Harnessing enforcement leverage at the border to minimize biological risk from international live species trade

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Harnessing enforcement leverage at the border to minimize biological risk from international live species trade☆

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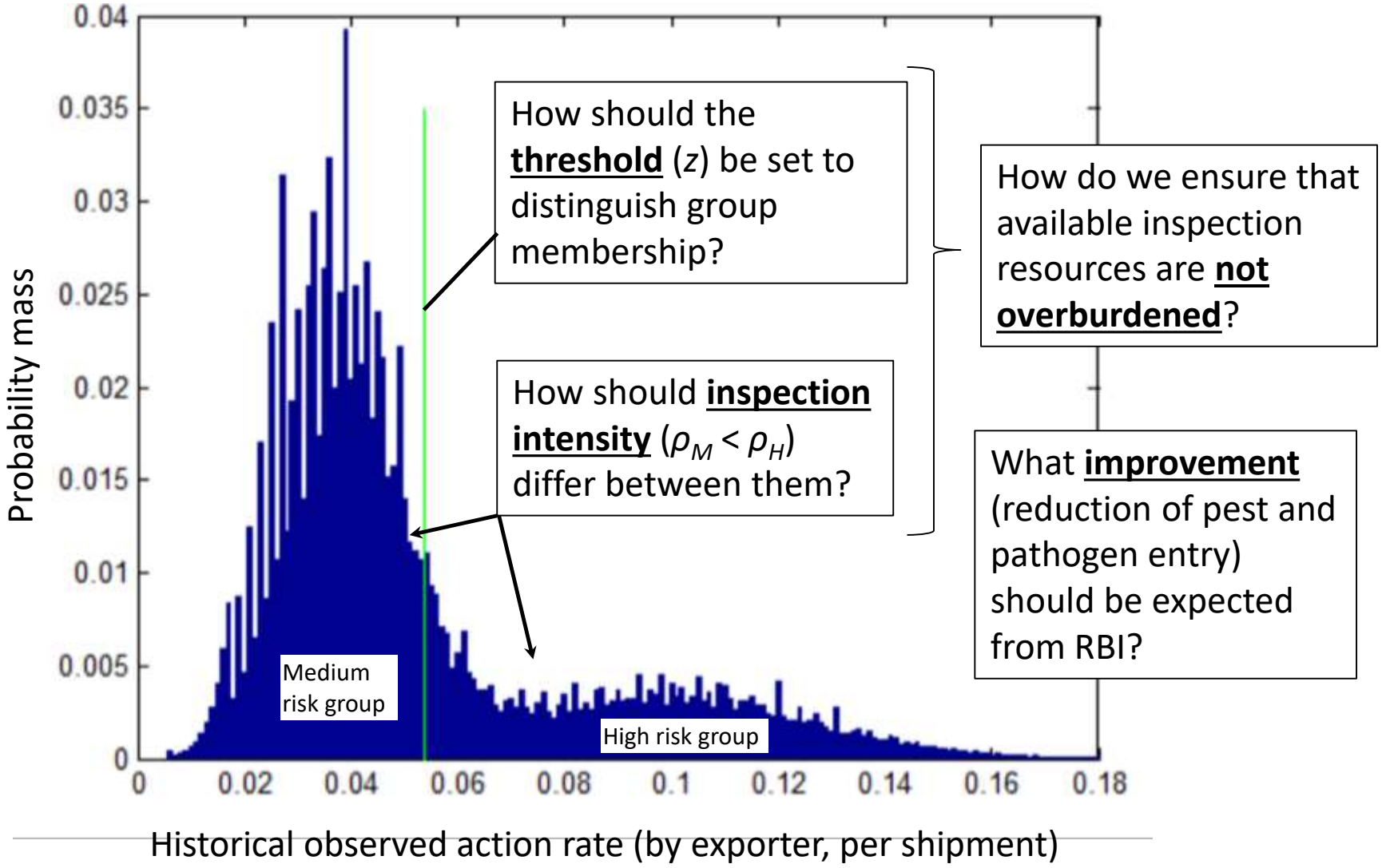
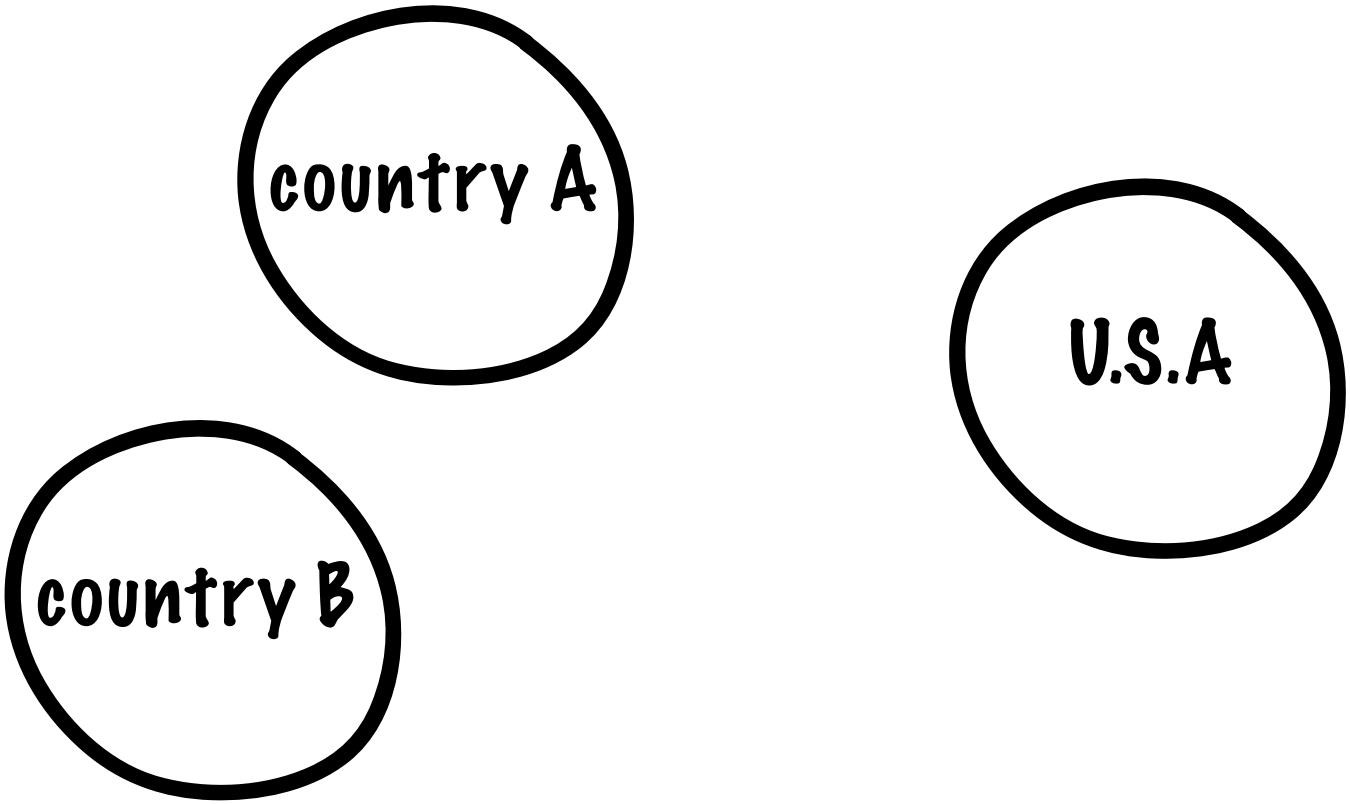
Importing countries typically have a fixed capacity to inspect plant material—infeasible to examen exhaustively.

APHIS's Miami Plant Inspection Station (APHIS, 2010).

Research question: what is the ideal structure and benefit of risk-based inspections (RBI)



An Example:



