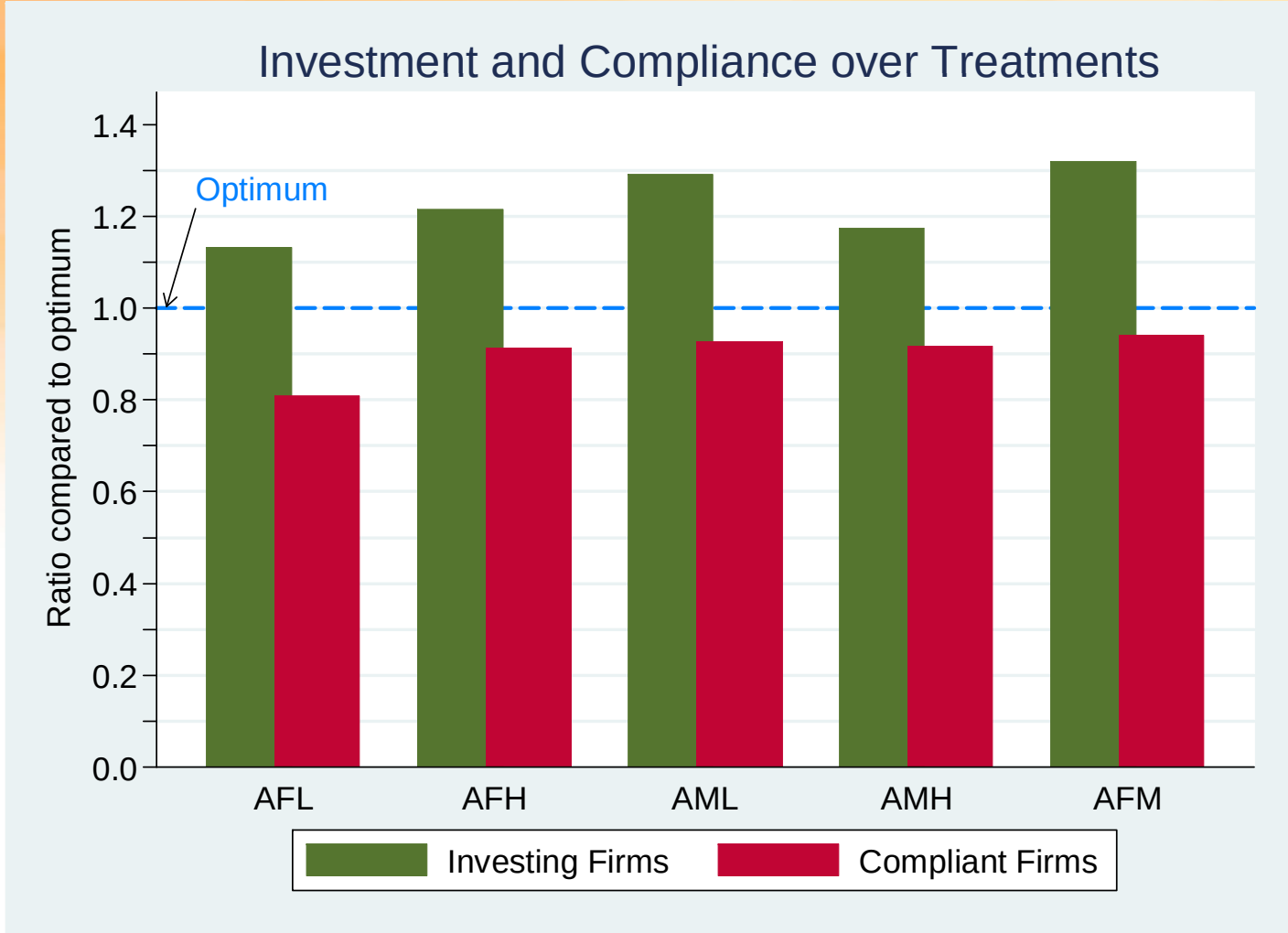


Result: auction price

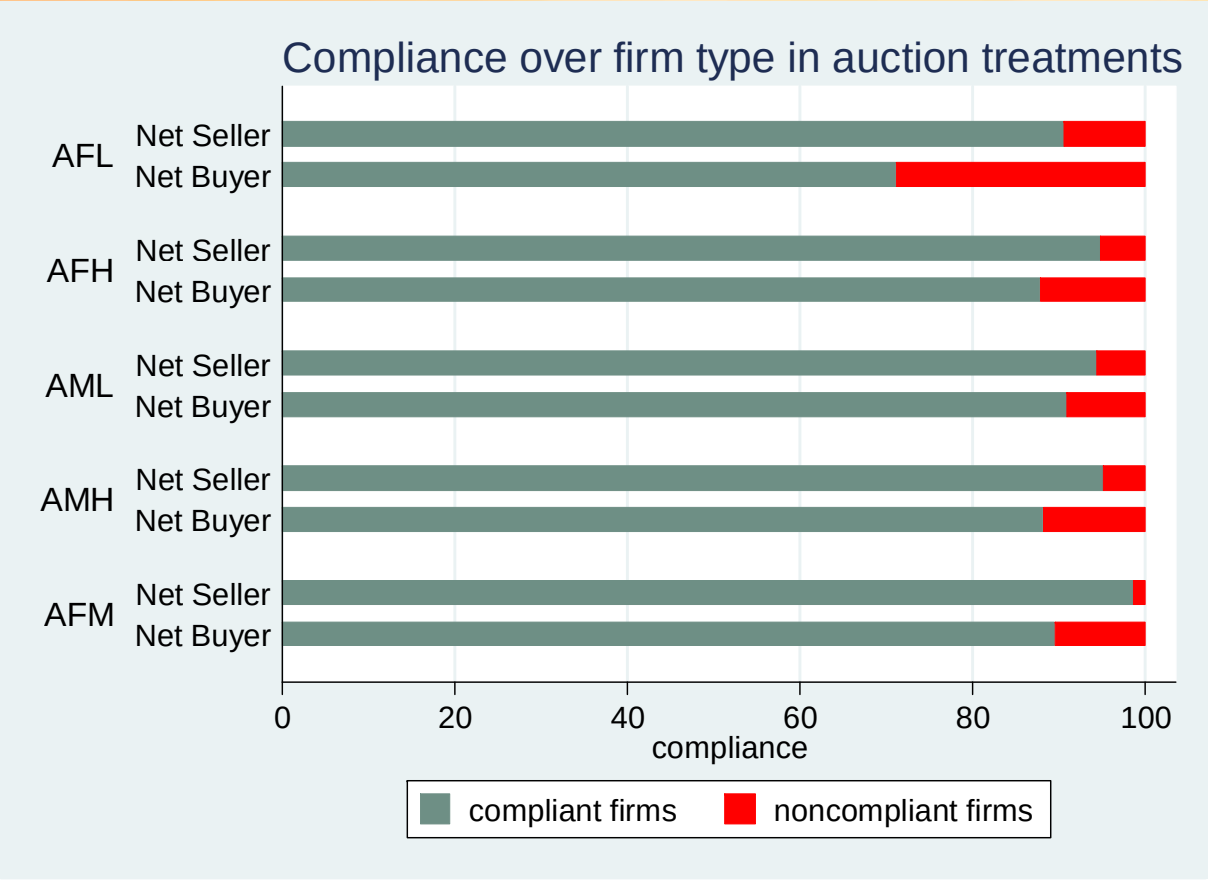


Notes: AFL= Auction Fixed Penalty Rate Low Level
AFH= Auction Fixed Penalty Rate high Level
AML= Auction Make-Good Provision Low Level
AMH= Auction Make-Good Provision High Level
AFM =Auction Mix of FPR & MGP

