How Many Containers to Inspect to Deter Terrorist Attacks

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Introduction

- Department of Homeland Security recently announced 100% container screening at several large overseas ports
- Retailers claim that the policy will hinder product transportation:
  - Resulting in higher product prices
- If the US is concerned about deterring terrorist attacks:
  - How many containers should be inspected?
- We develop a method to answer this question using game theory

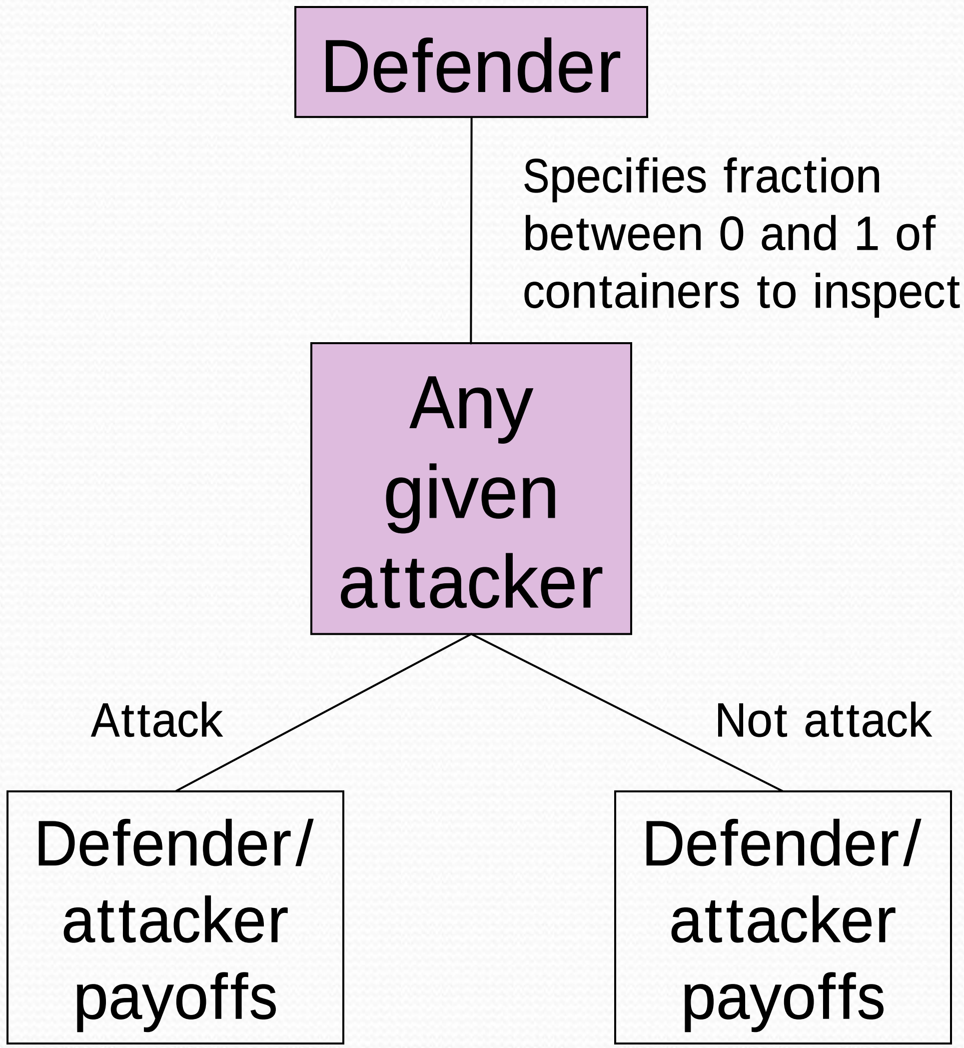
Assumptions

- We adapted a model by Dighe et al.:
  - Attacks can be deterred with less than 100% inspection
  - Provided that the defender discloses the overall level of defense
  - (But not the detailed defensive allocation)
- We consider multiple attackers:
  - Each trying to smuggle in a particular weapon type
  - E.g., dirty bombs versus nuclear weapons
- An “attack” is defined to be a smuggling attempt:
  - Regardless of whether the attempt succeeds

Assumptions (cont'd)

