Regulatory Enforcement with Competitive Endogenous Audit Mechanisms

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Introduction

- Compliance theory generally assumes firms will comply with mandates if (to the extent) doing so is cost minimizing
  - Costs of noncompliance typically arise from probabilistic enforcement mechanism (e.g. random audits)
  - This framework applies to regulations that require actions (abatement) and those that require information disclosure (tax)

Introduction

- High rates of compliance with environmental regulations a puzzle given low audit / inspection frequency and typically small fines for violations (Russell et al., 1986; Harrington, 1988; Livernois and McKenna 1999)
- Harrington first suggested this is due to leverage from "targeted" enforcement
  - Firms are targeted based on compliance history
  - Being transitioned to targeted group if found in violation creates additional cost of noncompliance

Introduction

- Tax compliance is similar problem, and surprisingly high compliance is observed here too (Alm and McKee, 1998)
- Tax compliance has emphasized endogenous audit mechanisms that render individual’s audit probability conditional on his report relative to others
  - In information disclosure framework it is clear that audit probability can depend on current compliance effort rather than solely historical compliance effort
  - Modeled as continuous choice rather dichotomous (comply or not)

Introduction

– We develop two endogenous audit mechanisms that make firms' audit probability conditional on relative compliance effort
  - This generates competition among firms and induces significant incentive for compliance beyond that with random enforcement
  - Very similar to tax compliance, but we frame this in the context of environmental information disclosure
  - May apply in some contexts of required actions as well as required disclosure

Introduction

- Central characteristics of our models:
  - Audits are imperfect
  - Regulator can compare behavior among a group of peer firms and select to audit those that appear most likely to be noncompliant

- In this context compliance effort both reduces expected penalties for noncompliance conditional on being audited, and reduces the probability a firm is audited

Introduction

- We test the predictions of our theory in the experimental laboratory
- Results confirm that competitive endogenous audit mechanisms yield significantly higher compliance than random audits
- Effects of changes in the equilibrium audit probability, penalty for noncompliance, and cost of being audited are all consistent with the theory

Models

– Firms are required to disclose level of activity (emissions)

α the cost to a firm of disclosed emissions (“tax”)

β the cost to a firm of revealed undisclosed emissions (“penalty”)

γ the cost to a firm of being audited

e a firm’s quantity of emissions

z the share of emissions a firm chooses to disclose

Models

- Audits are imperfect (Evans et al., 2009)
  - If audited a share *t* of a firm's emissions are revealed
  - *t* is drawn from distribution $F(t)$ on $[0,d]$
  - Errors may be one-sided, unbiased, or otherwise

Models—Random Audits

– Firms are audited with independent probability *p*

– Firms minimize expected costs:

$$\min_z \alpha z e + p\left\{\gamma + \beta e \int_z^d (t-z) f(t)\,dt\right\}$$

– Optimal disclosure z^* is defined by

$$\frac{\alpha}{p\beta} = \int_{z^*}^d f(t)\,dt$$

Models—Audit Tournament

- Regulator audits k firms from a peer group of N firms
  - Assume regulator seeks to audit k firms that appear to be least compliant, but relative evaluation is subject to error
  - Errors may occur due to heterogeneity among firms, but we model firms as identical
  - Generates a Lazear-Rosen (1981) style tournament
- Central assumption is that relative disclosure is (noisy) signal to regulator of compliance effort
- By auditing firms that stand out from peer group regulator achieves some correlation between compliance effort and audit probability

Models—Audit Tournament

- Probability a firm is audited is $p_i(z_i, z_{-i})$
- Firm i's "error adjusted report" is $y_i = z_i + \varepsilon_i$
- Errors ε are drawn from distribution G which is symmetrically distributed around 0
- For k=1 this yields an audit probability for firm i

$$p_i(z_i, z_{-i}) = \int g(\varepsilon_i)\left(1 - G(\varepsilon_i + z_i - z_{-i})\right)^{N-1} d\varepsilon_i$$

which decreases with i's disclosure

$$\frac{\partial p_i(z_i, z_{-i})}{\partial z_i} = -(N-1)\int g(\varepsilon_i)g(\varepsilon_i + z_i - z_{-i})\left(1 - G(\varepsilon_i + z_i - z_{-i})\right)^{N-2} d\varepsilon_i < 0$$