Result: compliance strategy and compliance rate

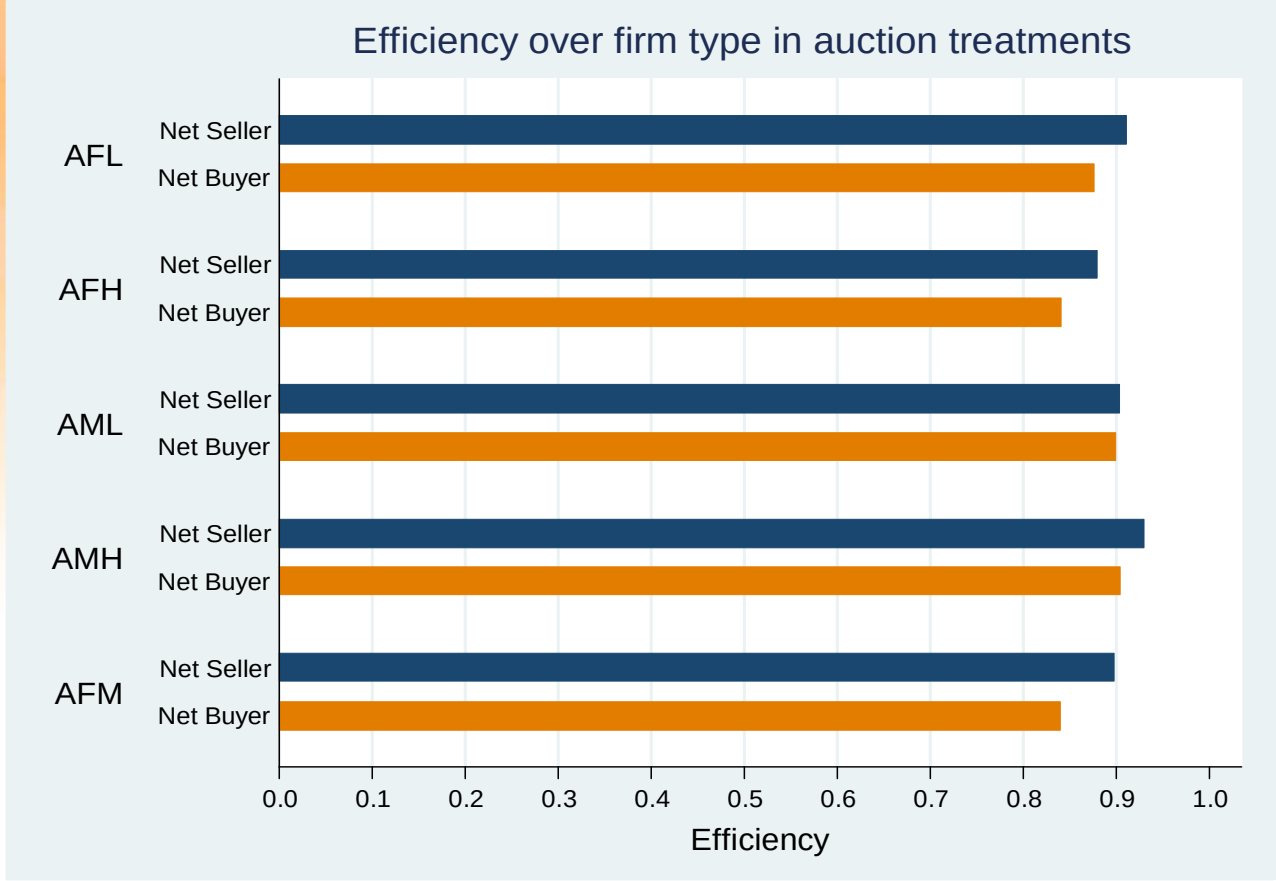


Compliance over firm type across treatments



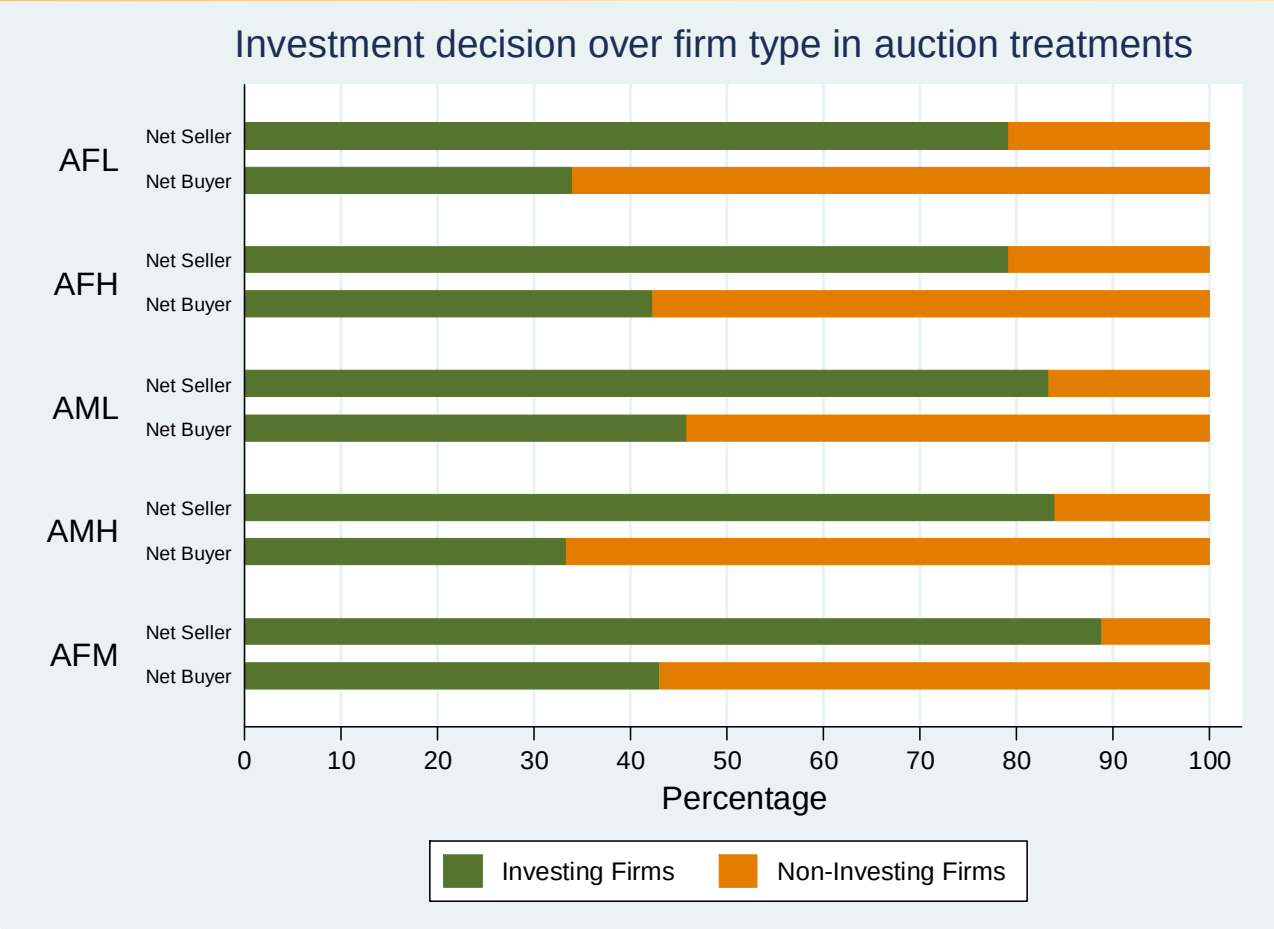
- **Significant differences (p<0.001) with parametric and non-parametric tests in efficiency across treatments for each net buyer and net seller group**
- **Across treatments, net seller has higher compliance level than net seller at 0.1%**

Result: 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**

Investment Decision over firm type across treatments



Test of treatment effect: Result 1

- *Auction prices remain above the optimal equilibrium level.*
- ***Result 1**: There are no differences in auction prices across all treatments (consistent with Hypothesis 1).*
- ***Support**:*
  - Kruskal-Wallis non-parametric test gives a p-value of 0.1537, thus we cannot reject the null hypothesis that the auction prices come from the same underlying population distribution.
  - Pairwise comparison of treatments with Wilcoxon-Mann-Whiteny test and Kolmogorov-Smirnov test show that the test statistics is only slightly significant with the Wilcoxon test which tends to show more significant results. A separate test with parametric t-test does not support the evidence.