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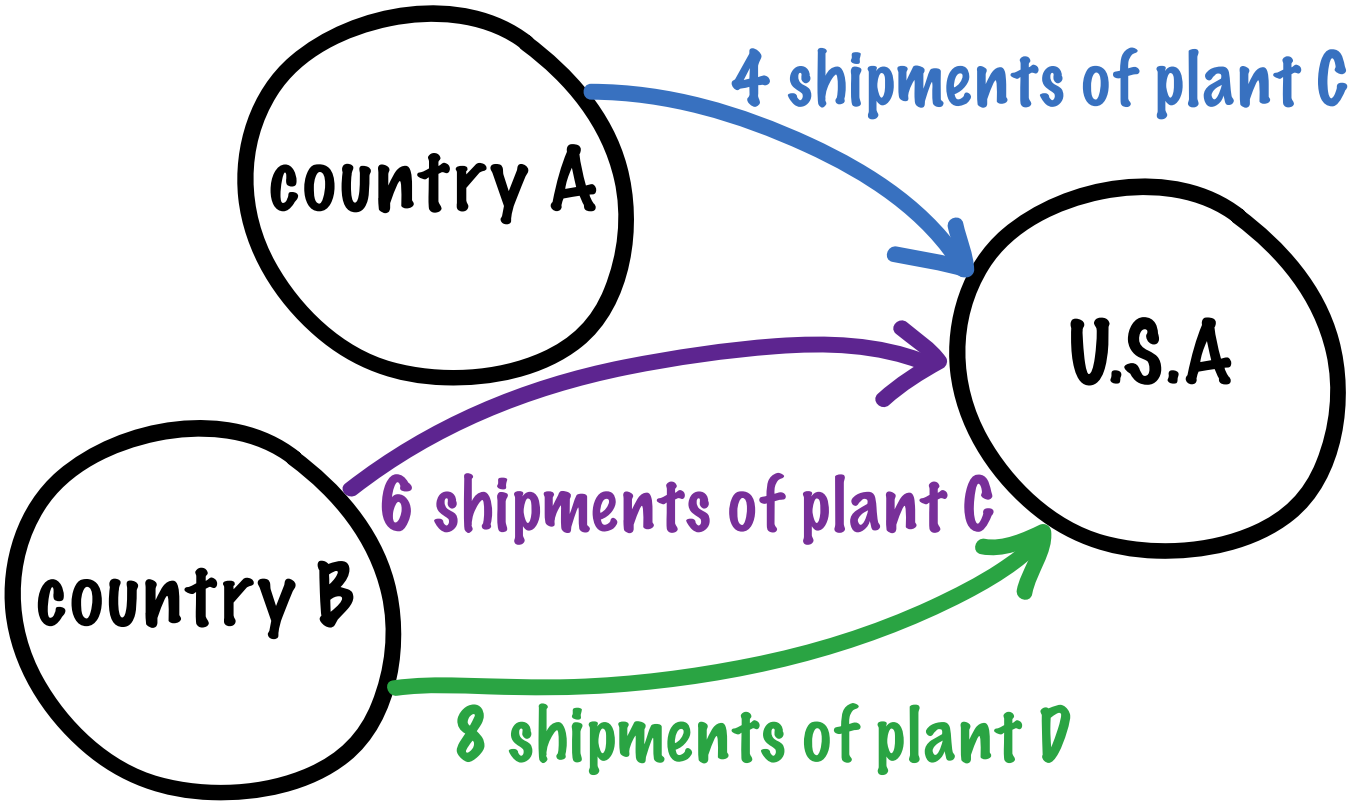
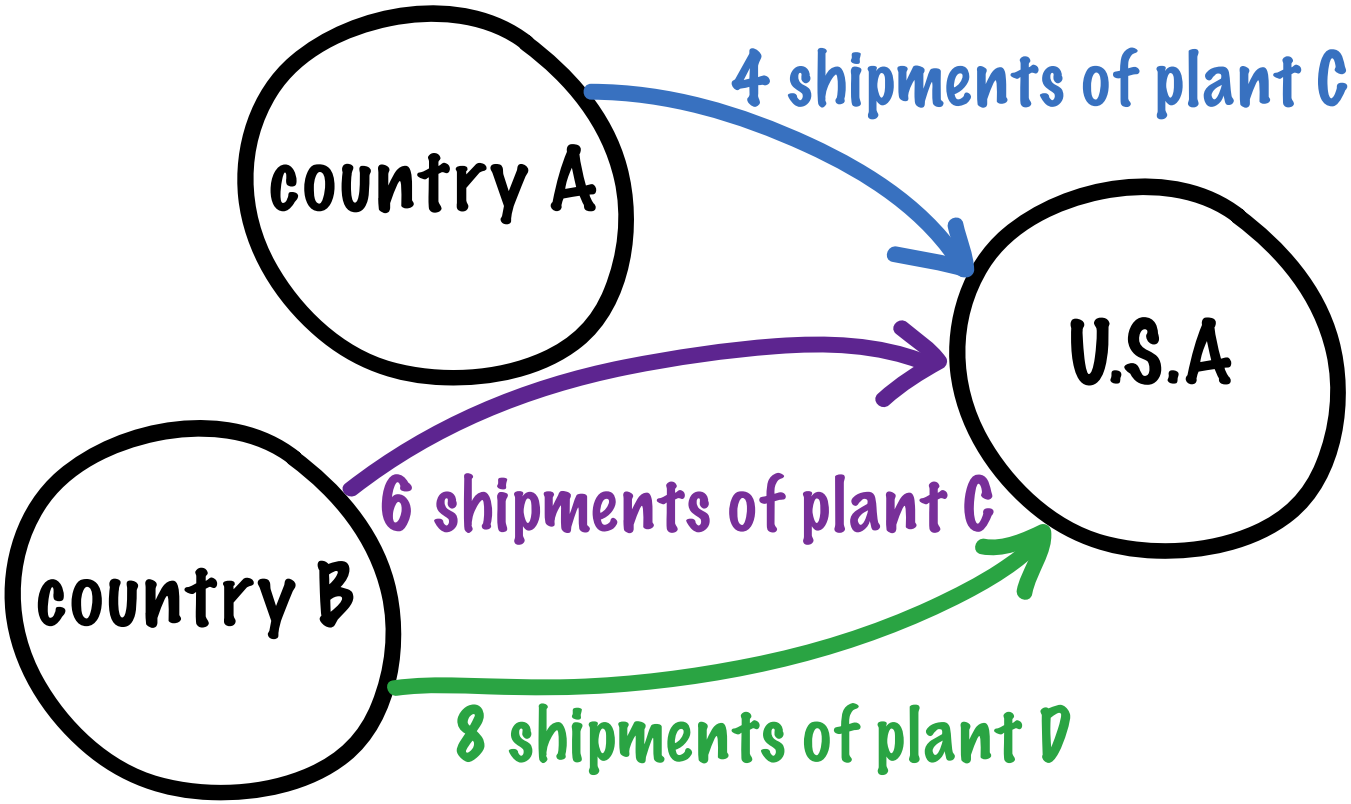

country A
4 shipments of plant C
U.S.A
country B
6 shipments of plant C
8 shipments of plant D

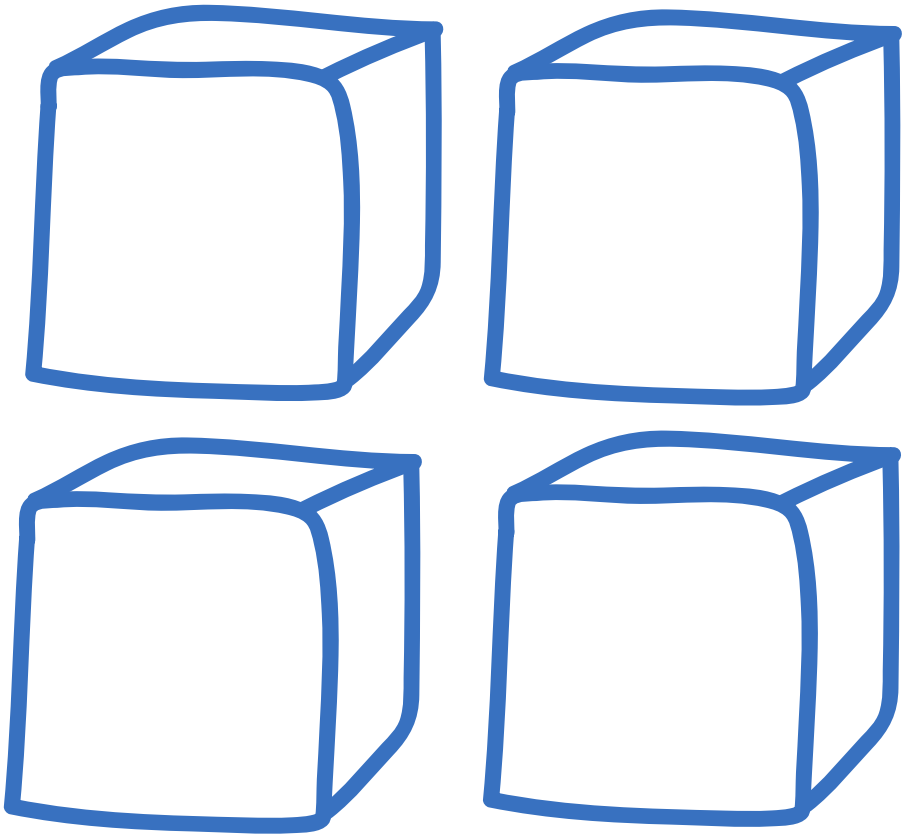
An Example: Three ‘exporters’



