Crime and Punishment.
Experimental Evidence on the Inspection Game.

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1. How is this puzzle solvable?
   In other words: What is the theoretical argument?

2. How is it possible to test the argument
   (a) with high construct validity
   (b) with high internal validity?

“Sentence severity and crime: Accepting the null hypothesis.“
(Doob & Webster, 2003)

“Penalty has no impact on crime”
(Tsebelis, 1990)
Economic model of crime (Becker, 1968)
Decision theoretic formulation
- Criminals as rational actors
- Higher punishment → less crime

Game theoretic model of crime: Inspection Game

<table>
<thead>
<tr>
<th>Criminal</th>
<th>Controller control</th>
<th>Controller not control</th>
</tr>
</thead>
<tbody>
<tr>
<td>crime</td>
<td>π₁, π₂</td>
<td>π₄, 0</td>
</tr>
<tr>
<td>no crime</td>
<td>0, π₅</td>
<td>0, 0</td>
</tr>
</tbody>
</table>

- Only mixed equilibria
- Criminals’ decision based on controller’s utility → punishment no impact on crime
- Controller’s decision based on criminal’s utility → punishment impact on control
- Conclusion: Interaction between criminals and controllers neglected so far
Review: Inspection Game (Tsebelis, 1989)

<table>
<thead>
<tr>
<th></th>
<th>Criminal</th>
<th>Controller</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>control</td>
<td>not control</td>
</tr>
<tr>
<td>crime</td>
<td>$\pi_1$</td>
<td>$\pi_2$</td>
</tr>
<tr>
<td>no crime</td>
<td>0</td>
<td>$\pi_3$</td>
</tr>
</tbody>
</table>

Extension: Welfare loss due to crime has to be incorporated in model because

(a) Theoretical model reflects better what we mean by crime
(b) Higher construct validity in experiment

However: Conclusions might be different

Extended inspection game:

2 "players" who can commit crime. Crime defined as welfare transfer, which

(a) increases player’s payoff on cost of other player’s payoff
(b) decreases collective welfare

1 controller for each "player" with:

(a) negative control costs
(b) positive net rewards for successful controls

Player:

- $s$: Welfare transfer
- $\gamma$: Welfare inefficiency; $0 < \gamma < 1$
- $p$: Punishment; $\gamma s < p$

Controller:

- $k$: control cost
- $r$: reward; $r > k$
### Theoretical analysis

**Payoffs**

$\sigma = \begin{pmatrix} P_1 \\ P_2 \\ C_1 \\ C_2 \end{pmatrix} (s_1, s_2, c_1, c_2) = \begin{pmatrix} \frac{s_1 \gamma s - c_1 p}{s_2 \gamma s - c_2 p} - s_2 s \\ \frac{s_2 \gamma s - c_2 p}{s_1 \gamma s - c_1 p} - s_1 s \\ c_1 (s_1 r - k) \\ c_2 (s_2 r - k) \end{pmatrix}$

**Best answers**

$s^*_i = \begin{cases} 1, & \gamma s > c_i p \\ [0, 1], & \gamma s = c_i p \\ 0, & \gamma s < c_i p \end{cases}, \quad s^*_2 = \begin{cases} 1, & \gamma s > c_2 p \\ [0, 1], & \gamma s = c_2 p \\ 0, & \gamma s < c_2 p \end{cases}$

$c_1 = \begin{cases} 1, & s_1 r > k \\ [0, 1], & s_1 r = k \\ 0, & s_1 r < k \end{cases}, \quad c_2 = \begin{cases} 1, & s_2 r > k \\ [0, 1], & s_2 r = k \\ 0, & s_2 r < k \end{cases}$

**Pure Nash equilibria**

$c_1 = 1 \Rightarrow s_1 = 0 \Rightarrow c_1 = 0 \Rightarrow s_1 = 1 \Rightarrow c_1 = 1 \Rightarrow s_1 = 0$

Result: No pure equilibria

**Mixed Nash equilibrium:**

$s^*_1 = s^*_2 = \frac{k}{r}, \quad c^*_1 = c^*_2 = \frac{\gamma s}{p}$

**In Words:**

- **Probability of crime:** Control costs / Reward
- **Probability of control:** Loot / punishment

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### Research Question

### Theoretical analysis

### Experimental Design

### Empirical Results
Subjects earn money in knowledge quiz

Subjects randomly split half into »players« and »controllers«

Each player randomly matched with one different player and controller each period

Players can take simultaneously money from personal account of the other

Controllers could invest control costs to reveal decision of matched player.

Conducted with Z-tree (Fischbacher) in computer lab

Experimental Design

2 Experiments:
1) Low punishment → High punishment (5 sessions à 20 subjects, 48 players, 48 controllers)
2) High punishment → Low punishment (5 sessions à 20 subjects, 50 players, 50 controllers)
### Parameters and information conditions

<table>
<thead>
<tr>
<th>Players</th>
<th>Low Punishment</th>
<th>High Punishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_1$ Loss victim</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>$\gamma$ crime inefficiency parameter</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>$\gamma_s$ Gain thief</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>$p_s$ Strength of punishment</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>Exchange Rate (Pt.-€)</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

### Controllers

<table>
<thead>
<tr>
<th></th>
<th>Low Punishment</th>
<th>High Punishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_c$ Control costs</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>$r_c$ Reward successful control</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Exchange rate (Pt.-€)</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