Test of treatment effect: Result 2 & Result 3

- ***Result 2****: There are differences in compliance rates but not in the investment level between low and high level penalty in the Fixed Penalty Rate treatment. The compliance rate is statistically higher in the high level penalty treatments (inconsistent with Hypothesis 2).*
- ***Support****:* pairwise comparison of treatments with Wilcoxon-Mann-Whitney test and Kolmogorov-Smirnov test yield consistent test statistics in which the effect is highly significant for compliance rate at 0.1% or 1% level.

- ***Result 3****: Penalty level does not affect investment level and compliance rates in the Make-Good Provision treatment (consistent with Hypothesis 3).*
- ***Support****:* Test statistics show that only the Wilcoxon test confirms significant estimates consistent test statistics in which higher investment is observed in low MGP treatment at 5% level, but the same inference cannot be drawn from the other tests (Kolmogorov-Smirnov test and t-test).

Test of treatment effect: Result 4

- ***Result 4**:*
  - *In the high penalty level, different penalty type does not provide different compliance incentives as there are not any significant differences in terms of investment level and compliance rates between the Fixed Penalty Rate and the Make-Good Provision (consistent with Hypothesis 4).*
  - *On the other hand, different compliance rates are observed in the low penalty level in which the Make-Good Provision treatments have higher compliance rates than the Fixed Penalty Rate treatments (inconsistent with Hypothesis 4). However, this difference is not found with regard to investment levels.*
- ***Support**:*
  - High penalty treatments: We cannot reject the null hypothesis that the two samples are derived from the same population distribution (p-value = 1.00) for both investment level and compliance rate.
  - Low penalty level: we obtain a highly significant statistics for compliance rate (p-value =0.000) but not for the investment level (p-value =0.213)

Test of treatment effect: Result 5

- ***Result 5****:*
  - *The Mixed Penalty design provides the same investment and compliance incentives as with the Make-Good Provision treatments*
  - *But differences are found in both investment levels and compliance rates compared to Fixed Penalty Rate (inconsistent with Hypothesis 5)..*
- ***Support****:*
  - No significant differences are found compared to low MGP treatment.
  - Test statistics are significant at 1% level for both investment and compliance compared to low FPR treatment

Estimation model: auction price

Variables	Model 1 (basic)	Model 2 (Model 1 + risk)	Model 3 (Model 2 + study variables)	Model 4 (Model 3 + income variables)
Dummy for FPR	2.9861	4.3953	2.8073	3.4850
	(2.6218)	(3.0792)	(3.0787)	(3.5141)
Dummy for FPR high level	3.1944	2.3382	4.2525	3.3898
	(3.7962)	(3.0537)	(2.8568)	(3.5971)
Dummy for MGP	0.5556	1.1085	3.3148	3.4868
	(3.5854)	(3.4998)	(2.5991)	(3.1911)
Dummy for MGP high level	5.6944	6.7694	4.7335	5.2603
	(4.7587)	(4.2066)	(3.6255)	(3.9259)
Round	-2.4024***	-2.4024***	-2.4024***	-2.4024***
	(0.6777)	(0.6796)	(0.6845)	(0.6885)
Dummy for sub period 2	-0.3611	-0.3611	-0.3611	-0.3611
	(1.7946)	(1.7997)	(1.8127)	(1.8232)
Group risk preference index		-0.3280	-0.6487**	-0.6538**
		(0.2126)	(0.2412)	(0.2501)
Number of subject with inconsistent risk choices		2.5873*	2.2587**	2.1594*
		(1.1067)	(0.7914)	(0.9004)
Constant	50.6167***	59.2014***	121.6472***	115.0062*
	(4.5917)	(10.9804)	(31.7207)	(48.2215)
Observation	360	360	360	360
Within correlation	0.0580	0.0580	0.0580	0.0580
Between correlation	0.0897	0.2752	0.4529	0.4581
Overall correlation	0.0627	0.0904	0.1169	0.1177
Chi2	15.4591	35.8100	75.1069	104.2794
Rho (% due to u_i)	0.0926	0.0716	0.0666	0.1021
Theta	0.3294	0.2792	0.2660	0.3496