- Containers are assumed to be homogeneous
- The cost of inspecting a container is assumed to be the same regardless of whether it contains a weapon
- The cost of a smuggling attempt is assumed to be the same regardless of whether it succeeds:
  - The cost of unsuccessful smuggling attempts is what makes deterrence with less than 100% inspection possible!
  - (This does not include the cost of any possible retaliation)
- The same inspection technology can detect multiple types of attacks

Model Illustration



Notation

$\boldsymbol{n}$ = Number of containers inspected

$\boldsymbol{N}$ = Total number of containers

$\boldsymbol{m}$ = Number of attacker types

$\boldsymbol{V_i}$ = Expected damage if attacker i successfully smuggles a weapon into US

$\boldsymbol{p_i}$ = Probability of successfully detecting a weapon smuggled by attacker i

$\boldsymbol{I_i}$ = Indicator function:
Equals 1 if attacker i decides to attack, 0 if otherwise

$\boldsymbol{C_d}$ = Inspection cost per container

$\boldsymbol{C_i}$ = Cost of a smuggling attempt by attacker i

Mathematical Model

- The defender is assumed to minimize expected losses, as given by:

$$\min_{n=1,\dots,N}\left\{\sum_{i=1}^{m}\left[\underbrace{V_i\left(1-\frac{n}{N}p_i\right)I_i}_{\text{Expected damage caused by attacker } i}\right]+\underbrace{nC_d}_{\text{Inspection cost}}\right\}$$

- Attacker i is assumed to maximize expected reward, as given by:

$$\max_{I_i=0,1}\left\{\left[\underbrace{V_i\left(1-\frac{n}{N}p_i\right)}_{\text{Expected reward to attacker } i}-\underbrace{C_i}_{\text{Cost of an attack}}\right]I_i\right\}$$

Attacker's Optimal Decision

- Consider attacker i's optimal decision first
- Attacker i will attack if $n \leq \frac{N}{p_i}\left(1 - \frac{C_i}{V_i}\right)$, and not otherwise
- Attacker i will always attack with:
  - Sufficiently low detection probability, p_i
  - Sufficiently low attack cost, C_i
  - Sufficiently high expected damage given a successful attempt, V_i

Two-Attacker Example

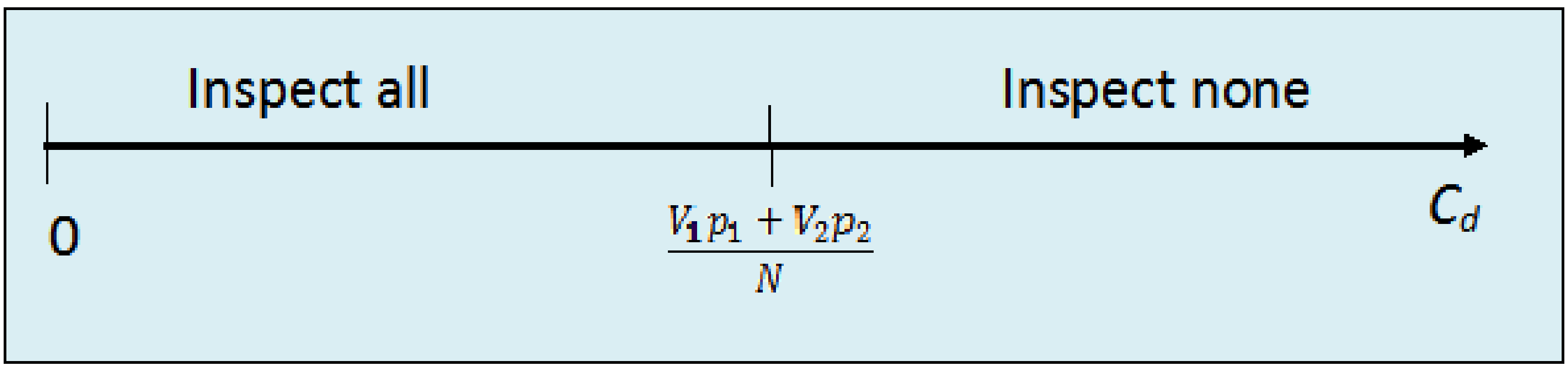
- Consider two attackers:
  - Each attempting to smuggle in a particular type of weapon
- We consider three possible scenarios (based on attack costs):
  - Neither attacker can be deterred with less than 100% inspection when both attack costs are small
  - Attacker 1 can be deterred, but not attacker 2 when the attack cost to attacker 1 is small, but the attack cost to attacker 2 is large
  - Both attackers can be deterred with less than 100% inspection when both attack costs are large