### Experimental Design

#### Predictions

\[
\delta_1^* = \delta_2^* = \frac{k}{r} = \frac{5}{10} = 0.5 \\
\gamma_s = \frac{\gamma s}{p} = \frac{5}{6} = 0.8 \\
\gamma_s = \frac{\gamma s}{p} = \frac{5}{25} = 0.2
\]

Prediction 1: Theft rate $\rightarrow 0.5$ all 30 periods

Prediction 2: Control rate $\rightarrow 0.8$ low punishment condition $\rightarrow 0.2$ high punishment condition
Subjects

- 5 Euro show up fee + 5 Euro stakes in average
- 196 subjects
- Randomly chosen from address pool of 692 students from various fields from the University of Leipzig
- Randomly allocated to one experimental session
(1) Description of welfare dynamic over time
(2) Static analysis of mixing
Empirical Results

(3) Dynamic analysis of mixing:
Learning dynamic results in convergence towards Nash equilibria
(Macy, 1991; Roth & Erev, 1995; Fudenberg & Levine, 1998; Macy & Flache, 2002)
Empirical Results

Theft for low and high punishment
Experiment 1: Low punishment first

Theoretical prediction
Observed values
Regression prediction

Low Punishment
(Net Punishment = 1 Pt.)
High Punishment
(Net Punishment = 20 Pts.)

Period

Theft rate
Empirical Results

Theft for low and high punishment
Experiment 1: Low punishment first

Control for low and high punishment
Experiment 1: Low punishment first
Empirical Results

Control for low and high punishment
Experiment 1: Low punishment first

Period

Low Punishment (Net Punishment = 1 Pt.)
High Punishment (Net Punishment = 20 Pts.)

Theoretical prediction
Theoretical prediction

Observed values
Observed values

Regression prediction
Regression prediction

Experiment 1: Low punishment first
Control for low and high punishment
Empirical Results

Theft for low and high punishment

Experiment 2: High punishment first

Period

Theft rate

High Punishment
(Net Punishment = 20 Pts.)

Low Punishment
(Net Punishment = 1 Pt.)

Theoretical prediction

Theoretical prediction

Observed values

Observed values

Regression prediction

Regression prediction

Experiment 2: High punishment first

Theft for low and high punishment

Period

Theft rate

High Punishment
(Net Punishment = 1 Pt.)

Low Punishment
(Net Punishment = 20 Pts.)

Theoretical prediction

Theoretical prediction

Observed values

Observed values

Regression prediction

Regression prediction
Empirical Results

Theft for low and high punishment
Experiment 2: High punishment first

Control for low and high punishment
Experiment 2: High punishment first
Empirical Results

Control for low and high punishment
Experiment 2: High punishment first

Period

Control rate

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

High Punishment
(Net Punishment = 20 Pts.)

Low Punishment
(Net Punishment = 1 Pt.)

Theoretical prediction

Theoretical prediction

Observed values

Observed values

Regression prediction

Regression prediction

Experiment 2: High punishment first
Control for low and high punishment
Empirical Results

Regression Models for Theft and Control

<table>
<thead>
<tr>
<th>Model</th>
<th>Theft</th>
<th>Control</th>
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<tbody>
<tr>
<td>Intercept</td>
<td>0.69 *</td>
<td>0.58 *</td>
</tr>
<tr>
<td></td>
<td>(22.18)</td>
<td>(19.14)</td>
</tr>
<tr>
<td>High Punishment</td>
<td>- 0.21 *</td>
<td>- 0.15 *</td>
</tr>
<tr>
<td></td>
<td>(- 12.53)</td>
<td>(- 8.36)</td>
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<tr>
<td>First low punishment</td>
<td>- 0.16 *</td>
<td>- 0.11 *</td>
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<tr>
<td></td>
<td>(- 4.99)</td>
<td>(- 3.44)</td>
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<tr>
<td>Period / 15 (First low punishment)</td>
<td>0.19 *</td>
<td>0.10 *</td>
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<tr>
<td></td>
<td>(4.50)</td>
<td>(2.40)</td>
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<tr>
<td>Period / 15 (First high punishment)</td>
<td>- 0.00</td>
<td>0.05</td>
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<tr>
<td></td>
<td>(- 0.12)</td>
<td>(1.27)</td>
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<tr>
<td>Random intercept</td>
<td>0.0183</td>
<td>0.0142</td>
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<tr>
<td>Random period</td>
<td>0.0005</td>
<td>0.0004</td>
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* significant at 5%, t-values in parentheses

Conclusions

1. Higher punishment → less control
2. Higher punishment → less crime
3. Controllers insensitive:
   Control too little for low punishment and too much for high punishment
4. Criminals sensitive:
   Adapt to inefficiency of controllers
5. Efficient policy: High control incentives
Next steps:

1. Do higher control incentives result in less crime?
   → 2nd Experiment on variation of reward levels

2. Improvement of measurement
   (a) Metric measurement of crime & control: “Frequentistic” design
   (b) More periods
   → 3rd Experiment

Pilotstudy: Frequentistic Inspection Game

Player 1 ($S_1$)

Controller 1

<table>
<thead>
<tr>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
<th>S8</th>
<th>S9</th>
<th>S10</th>
<th>S11</th>
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Pilot study (n=44)
Preliminary Conclusion for frequentistic design

1. Frequentistic design allows for more precise testing of mixing hypotheses

2. Low punishment results in positive “balance” while high punishment results in negative “balance” for both parties