UNIVERSITY OF TRENTO

SECONOMICS

Effective Enforcement Strategy in the Implementation of Security Regulations

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Security protection is…

Background

- The accident on 11 September 2001 have resulted in major modifications in security standards and their implementation.
- While various security standards and regulations have been enacted to increase the level of security, relatively little attention has been paid to effective enforcement strategies.

Background (cont'd)

- National and international aviation security agencies
  - Regarding aviation security, various national and international agencies (e.g., ICIO and ECAC) perform monitoring and regulatory activities.
  - One of the primary goals of these agencies is the prevention of damage due to security incidents through a variety of preventive and investigative enforcement efforts.

Background (cont'd)

- Stakeholders in the aviation industry have the distinct nature in their security environment.
- The stakeholders must take into account their own budget constraints.
- This is why it is difficult to develop and design an appropriate enforcement strategy

Background (cont'd)

- In addition, due to the noncontractibility of the security-related effort (and moral hazard), designing an enforcement strategy which results in optimal effort and expenditure would be very difficult.

How the national and international security agencies can design and implement an enforcement strategy to elicit optimal level of security-related effort by the stakeholders

Activities of government agencies

Before incidents

- Ex ante inspections and monitoring
- Act-based sanctions depending on violations

After incidents

- Ex post detections and investigations
- Harm-based sanctions based on damage and recovery costs

Activities of government agencies (Cont'd)

- Internal resource allocation to solve two problems
  - The enforcement of ex ante compliance
  - The ex post detection and penalizing of an occurred security incident
- But, which one is better?
  - It seems that ex ante inspections dominate the industry

The economic model presented here will theoretically investigate how to design an optimal enforcement strategy.

Economic model: Assumptions

- An airport's security-related activities, e, are private information and is not fully observed by the government agency.
- A security incident, x, is a stochastic externality. This can be considered as the size of an occurred incident. We assume that it has cumulative distribution function $\mathrm{F}(x, e)$, where e shifts the distribution: $F(x, e_1) < F(x, e_2)$ if $e_2 > e_1$.
- Both the government agency and airports are risk neutral.

Ex Post Detection Only

- The airport will choose e to maximize expected profit:

$$E\mu(e) = -\int_x \{v(x) + P_D(x, m_1) \cdot T_D(x)\} f(x, e) dx - e,$$

where m_1 is the resources expended by the government agency, $v(x)$ is private loss, $P_D(x, m_1)$ is the probability that x is detected, and $T_D(x)$ is a penalty if detected.

- The social welfare-maximizing government agency, cognizant of the fact that airports maximize the expected profit, chooses the function $T_D(x)$ to maximize its expected welfare:

$$EW(e, m_1) = -\int_x \{v(x) + D(x) + C(x)\} f(x, e) dx - e - m_1,$$

where $D(x)$ is the damage function caused by an incident and $C(x)$ is the recovery cost function.

Ex Post Detection Only (cont'd)

- If an airport's level of security investment were contractible and perfectly observable, a first-best solution to the problem would be to set $m_1 = 0$, and choose e to satisfy the first-order condition: the marginal expected social benefit of increasing e by one unit equals its marginal cost.

$$-\int_x \{v(x) + D(x) + C(x)\} f_e(x, e) dx = 1$$

- If e is not contractible, first-best solution can be derived by imposing the penalty (harm-based sanctions) given by:

$$T_D(x) = \frac{D(x) + C(x)}{P_D(x, 0)}$$

where and $T_D(x)$ is a penalty if an incident is detected, $P_D(x, 0)$ is the probability that x is detected, $D(x)$ is the damage function caused by an incident and $C(x)$ is the recovery cost function

Ex Post Detection Only (cont'd)

- The penalty function $T_D(x) = \frac{D(x) + C(x)}{P_D(x,0)}$
  - $P_D(x,0) > 0$: the social optimum may be achieved without expending any resources towards detection.
  - If $P_D(x,0) > 0$ is not viable, for example, x is very small, a positive level of ex post detection spending is desirable.
  - Where $P_D(x,0)$ is very low, the optimal penalty, once detected, becomes extremely high. This implies that, to induce airports to take the socially optimal level of security care, penalties increase as the probability of detection decreases.
- If there are no limits to liability (i.e., if an airport does not have an upper limit on its budget), the penalty function may well be satisfied in practice even for extremely large security incidents.