Neither Attacker Can Be Deterred

- The defender should inspect no containers if

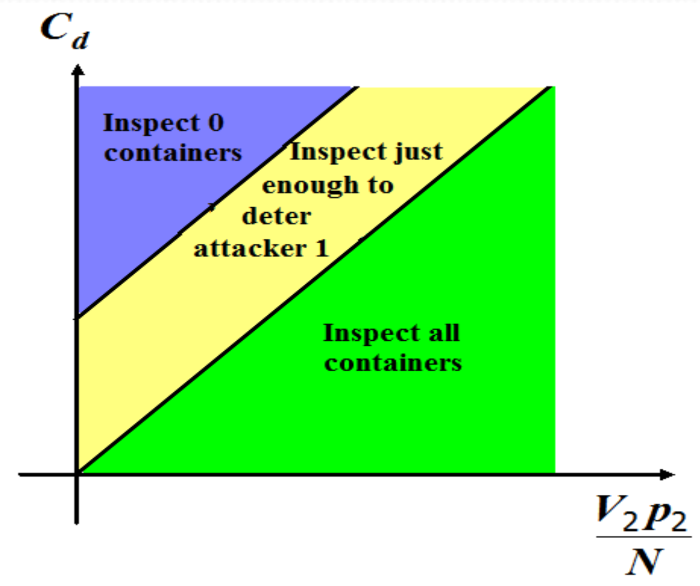
$$\frac{V_1 p_1 + V_2 p_2}{N} \leq C_d$$

and 100% of all containers otherwise



Only Attacker 1 Can Be Deterred

- The defender's optimal strategy depends on:
  - The inspection cost per container, C_d
  - The expected damage from a successful smuggling attempt, V_2
  - The detection probability for the undeterred attacker, p_2
  - Total number of containers, N