Models—Audit Tournament

– Normalizing all firms emissions to e=1, firms minimize:

$$\min_{z} \alpha z_i + p(z_i, z_{-i})\left\{\gamma + \beta \int_{z_i}^{d} (t - z_i) f(t) dt\right\}$$

FOC: $$\alpha + \frac{\partial p_i(z_i, z_{-i})}{\partial z_i}\left\{\gamma + \beta \int_{z_i}^{d} (t - z_i) f(t) dt\right\} - p(z_i, z_{-i})\beta \int_{z_i}^{d} f(t) dt = 0$$

– Symmetric Nash equilibrium disclosure level is implicitly defined by

$$\alpha + \left(\frac{\partial p_i(z_i, z_{-i})}{\partial z_i}|_{z_i = z_{-i}}\right)\left\{\gamma + \beta \int_{z_i}^{d} (t - z_i) f(t) dt\right\} - \frac{1}{N}\beta \int_{z_i}^{d} f(t) dt = 0$$

where $$\frac{\partial p_i(z_i, z_{-i})}{\partial z_i}|_{z_i = z_{-i}} = -(N-1)\int \left(g(\varepsilon_i)\right)^2 \left(1 - G(\varepsilon_i)\right)^{N-2} d\varepsilon_i$$

Models—Linear Relative Evaluation

– Firm *i*'s audit probability is function of the difference between *i*'s report and the average of other firms reports

$$p(z_i, z_{-i}) = P(\bar{z}_i - z_i)$$

- Number of audits not fixed
- *P* assumed linear, $\frac{\partial P}{\partial z_i} < 0$ constant
- symmetric audit probability, *P*(0), strictly positive

– Symmetric Nash equilibrium disclosure defined by

$$\alpha + \frac{\partial P}{\partial z_i}\left\{\gamma + \beta\int_{z_i}^{d}(t - z_i)f(t)dt\right\} - P(0)\beta\int_{z_i}^{d}f(t)dt = 0$$

Experimental Design

- Sessions of 20 players, 20 decisions periods, with players in groups of 5 randomly rematched after each period
- Players receive an endowment (varied to equalize overall earnings) and all have equal emissions ("output") of 20
- Players chose level of disclosure ("reported output") each period by selecting whole number between 0 and 40
- Per unit tax ("reporting cost") is $1

Experimental Design

– Players face one of three audit mechanisms
  - Tournament mechanism is implemented with errors drawn from uniform distribution on [-10,10]
  - LRE mechanism is implemented as

$$P_i = \begin{cases} P(0) + (\bar{z}_{-i} - z_i) & if\ (\bar{z}_{-i} - z_i) \in [-P(0), 1 - P(0)] \\ 1\ if\ (\bar{z}_{-i} - z_i) > 1 - P(0) \\ 0\ if\ (\bar{z}_{-i} - z_i) < -P(0) \end{cases}$$

  - This equates marginal effect of disclosure on audit probability at symmetric equilibrium across tournament and LRE, so predicted behavior is identical

Experimental Design

Parameter / variable	Description	Value(s)
β	Penalty	1 or 3
γ	Audit cost	0 or 40/3 (0 or 2/3)
p, k/N, $P(0)$	Eq. audit probability	20% or 60%
α	Tax	1
e	Emissions	20 (1)
t	Revealed emissions	*i.i.d.* Uniform[0, 40] (*i.i.d.* Uniform[0, 2])
ε	Regulator error	*i.i.d.* Uniform[-10, 10] (*i.i.d.* Uniform[-.5,1.5])

Note: values in parentheses correspond with normalization e=1.

DECISION SCREEN

Your actual output is **20**.

Your task is to choose how much output to report.

You can choose to report any amount between 0 and **40**.

Your reporting cost is equal to your reported output multiplied by **$1**.

Your chance of being audited depends on the difference between the average reported output
of the other players in your group and your reported output

If you are inspected you pay an inspection cost of **$13**.

If your estimated output is *greater* than your reported output, you pay a penalty equal to the amount you are estimated to have under-reported multiplied by **$1**.

Choose reported output

Proceed

RESULTS SCREEN

Your actual output was: **20**.

Your reported output was: **20.**

The average reported output for the other players in your group was: **21.75.**

You were not inspected, so you do not pay an inspection cost.