Ex Ante Inspections Only

- Assume that the government agency only uses ex ante inspections designed to reveal violations of regulations and standards.
- With the spending, m_2, the inspections technology reveals the number of security violations, v, with probability $P_I(v, m_2)$. We assume that no inspections reveal no violations, so $P_I(v, 0) = 0$.
- The number of violations, v, depends stochastically on security-related activities, e, given by a c.d.f. $G(v, e)$, with $G(v, e_1) < G(v, e_2)$ for $e_2 > e_1$.

Ex Ante Inspections Only (Cont'd)

- An airport chooses e to maximize expected profit:

$$E\mu(e) = -\int_x P_I(v, m_2) \cdot T_I(v) g(v, e) dv - e,$$

where $T_I(v)$ is a penalty function based on the number of violations detected.

- The government agency, cognizant of the fact that airports maximize expected profit, chooses the function $T_I(v)$ to maximize its expected welfare:

$$EW(e, m_2) = -\int_v [\int_x [D(x) + C(x)] p(x, v) dx] g(v, e) dv - e - m_2,$$

where $p(x, v)$ is the **predictive density** of x given v. This is because information about v (probabilistically) reveals the condition of the airport and helps in predicting incidents .

- A first-best solution given by the following optimal penalty function is possible (act-based sanctions):

$$T_I(v) = \frac{\int_x [D(x) + C(x)] p(x, v) dx}{P_I(v, m_2)}$$

Harm-based vs. act-based sanctions

- While both harm-based and act-based sanctions can be used to achieve the social optimum, **a large part of the government agency budget is spent on ex ante inspections and less on ex post detections**.

Need to understand why act-based sanctions are preferred over harm-based sanctions.

Why act-based sanctions are preferred?

- First, because of the predictive density term (p(x,v)) in act-based penalty function, it needs not be as high as harm-based penalties to accomplish a given level of security-related activities, e. This is attractive to the government agency because it relaxes the participation constraint on airports.
- Second, if every airport were subject to the optimal penalty according to harm-based sanctions, the possibility of a huge damage may well be sufficient to keep airports from complying with regulations.
- Third, it may be desirable to determine how well airports maintain their security rather than detect an incident since an incident can cause huge damage.

In reality, however,

- There are institutional constraints on imposing high penalties on the basis of v. That is, even if ex ante inspection expenditures, m_2, can be low and the penalty, $T_I(v)$, can be high, the opposite occurs in reality. This implies that optimality requires expending more m_2 to raise $P_I(v, m_2)$, thereby lowering the optimal act-based penalty.
- In addition, there is uncertainty inherent in the predictive density $p(x, v)$. The variance on the optimal penalty may be too high to justify the optimal penalty function.
- These two facts discourage policymakers to use penalties on v.
- **The question is: Do we need to combine ex ante inspections and ex post detections?**

Why combine sanctions?

- There are at least two reasons for why optimal policy may combine both harm-based and act-based sanctions
  - Act-based sanctions only: as explained, some facts may inhibit the use of ex ante sanctions
  - Harm-based sanctions only:
    - If liabilities were unlimited, the government would choose only optimal ex post penalties since the elimination of m_2 (ex ante compliance inspections) would result in substantial savings and they would need to spend only minimally on m_1 (ex post detections) – just enough that the probability of detection is positive.
    - In reality, however, there is limits on institutional liability and the government additionally need to use ex ante penalties to prevent damages that exceed what is recoverable by law.

Preliminary Conclusions

- Theoretically, the use of act-based penalties based on ex ante inspections is attractive due to the high payoffs at a small cost. However, there are several limitations in using act-based penalties.
- It would therefore be an optimal contract to use a harm-based penalty ($T_D(x)$) to the extent possible, and then an act-based penalty when it is no longer possible to contract on the amount of damage from incidents ($T_I(v)+T_D(x)$).

Thank you!!!