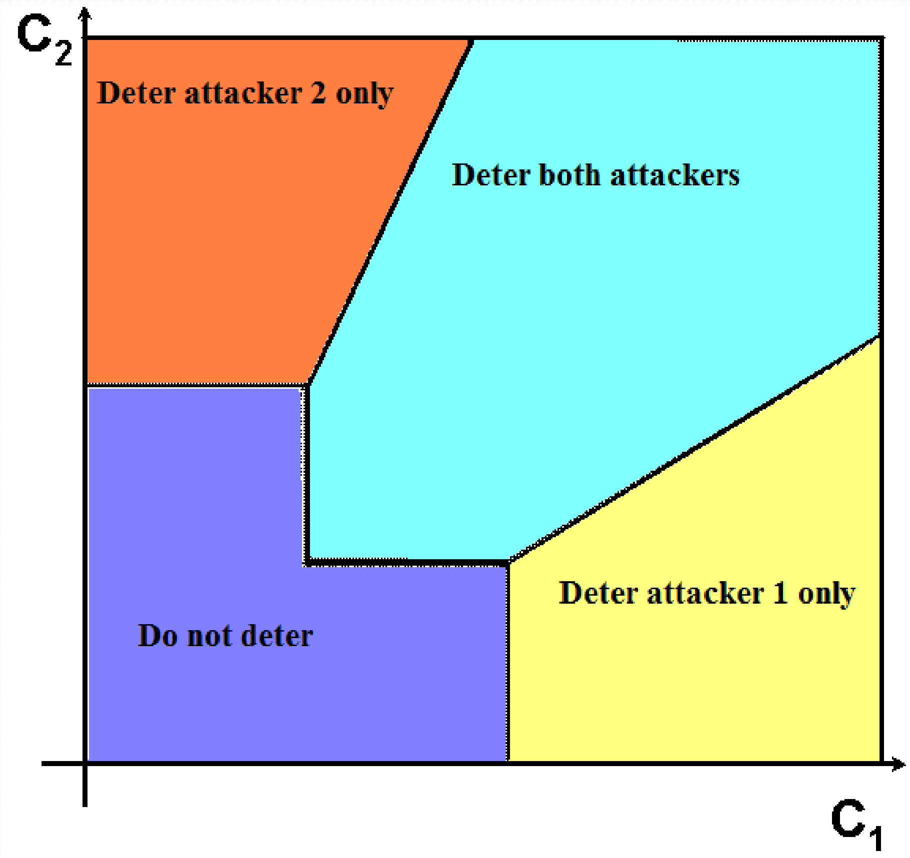


Both Attackers Can Be Deterred

- 100% inspection is not desirable:
  - Since both attackers can be deterred with less inspection effort
- However, the required inspection level might be virtually 100%:
  - Especially if the detection probability is low
- We identify the defender's optimal strategies as a function of:
  - The attack costs, C_1 and C_2
  - The detection probabilities, p_1 and p_2