Your earnings for this period are:

$28 (Initial earnings)

\- **20.00** x **$1** $(Reporting cost)

\- 0 $(Inspection cost)

\- 0 $(Penalty)

= **$8.00**

Prior to the next period, you will be randomly matched with different players.

The Rest of Your Group

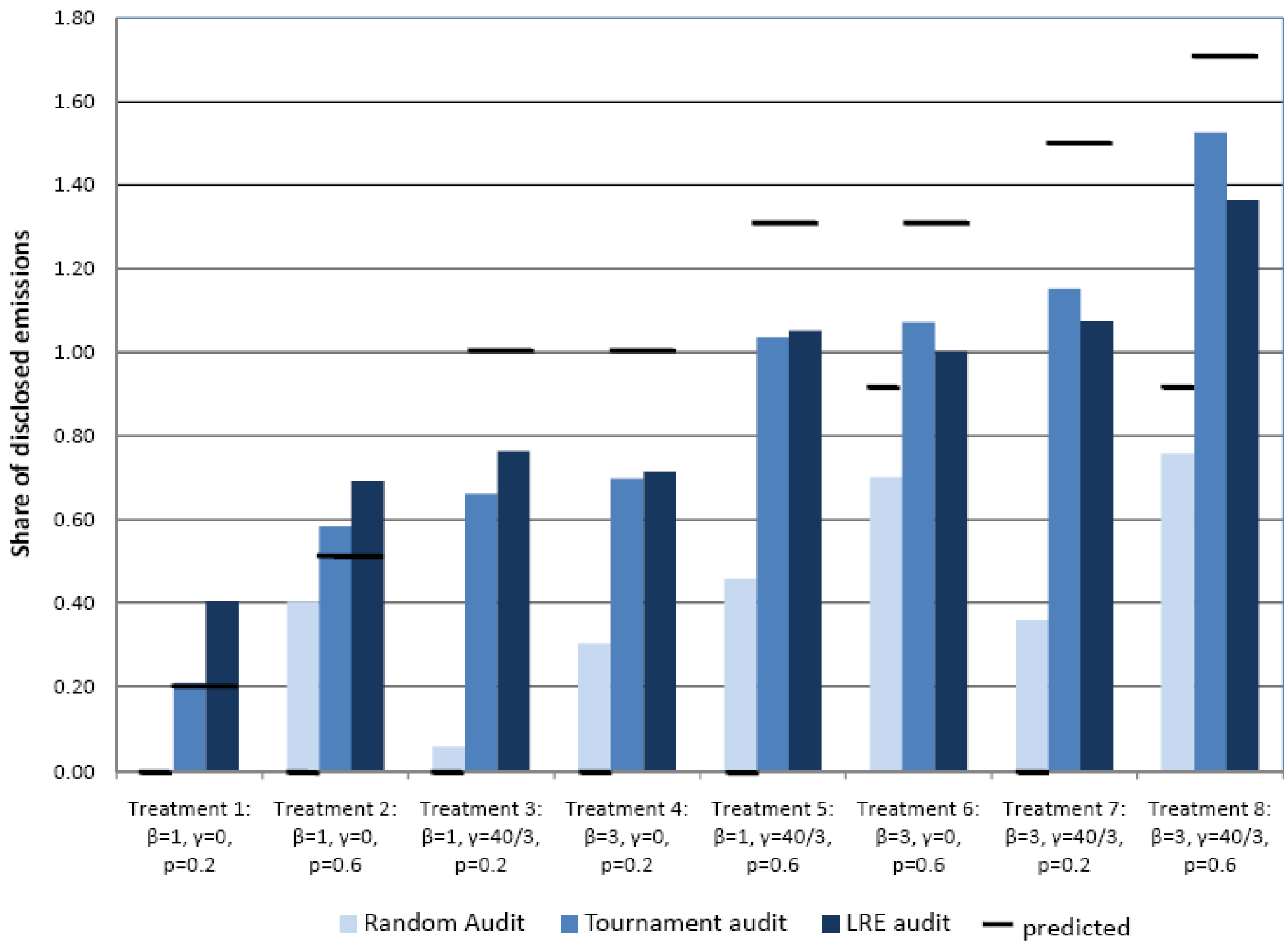
Subject Number	Reported Output	Inspected
2	27	N
4	15	Y
1	10	Y
5	35	N

