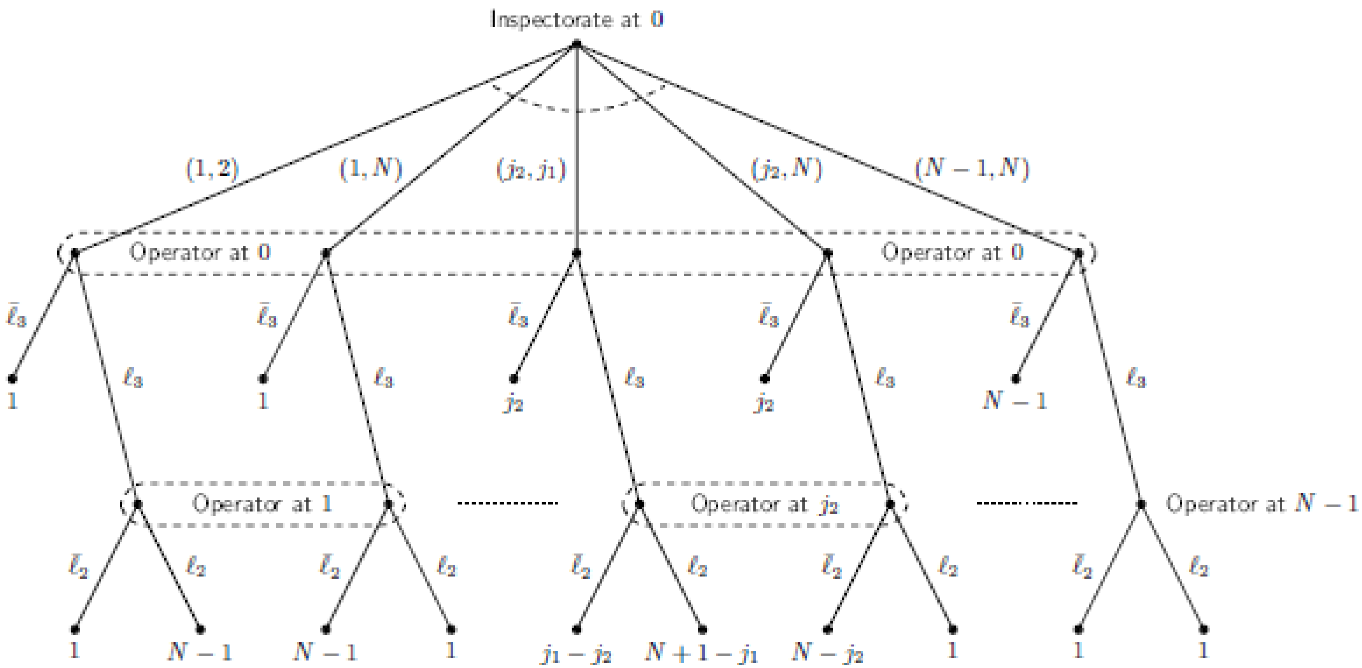

OPTIMAL SCHEDULING OF INSPECTIONS: MODELS AND APPROACHES

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CONTENT

- What is an inspection game?
- Probabilistic models for random inspection schemes
  - Assumptions
- Two inspection games:
  - Operator´s illegal behavior has to be detected within a critical time
  - They differ by only one assumption
    - Expected number of inspections
    - Fixed number of inspections
- Effectiveness and efficiency considerations

WHAT IS AN INSPECTION GAME?

- It is …
  - a mathematical model of a conflict situation between
  - Inspectorate and Operator (person, organization, State), where
  - the Inspectorate verifies that the Operator adheres to certain agreed rules, formal agreements or an international treaty
- The Operator may have an interest in violating these rules/ agreements/treaty where it must be assumed that an illegal behavior is planned strategically.
- This defines a game theoretical problem between an Operator and the Inspectorate.

PROB. MODELS FOR RANDOM INSP. SCHEMES

Classification of assumptions

- *Inspection philosophy:* What is the objective of the random inspection scheme?
  - playing for time vs. critical time
- *Time:* When does the Inspectorate performs its inspections and when does the Operator behaves illegally?
  - continuous time vs. discrete time
- *Planning:* How does the Inspectorate and the Operator plan their inspections resp. the illegally behavior?
  - non-sequentially vs. sequentially
- *Sampling:* Which statistical errors may occur during inspection?

# of inspections: Fixed #, expected #, at least … #

TWO INSPECTION GAMES

Assumptions (1)

- There are two players: Operator and Inspectorate
- The Inspectorate performs k inspections at steps $L, L-1, \ldots, 1$

Model 1	Model 2 (Thomas-Nisgav insp. game)
k: expected number of inspections	k: fixed number of inspections

- The Operator behaves illegally exactly once at one of the steps $L, L-1, \ldots, 1$.

TWO INSPECTION GAMES

Assumptions (2)

- During an inspection the Inspectorate may commit a statistical error of the second kind with probability β
- The number k of inspections is known to the Operator
- At each step/event both players decide independently of each other
  - whether to behave illegally at that step (if not behaved illegally before) and
  - whether to inspect at that step (if inspections are left).

  - Asymmetric information situation: Operator can observe the Inspectorate's behavior.

TWO INSPECTION GAMES

Assumptions (3)

- The payoffs to both players (Operator, Inspectorate) are given by

$(1, -1)$	for untimely inspection or timely inspection and no detection of the illegal behavior
$(-1, 1)$	for timely inspection and detection of the illegal behavior

  i.e. zero-sum games are considered.

- The game ends either after an inspection at which the illegal behavior is detected or after step 1.

TWO INSPECTION GAMES

Game theoretical solution

- Optimal strategy: no player has an incentive to deviate from

	model 1	model 2
Operator: optimal probability for behaving illegally at step ℓ	$\frac{1}{\ell}$	
Inspectorate: optimal probability to inspect at step ℓ	$\frac{k}{L}$	$\frac{k'}{\ell}$ k': # of inspections left at step ℓ
$\mathbb{P}^*_{L,k}(\text{detection of the illegal behavior})$	$(1-\beta)\,\frac{k}{L}$	

- Comments:
  - Higher costs/effort might be associated with model 1
  - No deterrence effect in model 2 (because k fixed)
  - $k \in \mathbb{N}$ only possible in model 1

EFFECTIVENESS AND EFFICIENCY

Definitions and results

- If we define:
  - IAEA safeguards is effective if the equilibrium strategy of the State is legal behavior (i.e. deterrence from behaving illegally) in the sense of the purpose of the inspections.
  - an equilibrium strategy of the IAEA is efficient if the legal behavior equilibrium is achieved at minimum cost.

- State's utilities

d	for untimely inspection or timely inspection and no detection of the illegal behavior
$-b$	for timely inspection and detection of the illegal behavior
0	for legal behavior

- IAEA safeguards is effective if and only if

$$\underbrace{(1-\beta)\,\frac{k}{L}}_{\text{technical parameters}} > \underbrace{\frac{1}{1+b/d}}_{\text{political parameters}}$$

THANK YOU FOR YOUR ATTENTION

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