Optimal Defender Strategies

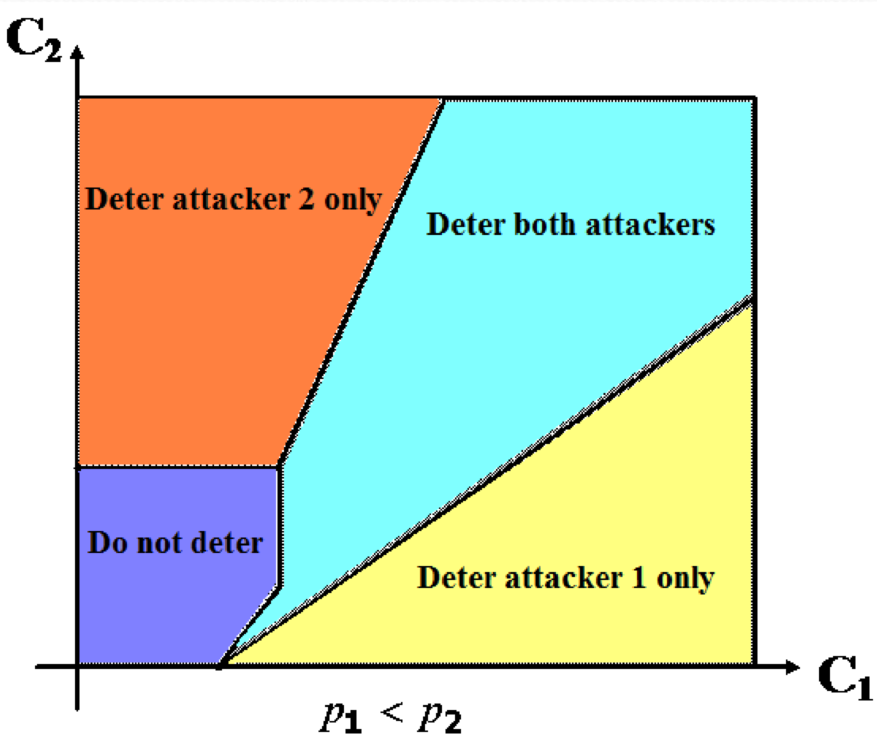
Case 1: Inspection cost extremely large

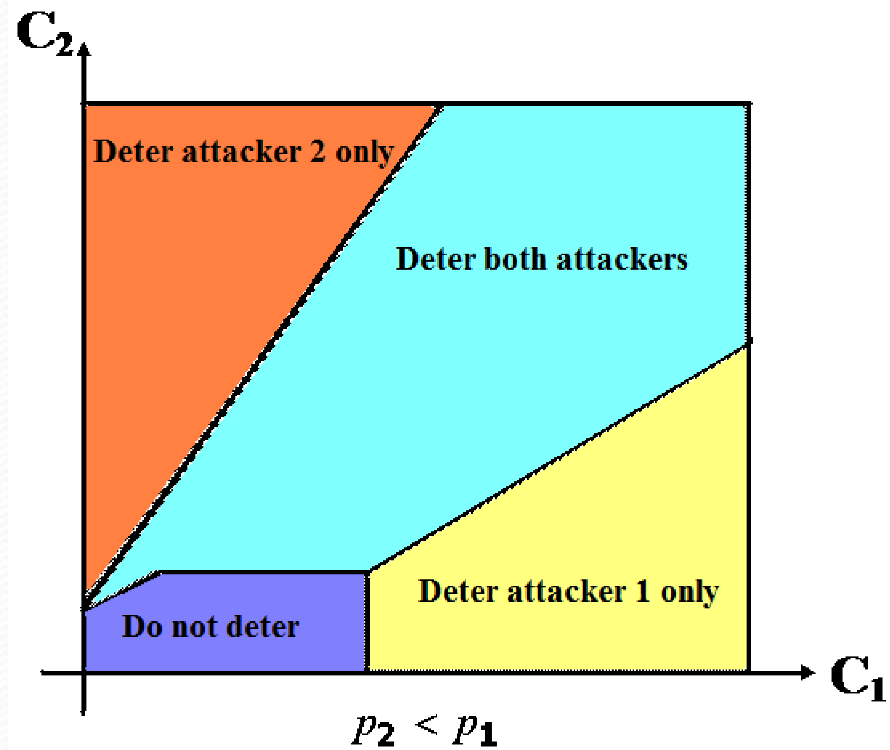


- Do not inspect when the attack costs are too low to achieve deterrence
- Deter only attacker *i* when that attacker's cost is relatively high
- Inspect enough to deter both attackers when attack costs are high

Optimal Defender Strategies

Case 2: Inspection cost moderately large



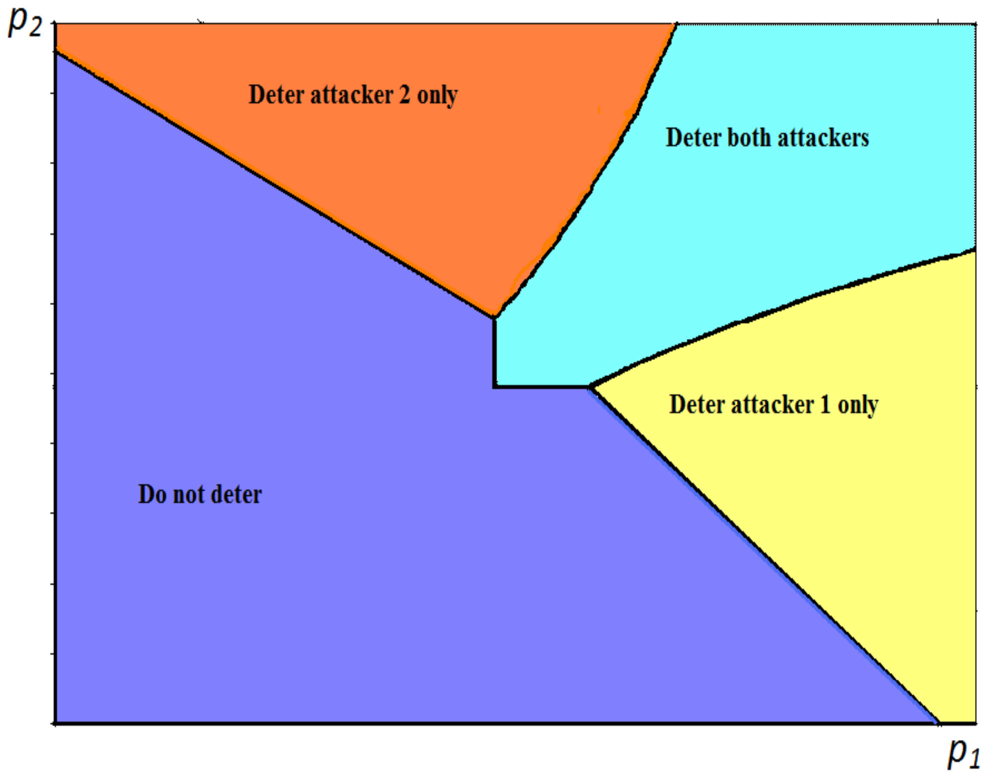


- Attacker *i* can be deterred even with arbitrary small attack cost if:
  - The inspection cost required to deter the other attacker is almost sufficient to also deter attacker *i*
  - The probability of detection is sufficiently large