country:	commodity:	shipment frequency:
A	C	4
B	C	6
B	D	8

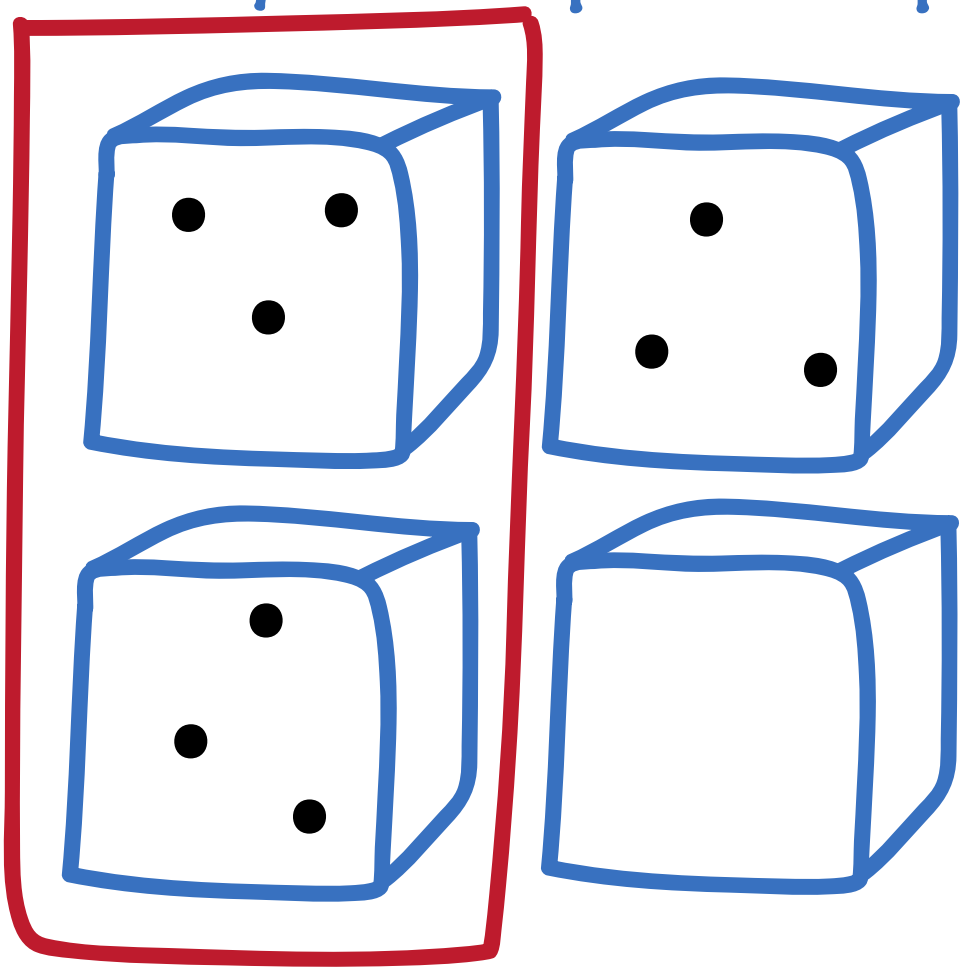
An Example: Inspect 50% of shipments

Country A's 4 shipments of plant C:



An Example: Inspect 50% of shipments

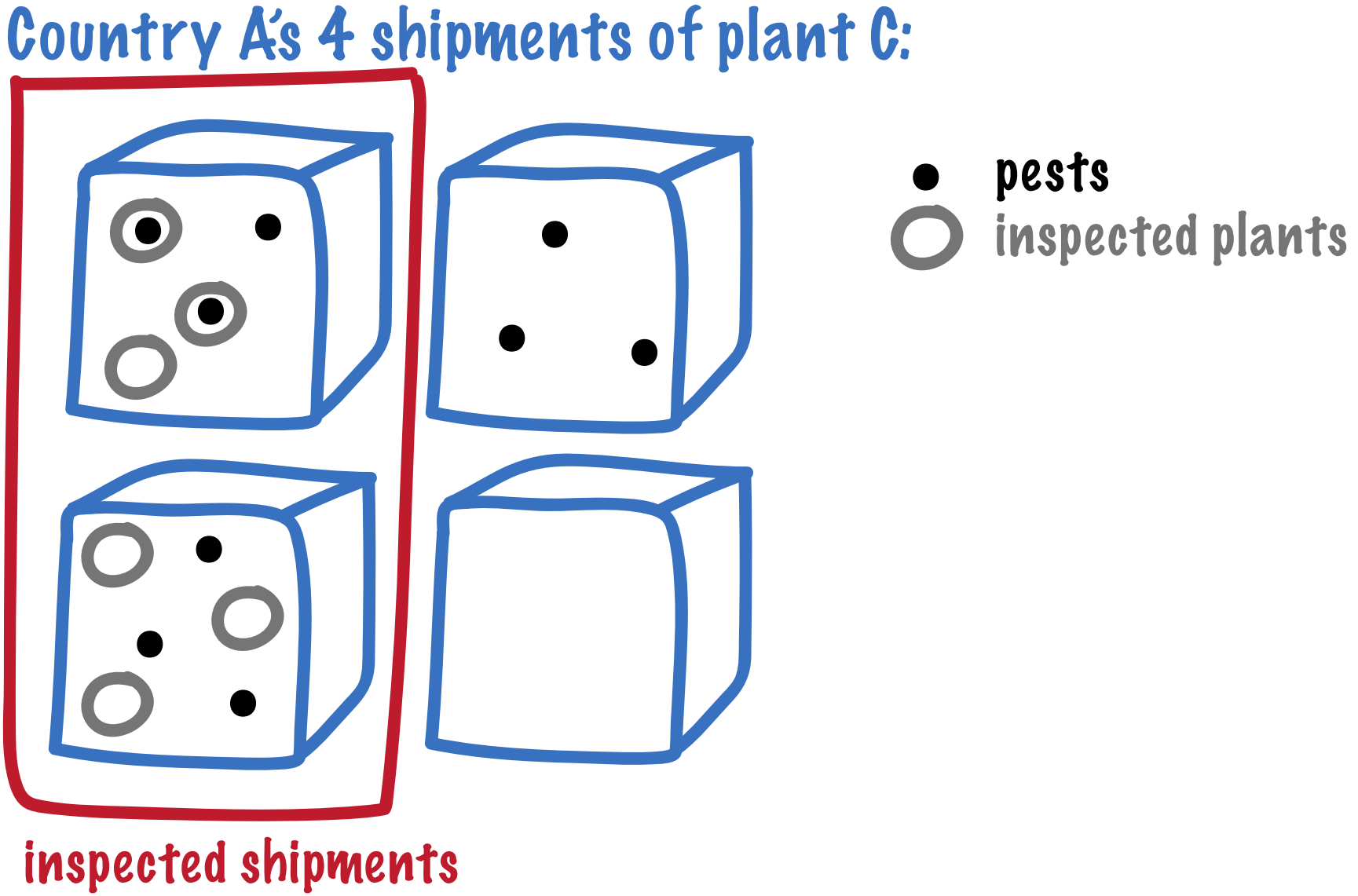
Country A's 4 shipments of plant C:



- pests

inspected shipments

An Example: Inspect 50% of shipments



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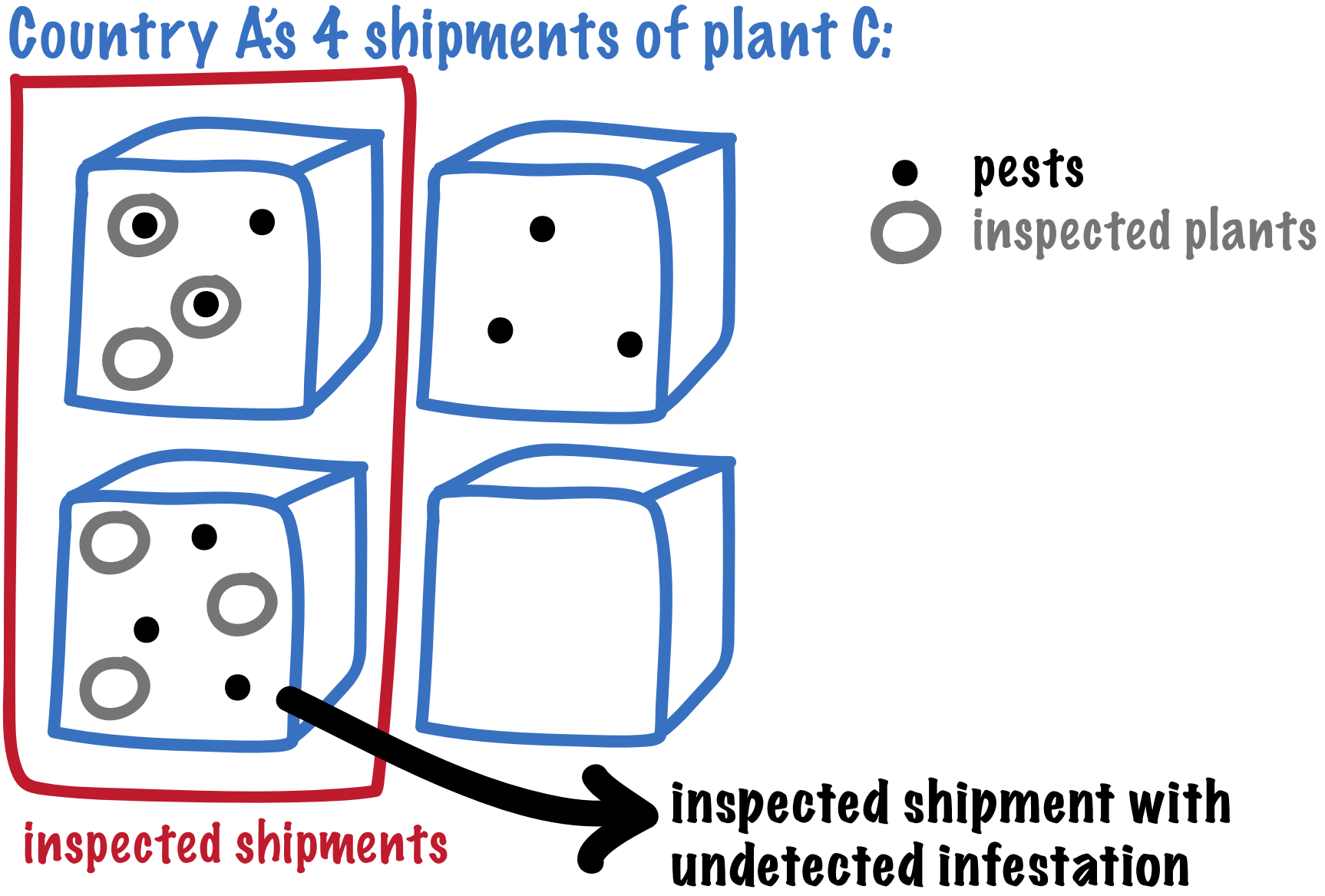