- **Estimation with heteroskedasticity-robust random effect model**
- **Main regressors are penalty design treatment variable: FPR, high FPR, MGP, high MGP**
- **The signs of the coefficients across models are consistent and as expected.**
- **Penalty design variables are not significant**
- **Learning effect is confirmed as Round is statistically & economically significant**
- **Risk-related variables are significant after controlling for demographic variables**

Estimation model: investment model

Regressor for investment decision	Model 1 Probit OLS cluster	Model 2 Probit RE bootstrap	Model 3 Probit RE bootstrap	Model 4 Probit RE bootstrap	Model 5 Logit RE bootstrap
Dummy for FPR	-0.045	-0.0746	-0.0713	-0.0515	-0.0534
	(0.2573)	(0.2573)	(0.2579)	(0.2767)	(0.5008)
Penalty rate	0.0023	0.0031	0.0032	0.003	0.0064
	(0.0026)	(0.0029)	(0.0029)	(0.0031)	(0.0056)
Dummy for MGP	0.5013*	0.5857**	0.5871**	0.5832**	1.0922**
	(0.197)	(0.2037)	(0.2033)	-0.1949	(0.3596)
Dummy for MGP high level	-0.3369	-0.3787	-0.3755	-0.3455	-0.5245
	(0.1775)	(0.2152)	(0.2137)	(0.1765)	(0.34)
High MAC firm	-0.8266***	-0.9084***	-0.9067***	-0.8914***	-1.6401***
	(0.097)	(0.1296)	(0.1316)	(0.1347)	(0.2509)
Auction price	0.0121***	0.0142***	0.0132***	0.0138***	0.0247***
	(0.0034)	(0.0032)	(0.0033)	(0.0036)	(0.0063)
Mean trading price	0.0000	-0.0002	-0.0002	0.0000	0.0000
	(0.0014)	(0.0019)	(0.0019)	(0.0019)	(0.0036)
Permit long position	-0.1191***	-0.1393***	-0.1394***	-0.1406***	-0.2623***
	(0.008)	(0.0113)	(0.0114)	(0.0102)	(0.0194)
Round			-0.0179		
			(0.0396)		
Group risk preference index				0.0065	
				(0.0467)	
Subjects with inconsistent risk choices				0.3338	
				(0.1798)	
_cons	-1.0329***	-1.2810***	-1.1820***	-1.3977***	-2.5122***
	(0.3073)	(0.2813)	(0.3538)	(0.3478)	(0.5691)
Statistics					
No. obs.	1440	1440	1440	1440	1440
No. subjects	240	240	240	240	240
Log likelihood	-448.63	-431.01	-430.859	-429.065	-422.93

- **Estimation with probit and logit model**
- **The signs of the coefficients across models are consistent and as expected.**
- **MGP treatment is the only significant penalty design variables.**
- **Firm made rational investment behaviour as indicated by the coefficients on firm type and permit position**
- **Auction price has positive effect on investment decision**
- **Learning effect is not verified**