Smaller Inspection Costs

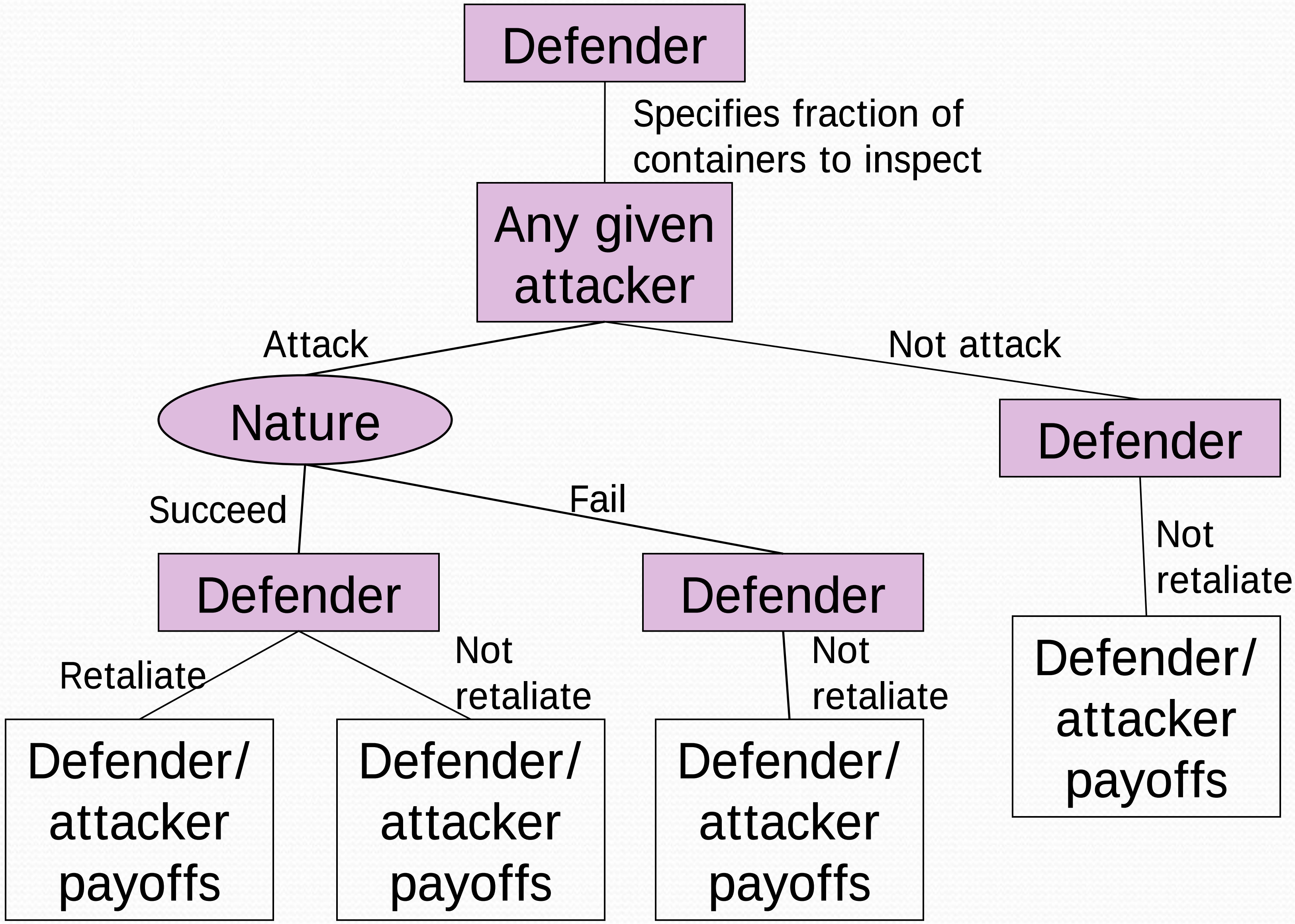
- The “do not deter” region becomes undesirable
- At least one attacker will always be deterred at optimality
- Defender will deter both when the attack costs are comparable:
  - Otherwise, deter the attacker with the higher attack cost
  - (Relative to the detection probability and expected damage for that type of attacker)