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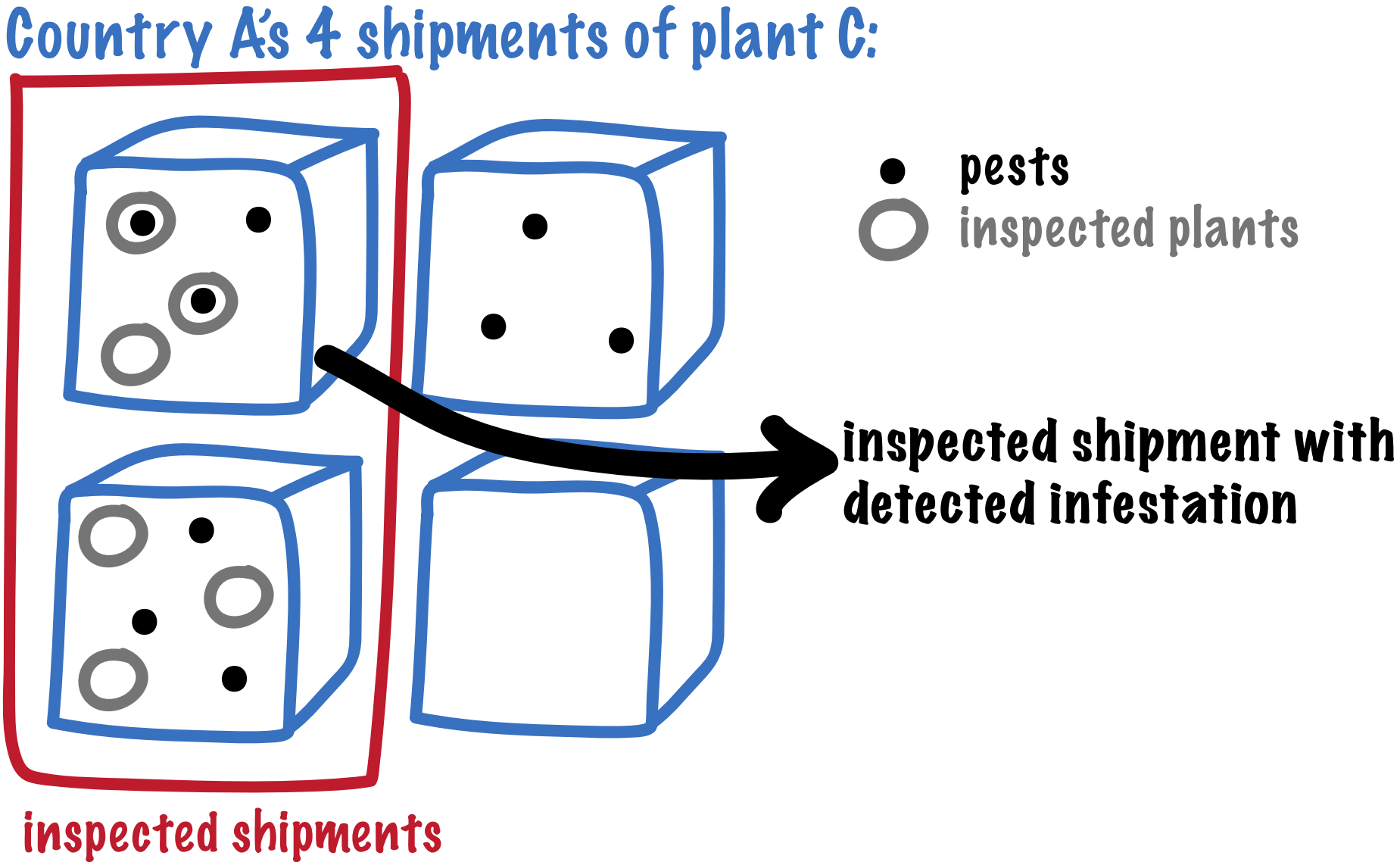

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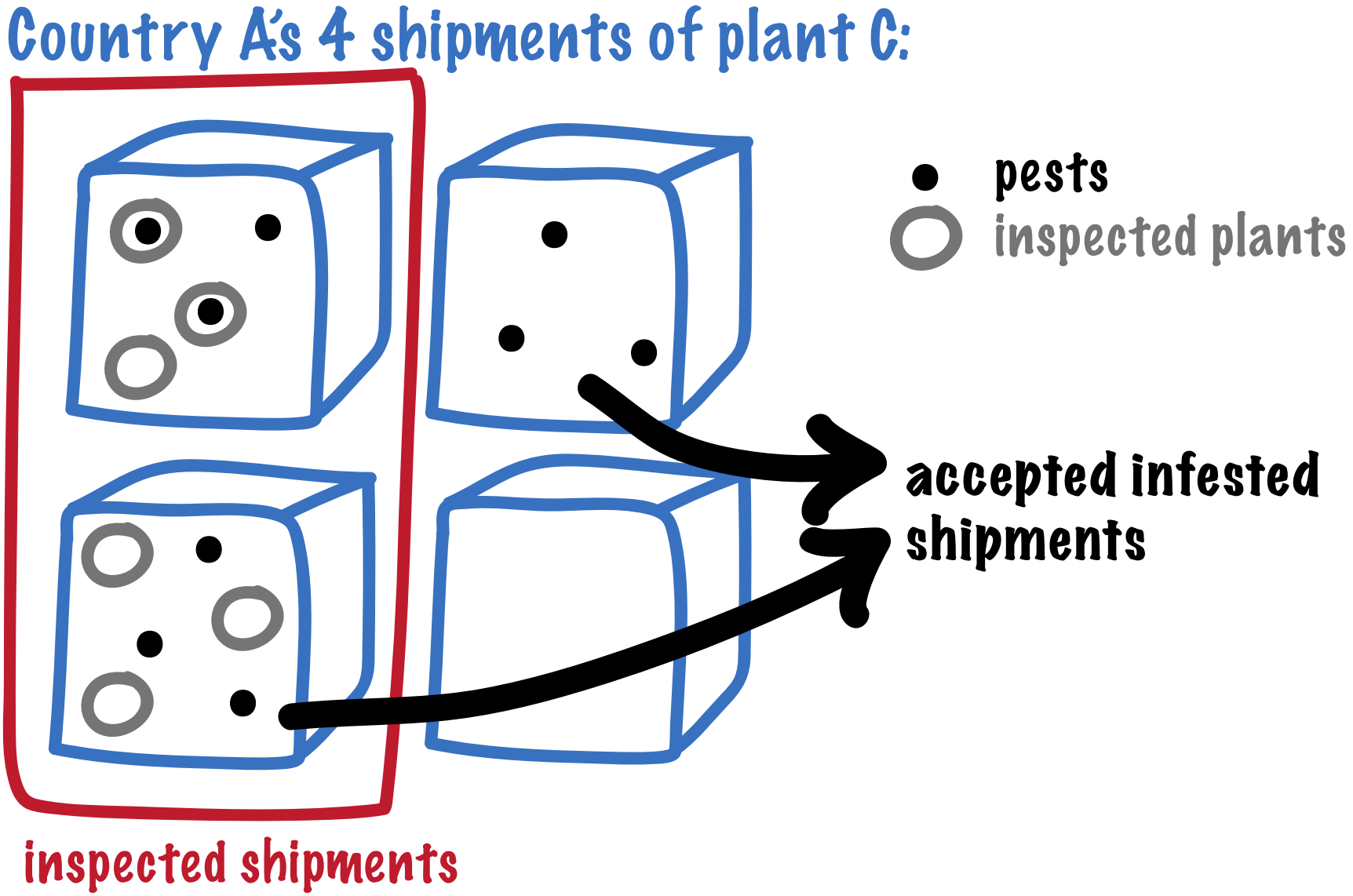


RBI of trade is an application of the idea of "state-dependent" monitoring and enforcement

- typical structure:
  - assign to groups based on compliance history
  - polluters with worst compliance record subject to
    - more intense inspection,
      (1) more frequent, (2) more thorough
    - greater fines for violations,
    - tougher standards
- enhanced abatement response:
  - inspection-driven incentives focused on the dirtiest polluters
  - "enforcement leverage" from possibility of group change (Harrington, 1988)

Model: Two stage game between regulators and exporters

1st Stage: Regulator announces policy parameters:

$\Omega = \{\rho_M, \rho_H, z\}$

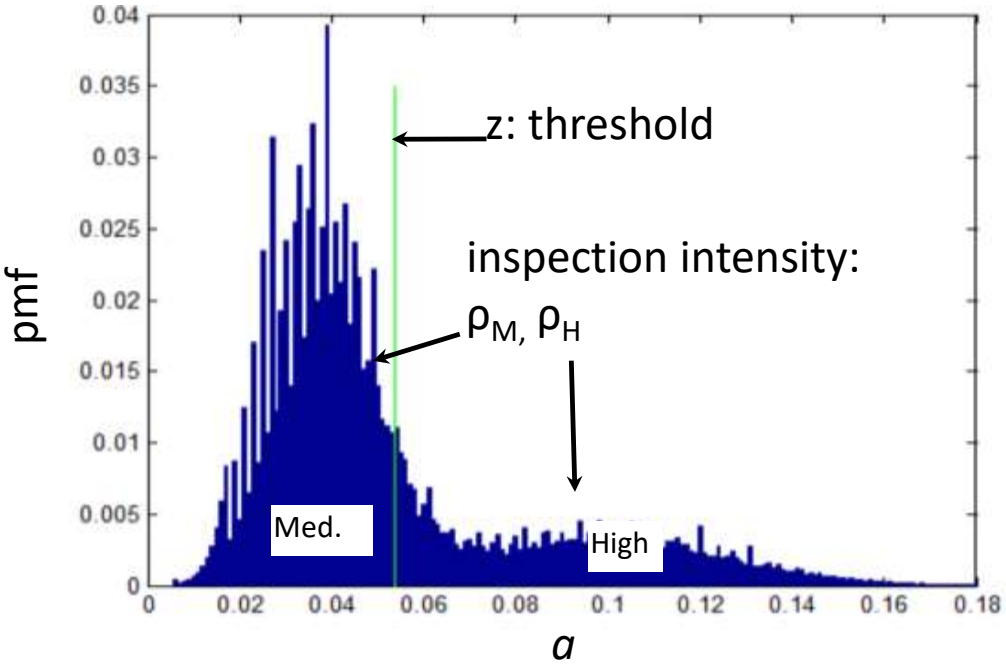
ρ_M – proportion of inspected shipments in medium risk group, e.g. 25%

ρ_H – proportion of inspected shipments in high risk group, e.g. 100%

z – compliance threshold for group assignment

a – cumulative historical infestation rate (by exporter, per shipment)

$a \geq z \rightarrow$ exporter assigned to high risk group



Regulator objective:
Minimize expected accepted infestation rate (EA)

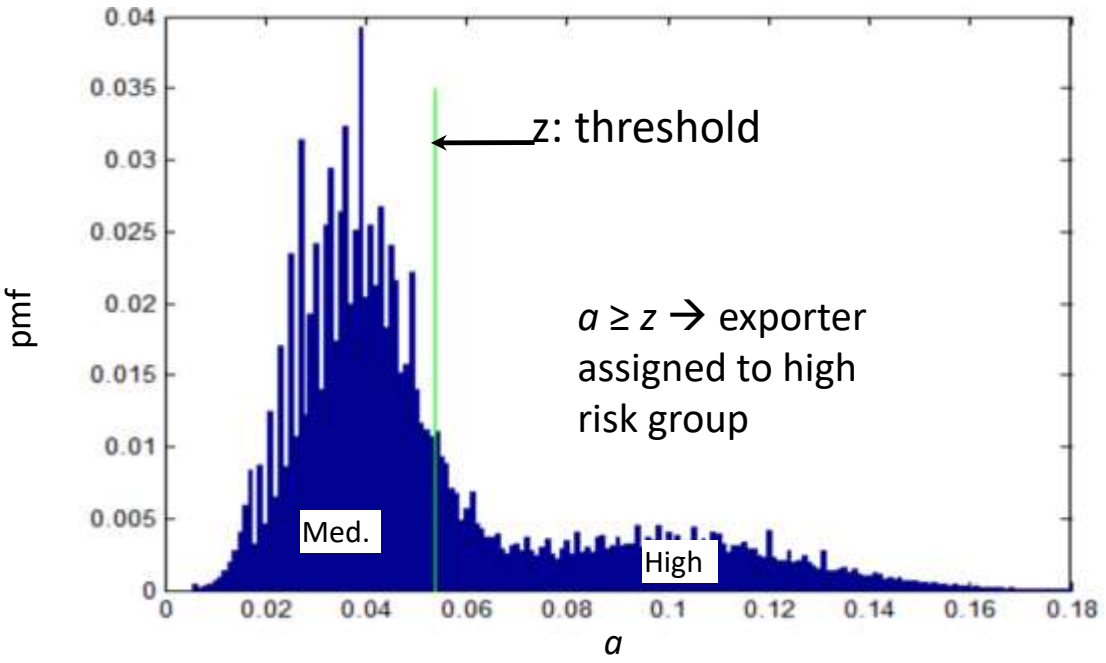
Model: Two stage game between regulators and exporters

2nd Stage: Given regulator's policy, exporters choose their level of sanitary/phytosanitary effort ("abatement") to minimize their expected losses.

Model: Two stage game between regulators and exporters

2nd Stage: Given regulator's policy, exporters choose their level of abatement to minimize their expected losses.

- Exporter's expected losses:
  - Abatement
  - Inspections
  - Detections
- Exporters consider their likelihood of moving from the medium to high risk group (and vice versa)



- *a:* cumulative historical infestation rate (by exporter, per shipment)
- cumulative compliance record, with memory loss

Model parameters are based on 2012 data, expert opinion or calibrated

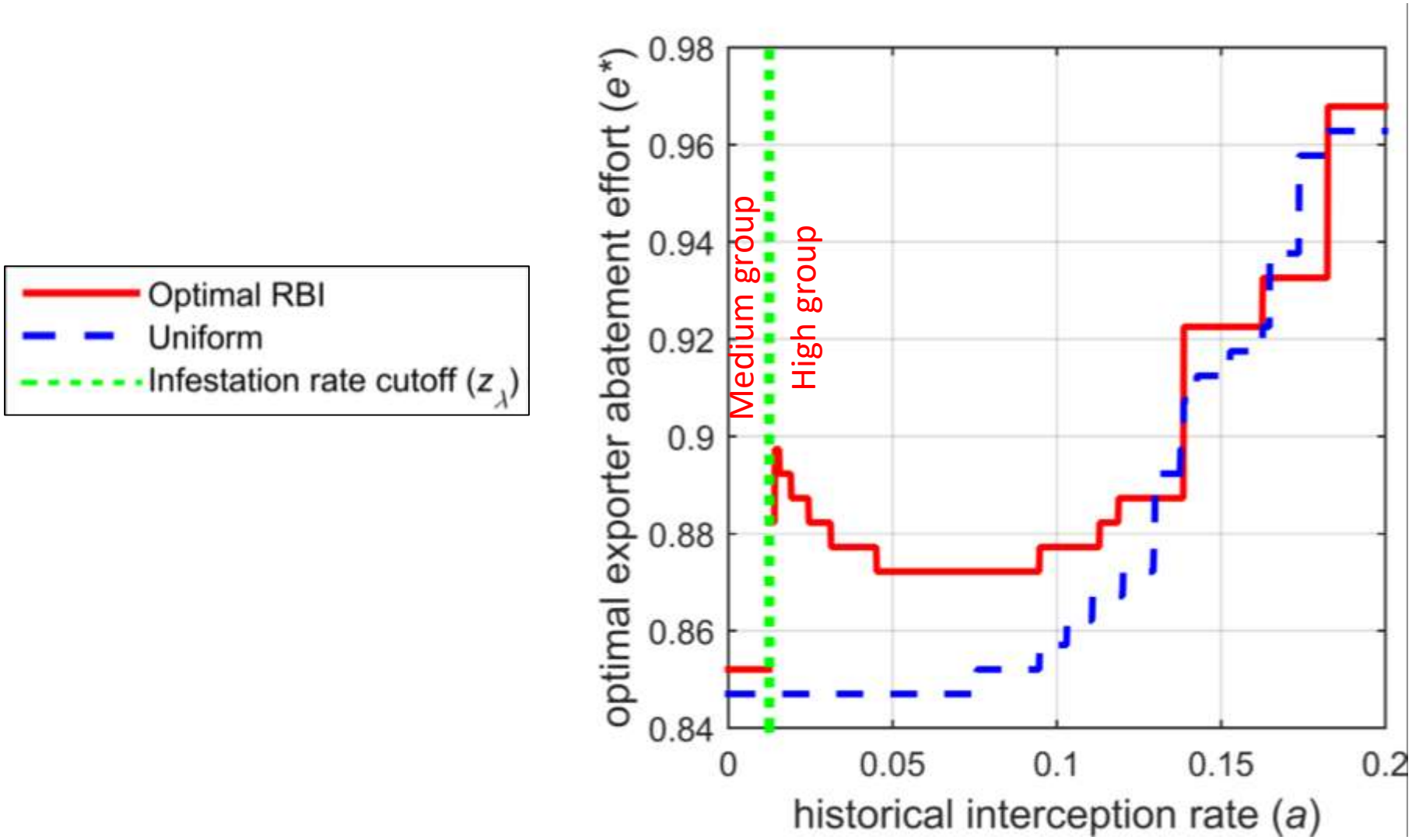
Table 1. Descriptions, values and sources for model parameters and variables.