Proceed

Experimental Design

- **Hypothesis 1**. Endogenous audits lead to higher disclosure than random audits.
- **Hypothesis 2**. Endogenous tournament and LRE audits generate equivalent disclosure.
- **Hypothesis 3**. Random audits: disclosure is invariant to inspection cost.
- **Hypothesis 4**. Endogenous audits: increasing the penalty, inspection cost, or audit probability increases disclosure.
- **Hypothesis 5**. Endogenous audits: increasing the penalty or inspection cost has an equivalent effect on disclosure.

Results



Share of disclosed emissions
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Treatment 1: β=1, γ=0, p=0.2
Treatment 2: β=1, γ=0, p=0.6
Treatment 3: β=1, γ=40/3, p=0.2
Treatment 4: β=3, γ=0, p=0.2
Treatment 5: β=1, γ=40/3, p=0.6
Treatment 6: β=3, γ=0, p=0.6
Treatment 7: β=3, γ=40/3, p=0.2
Treatment 8: β=3, γ=40/3, p=0.6
Random Audit
Tournament audit
LRE audit
predicted

	Mean disclosure rates			Difference of means		
	Random Audit	Tournament	LRE	Tournament = Random	LRE = Random	Tournament = LRE
Treatment 1: β=1, γ=0, p=0.2	0.004 (0.060)	0.208 (0.069)	0.403 (0.039)	0.204* (0.051)	0.400* (0.074)	-0.196* (0.082)
Treatment 2: β=1, γ=0, p=0.6	0.402 (0.079)	0.583 (0.076)	0.691 (0.050)	0.181* (0.079)	0.289* (0.093)	-0.108 (0.089)
Treatment 3: β=1, γ=40/3, p=0.2	0.060 (0.033)	0.661 (0.046)	0.764 (0.068)	0.601* (0.057)	0.704* (0.071)	-0.103 (0.081)
Treatment 4: β=3, γ=0, p=0.2	0.302 (0.056)	0.698 (0.036)	0.714 (0.067)	0.396* (0.066)	0.412* (0.069)	-0.016 (0.076)
Treatment 5: β=1, γ=40/3, p=0.6	0.458 (0.059)	1.037 (0.067)	1.052 (0.068)	0.578* (0.088)	0.594* (0.083)	-0.015 (0.094)
Treatment 6: β=3, γ=0, p=0.6	0.701 (0.065)	1.073 (0.041)	1.002 (0.077)	0.373* (0.076)	0.302* (0.087)	0.071 (0.085)
Treatment 7: β=3, γ=40/3, p=0.2	0.358 (0.060)	1.151 (0.066)	1.075 (0.041)	0.793* (0.067)	0.717* (0.071)	0.076 (0.076)
Treatment 8: β=3, γ=40/3, p=0.6	0.757 (0.066)	1.527 (0.077)	1.363 (0.049)	0.770* (0.083)	0.606* (0.082)	0.164 (0.091)

Results

Dependent variable: disclosure rate				
		Coefficient Estimates		
Variable	**Description**	**Random**	**Tournament**	**LRE**
High β	= 1 if β=3; = 0 if β=1	0.298* (0.060)	0.490* (0.073)	0.311* (0.070)
High γ	= 1 if γ=40/3; = 0 if γ=0	0.056 (0.062)	0.453* (0.065)	0.361* (0.066)
High p	= 1 if p=0.6; = 0 if p=0.2	0.399* (0.061)	0.376* (0.051)	0.288* (0.044)
Constant		0.004 (0.060)	0.208* (0.069)	0.403* (0.043)
Controls for order-effects?			Yes	
Controls for learning?			Yes	
R^2			0.88	
F			331.73*	
n			9600	

Results

- **Result 1**. All comparative statics of the audit mechanisms are confirmed.
- **Result 2**. Disclosure rates with endogenous audits are higher than with random audits. Further, with little qualification, tournament and LRE audits lead to similar disclosure rates.
- **Result 3**. For all audit mechanisms, when predicted disclosure rates are less than 1, there is a tendency of over-compliance; otherwise, when predicted disclosure rates are equal to or greater than 1, there is under-compliance.