Optimal Defender Strategies as a Function of Detection Probabilities



- Do not inspect when the detection probabilities are too low to achieve deterrence:
  - But 100% inspection may still be optimal, to detect undeterred attacks
- Deter only attacker *i* when that attacker's cost is relatively high
- Inspect enough to deter both attackers when both attack costs are high

Model with Retaliation



Model with Retaliation

- Defender minimizes expected losses, as given by:

$$\min_{n=1,\ldots,N} \left\{ \sum_{i=1}^{m} \left[(V_i + R_{d_i} D_i)(1 - \frac{n}{N} p_i) I_i \right] + nC_d \right\}$$

- Attacker *i* maximizes expected reward, as given by:

$$\max_{I_i=0,1} \left\{ \left[(V_i - R_{a_i} D_i)(1 - \frac{n}{N} p_i) - C_i \right] I_i \right\}$$

R_{d_i} = Cost of retaliation against attacker *i* to the defender
R_{a_i} = Cost of retaliation to attacker *i*
D_i = Indicator function:
1 if defender retaliates against attacker *i*
0 otherwise

Retaliation

- The model depends critically on the idea of "credible threat":
  - Attackers must believe that the defender will retaliate
  - Even if that is no longer advantageous after an attack
- Otherwise, attackers will treat the threat as "cheap talk"
- To ensure a credible threat, one can assume a repeated game:
  - With sufficiently high damage V_i

Analysis of Results

- Results indicate that the threat of retaliation (if credible) reduces how many containers must be inspected to deter attacks
- Retaliation also makes it possible to deter some attackers who cannot be deterred in the previous model:
  - Especially when retaliation is sufficiently costly to those attackers
- The model recommends retaliation against all deterred attackers:
  - In order to reduce inspection costs
- However, this may not be credible for attackers with low V_i:
  - Since future attacks will not be sufficiently damaging to justify retaliation

Defender's Strategies

- The defender's strategy is of the form (d_a, r_b)

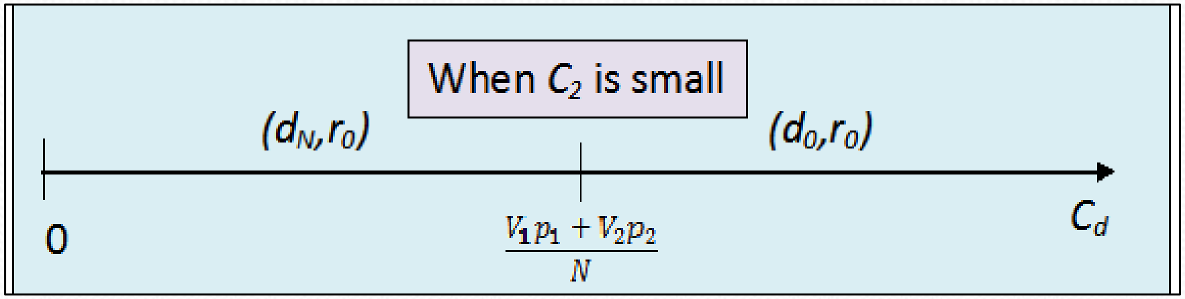
where $d_a \in D = \{d_0, d_1, d_2, d_N\}$ gives the level of inspection