Parameter	*Description*	*Value*
Regulator parameters and variables		
B'	Number of shipments inspected per period under uniform	36972[a,b]
B		
μ		
a_{ban}		
Pr(recovery)		
ρ		
ρ_g		
λ_g		
efficiency rate		
sample infestation confidence		
d		
Exporter parameters and variables		
θ_0	Base rate of shipment infestation given no abatement effort	0.80[b]
.	Average value of shipment	$5000
δ	Marginal cost of inspection (shipment delay) to the exporter. As a percentage of the total value of the shipment	0.01[b]
γ	Expected cost to exporter per infected shipment, associated with treatment, destruction and rejection of infested shipments. As a percentage of the total value of the shipment.	0.452[a,b]
e	Abatement effort. Endogenously selected by each exporter type	Exp. opt. choice
Homogenous exporter model parameters		
n	Total number of exporters	1,545
s	Average shipment rate per period	3[a]
w	Phytosanitary effort cost function parameter	0.89[c]
Heterogeneous exporter model parameters		
n_1, n_2, n_3, n_4	Total number of exporters for each exporter type	[603,202,669,71][a]
s_1, s_2, s_3, s_4	Average shipment rate per period for each exporter type	[2,7,1,19][a]
w_1, w_2, w_3, w_4	Phytosanitary effort cost function parameter for each exporter type	[1.7×10^{-4},5×10^{-6}, 8.26, 46.19][c]
Other parameters		
ϵ	Parameter of infestation rate updating function determining persistency of past observations	11/12
β	Discount factor	1/1.03

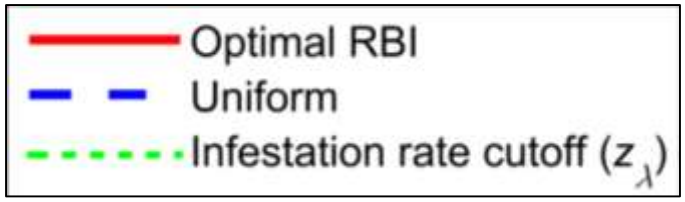
[a] Calculated from 2012 data, the benchmark year
[b] Established in personal communications with APHIS
[c] Calibrated to ensure uniform inspection model output matches 2012 data
[d] RBS (risk-based sampling) is a recently amended APHIS protocol for rigorously sampling units within a shipment.

Results (homogeneous exporters):

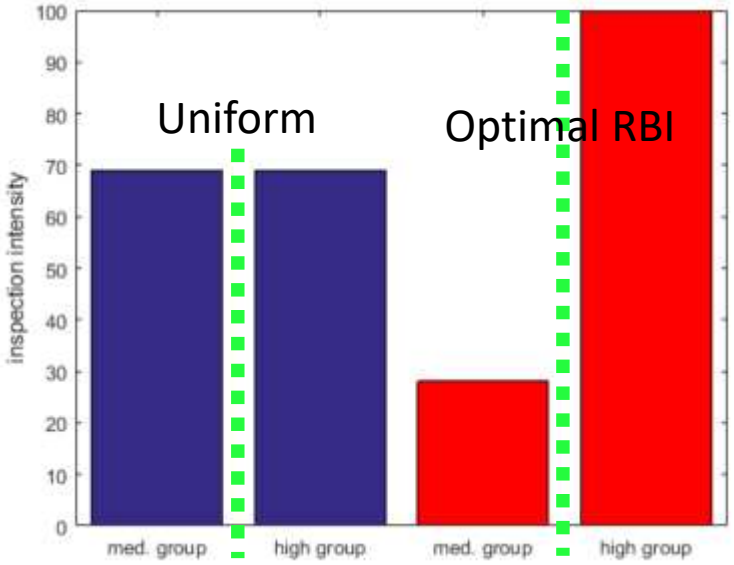
1. As expected, uniform policy creates a uniform response until banning cutoff (α = 0.20) becomes salient.

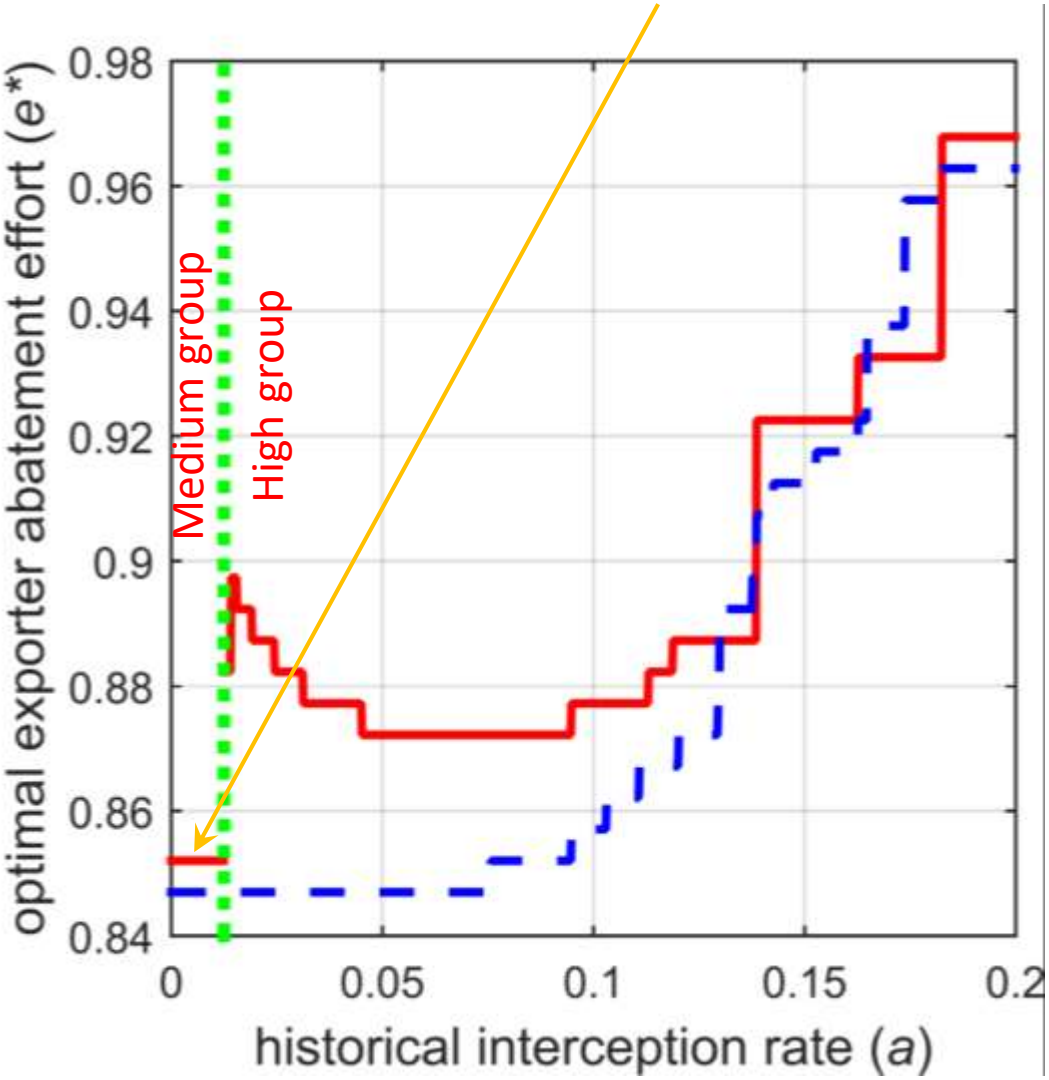


2. Though medium group is inspected with *less intensity* under RBI (relative to uniform), enforcement leverage means they have an incentive to invest in *more abatement effort*.