Estimation model: compliance decision model

Regressors for compliance decision	Model 1 Probit OLS cluster robust	Model 2 Probit RE bootstrap	Model 3 Probit RE bootstrap	Model 4 Probit RE bootstrap	Model 5 Logit RE bootstrap
Dummy for FPR	-0.0872 (0.1653)	-0.1416 (0.1911)	-0.1397 (0.2206)	-0.142 (0.2189)	-0.2593 (0.3500)
Penalty rate	0.0087*** (0.0021)	0.0089** (0.0028)	0.0088*** (0.0024)	0.0089*** (0.0025)	0.0152*** (0.0046)
Dummy for MGP	0.9548*** (0.2019)	0.9796*** (0.2354)	0.9776*** (0.2383)	1.0025*** (0.2298)	1.6834*** (0.4696)
Dummy for MGP high level	0.0779 (0.1801)	0.1307 (0.1870)	0.1306 (0.1796)	0.1235 (0.2176)	0.1954 (0.3814)
Round	0.051 (0.0291)	0.0749* (0.0334)	0.0750* (0.0331)	0.0727* (0.034)	0.1263* (0.0514)
Auction Price	-0.0088*** (0.0025)	-0.0103*** (0.0028)	-0.0102*** (0.0026)	-0.0086** (0.0029)	-0.0175*** (0.0043)
Dummy for Sub Period 2			-0.0094 (0.0762)		-0.0225 (0.1396)
Mean of trading price				-0.0031 -0.0018	
_cons	0.0802 (0.2639)	0.1508 (0.3028)	0.1559 (0.2984)	0.1912 -0.3093	0.2811 (0.5910)
N	1114	1114	1114		1114
Log likelihood	-592.4348	-572.8482	-572.8431	-570.8979	-572.347
R^2	0.0632	0.0461^	0.0461^	0.0493^	0.0456^
Chi2	41.7655	45.5528	62.4192	62.1237	60.0678
% Correctly predicted	74.78				

- **Estimation with probit and logit model**
- **Consistent estimates are obtained across models.**
- **Penalty rate and MGP treatment have significantly positive effect on compliance**
- **Auction price has negative effect on investment decision, but not trading price**
- **Learning effect is significant when we control for sub period or trading price**

Estimation model: efficiency

Regressor for efficiency	Model 1	Model 2	Model 3
	Tobit	Panel data Tobit	Panel data Tobit
Dummy for FPR	-0.0003	-0.0024	0.0094
	-0.0231	-0.0297	-0.0117
Penalty rate	0.0000	0.0001	-0.0004**
	-0.0002	-0.0002	-0.0001
Dummy for MGP	-0.0437**	-0.0395*	-0.0786***
	-0.0156	-0.0184	-0.0127
Dummy for MGP high level	0.0153	0.0154	-0.0058
	-0.0199	-0.0232	-0.0111
Auction Price	-0.0059***	-0.0059***	-0.0055***
	-0.0004	-0.0004	-0.0002
Mean of trading price	-0.0003	-0.0003	-0.0001
	-0.0002	-0.0003	-0.0001
Round	0.0062**	0.0061*	0.0003
	-0.0024	-0.0025	-0.0021
Dummy for Sub Period 2	-0.0697***	-0.0690***	-0.0678***
	-0.0113	-0.0103	-0.0071
Compliance rate			0.5168***
			-0.0373
Investment level			-0.2020***
			-0.0166
_cons	1.1733***	1.1709***	0.9885***
	-0.0324	-0.0313	-0.0324
N	360	360	360
Log likelihood	383.5838	385.8185	470.3238
Chi2	180.0935	492.9965	1445.322

- **Estimation with tobit model as possible values of efficiency are truncated**
- **Auction price and MGP treatment significantly reduce efficiency**
- **While compliance increases efficiency, opposite effect is produced by investment**
- **Learning effect is alsosignificant**

Conclusions

- **Risk related variables, rather than penalty design, affect auction price**
- **Estimation models show that penalty type and level have significant effect on the compliance strategy.**
- **Higher penalty level provides higher compliance incentive in FPR treatment but not in MGP treatment**
- **Penalty type, i.e. MGP and mixed penalty design, induce higher compliance rate compared low FPR treatment.**
- **Trade-off between efficiency and compliance is observed as MGP correlates to higher compliance rate and yet lower efficiency.**

Thank you

Email: p.restiani@student.unsw.edu.au

Centre for Energy and Environmental Markets

UNSW
THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY • AUSTRALIA

Many of our publications are available at:
www.ceem.unsw.edu.au