$r_b \in R = \{r_0, r_1, r_2, r_{12}\}$ gives the retaliation policy

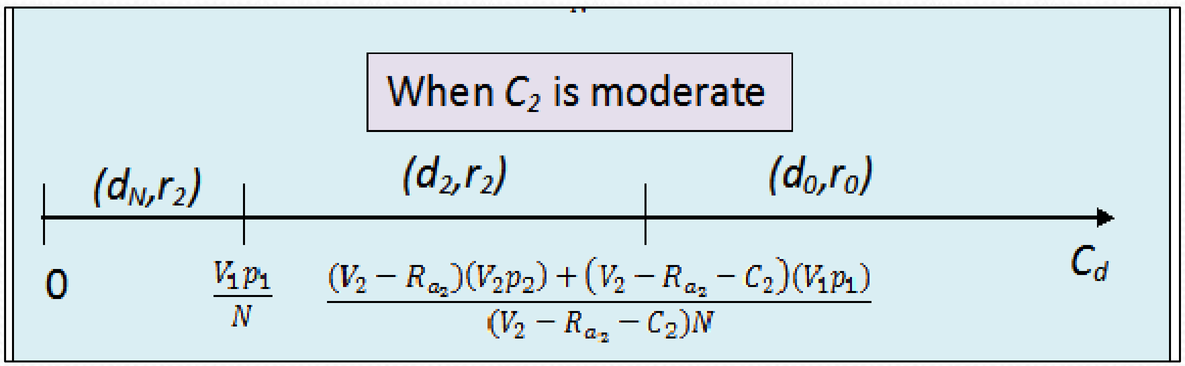
d_0 = Inspect no containers
d_1 = Inspect exactly enough to deter attacker 1
d_2 = Inspect exactly enough to deter attacker 2
d_N = Inspect all containers

r_0 = Not retaliate
r_1 = Retaliate against attacker 1
r_2 = Retaliate against attacker 2
r_{12} = Retaliate against both attackers

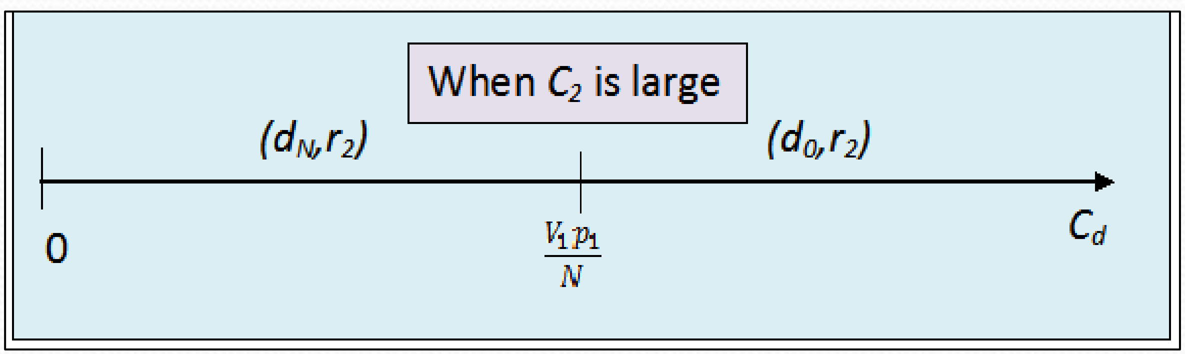
Optimal Defender Strategies for C_1 Small



Inspect all or none; Don't deter



Deter attacker 2 or no attackers; Inspect all if not too costly



Deter attacker 2 by retaliation alone; Inspect all if not too costly

Analysis of Results

- If the attack cost to attacker *i* is small:
  - The defender should not try to deter attacker *i*
- If the attack cost to attacker *i* is moderate:
  - The defender should inspect enough to deter attacker *i*
  - And also threaten to retaliate against that attacker
  - (Assuming a credible threat)
- If the attack cost to attacker *i* is large:
  - The defender can deter attacker *i* by threat of retaliation alone
  - (100% inspection may still be optimal, to detect other attackers)

Conclusions

- 100% inspection might not be necessary if the most severe attacks can be deterred with less inspection effort:
  - Especially if technology yields high detection probabilities
- Deterrence will be easier for attackers with high attack costs:
  - Deterring someone attempting to smuggle in a nuclear bomb may require much lower levels of inspection than deterring someone attempting to smuggle in a dirty bomb or assault rifle

Conclusions (cont'd)

- Retaliation, if credible, decreases the needed inspection effort:
  - Threat of retaliation alone may be enough to deter some attackers!
- Deterrence could result in attacks being deflected elsewhere:
  - Overland smuggling attempts from Canada or Mexico
  - Attacks against US interests outside of the US

Extensions

- Model has been extended to the case of multiple attackers:
  - Results are generally consistent with the case of two attackers
- Other possible extensions:
  - Allow for heterogeneous containers
  - Take into account the effects of inspection effort on product prices
  - Consider trade-offs between border security and target hardening

Acknowledgment

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Further questions/comments?

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