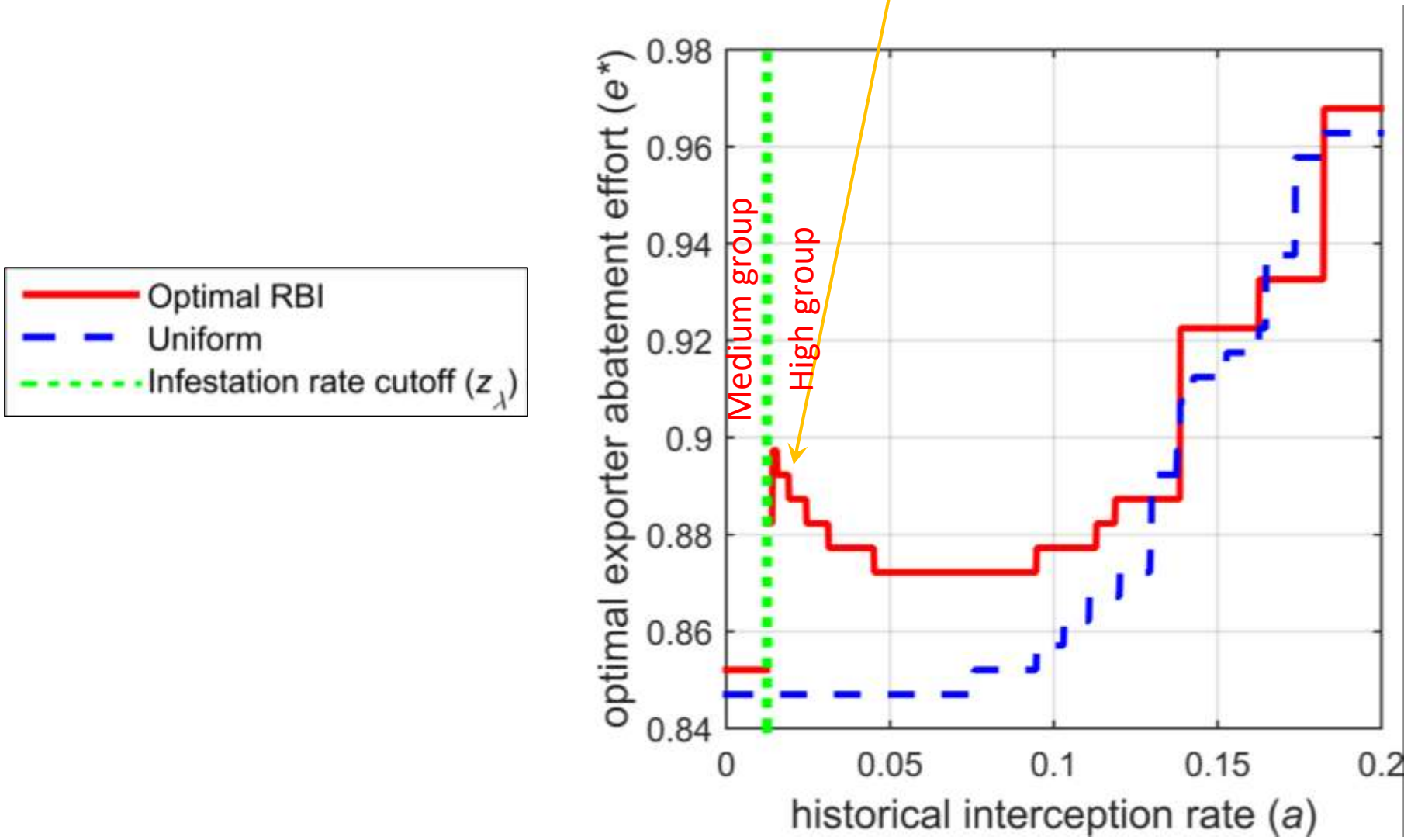


Inspection intensities





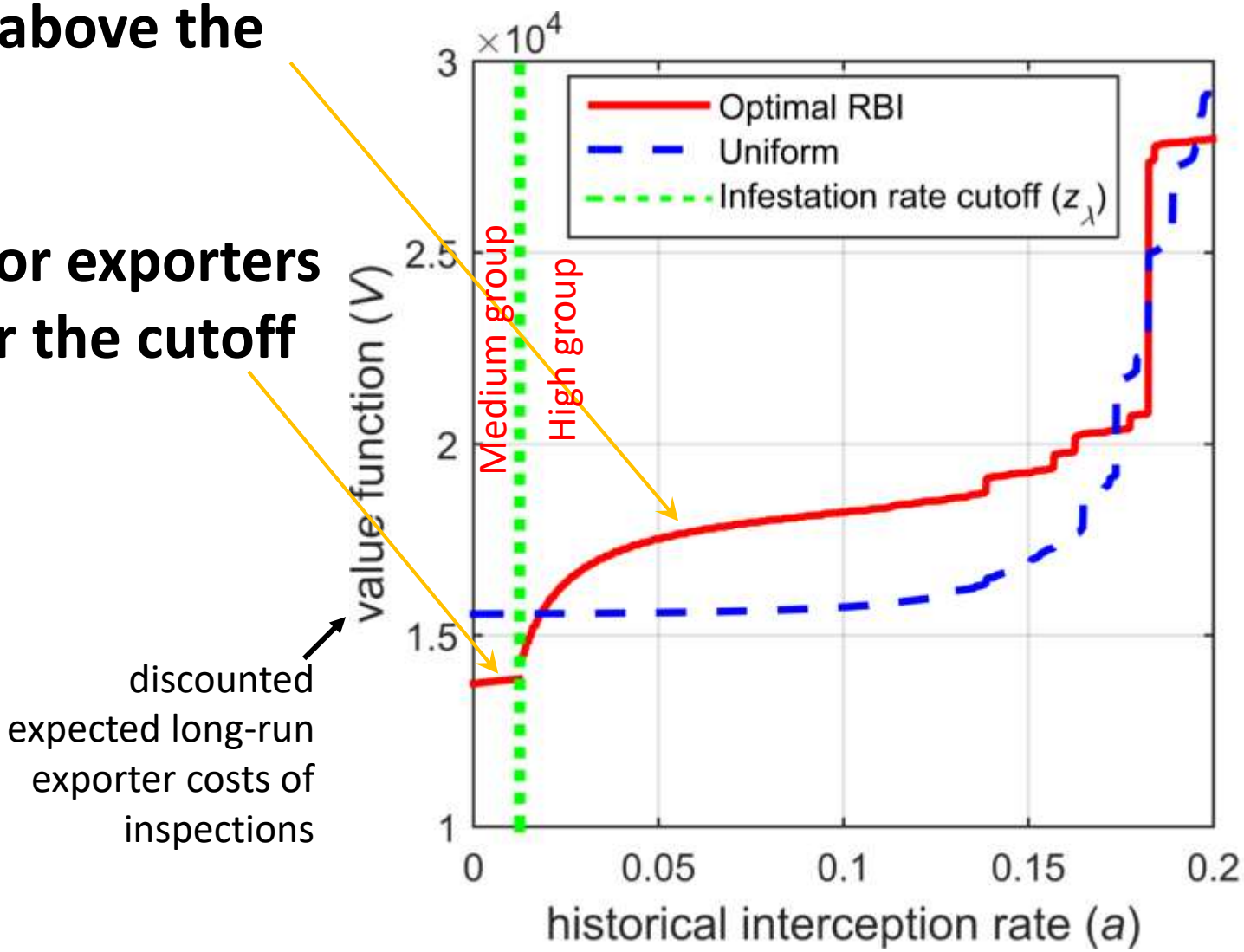
3. The high group has an increased incentive to abate in the neighborhood of the threshold.



4. Expected costs of inspections…

→ increase for exporters substantially above the cutoff

→ decrease for exporters below or near the cutoff



5. RBI enhances abatement incentives, shifting the distribution of cumulative infestation rates down towards and across the threshold.

Uniform inspection policy:

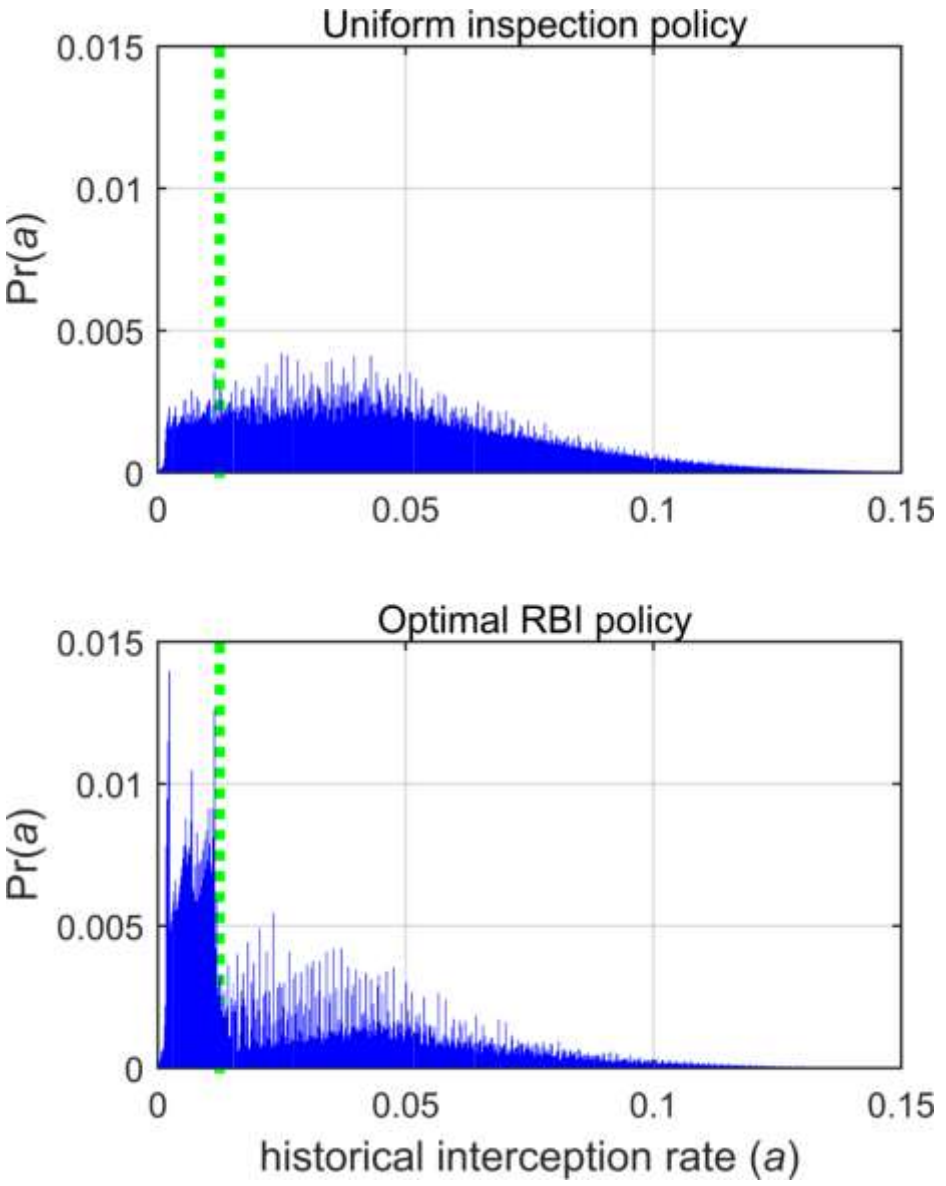
$\rho_M = \rho_H = 0.69$

RBI policy:

$\rho_M = 0.28$ $z = 0.012$

$\rho_H = 1.00$ $\lambda = 0.57$

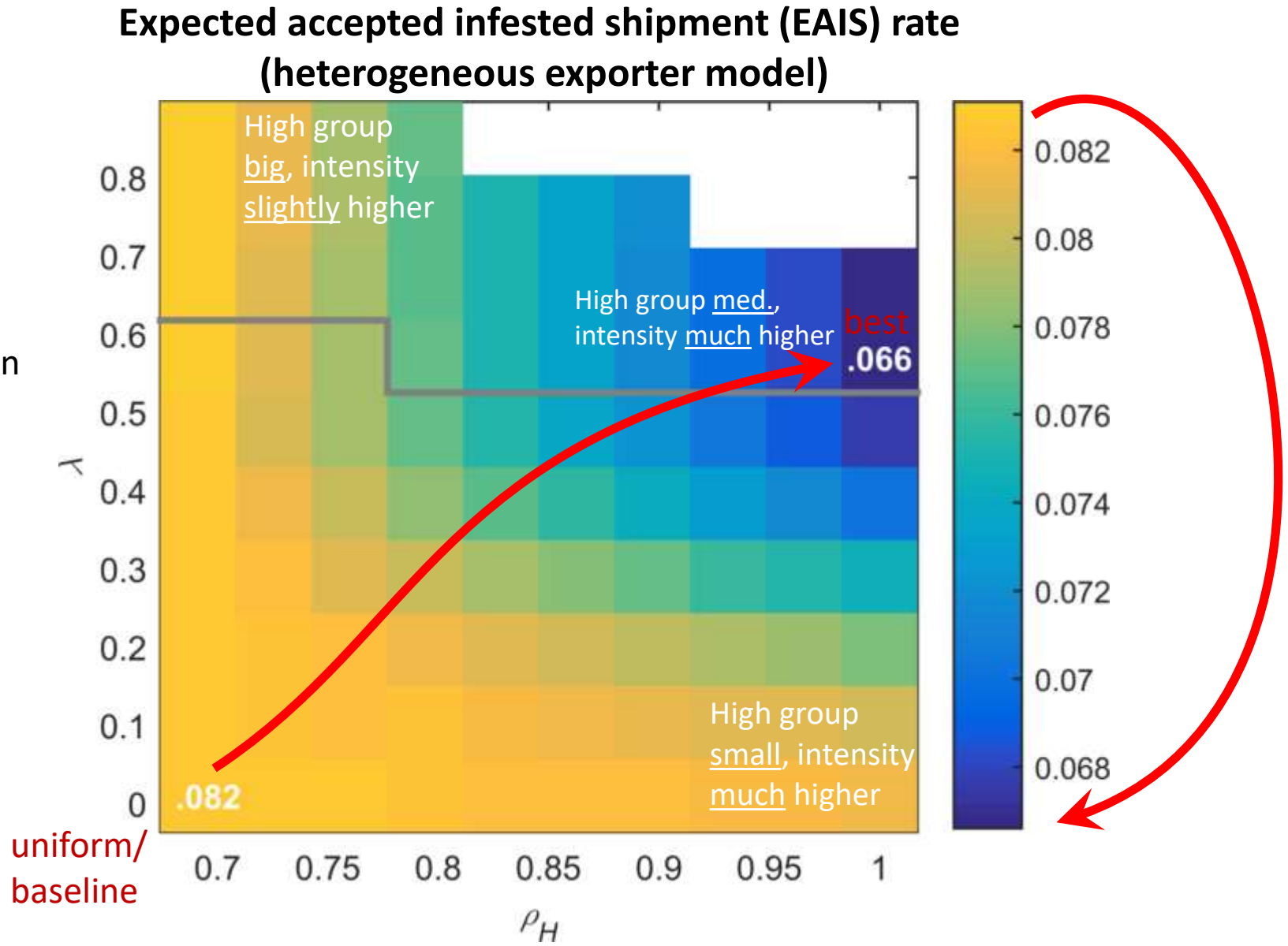
ρ – inspection intensity
z – threshold
λ – share in high risk group



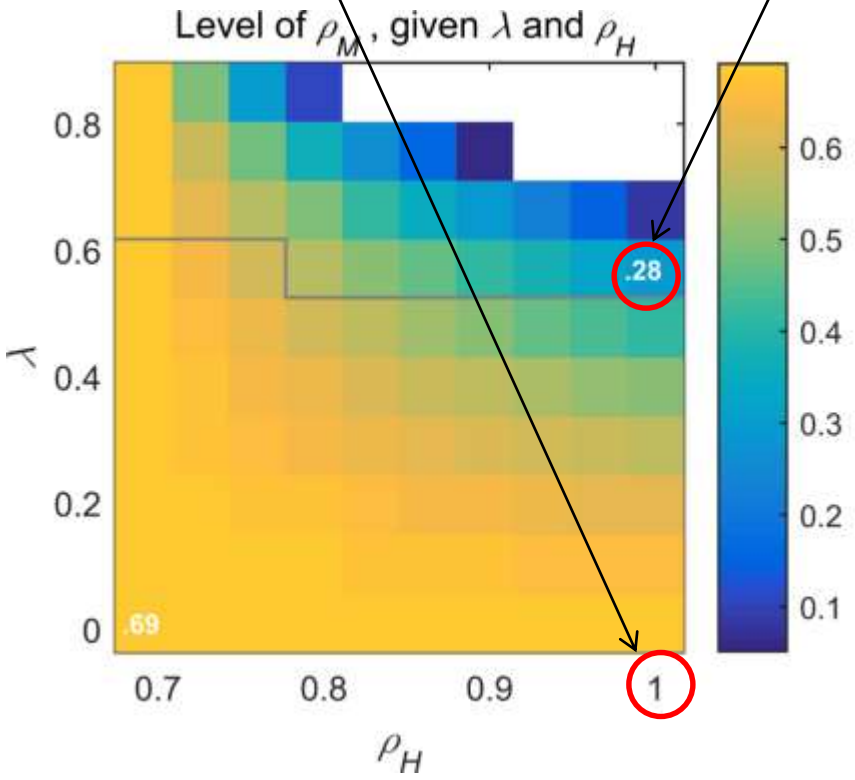
We extend the model to consider exporter heterogeneity in (1) infestation rate and (2) shipment frequency

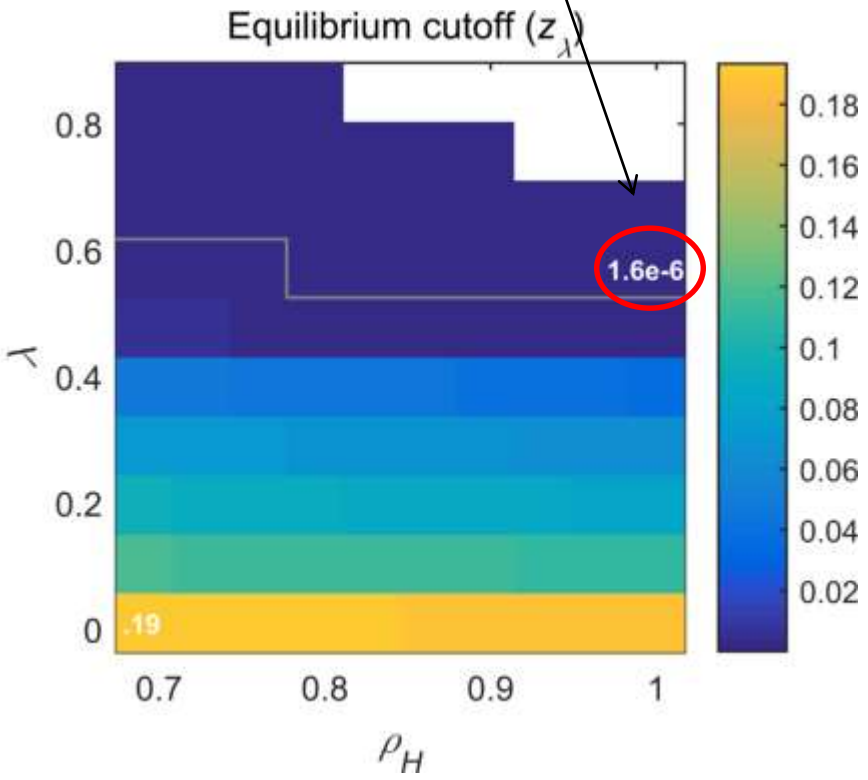
Infestation Rate Type	Shipment Frequency Type	Average Infestation Rate	Average Shipment Frequency (annual)	Av. Ship. Freq., (monthly, rounded)	Total Exporters	Total Shipments	% of Shipments	% of Exporters
Low	Low	0.19%	24.0	2	603	14469	26.2	39.0
Low	High	0.07%	82.8	7	202	16723	30.2	13.1
High	Low	6.10%	12.0	1	669	7993	14.5	43.3
High	High	7.31%	227.0	19	71	16117	29.1	4.6

6. The optimal policy reduces EAIS by 1/5 over the uniform baseline.



7. The optimal policy is to inspect those with $a > z = 0.0002\%$ at a rate of ρ_H=100% and the rest at ρ_M=28%. λ=57% of shipments are in high.





(heterogeneous exporter model)

Conclusions

- Extension of state-dependent, enforcement leverage model to inspections of international trade

- RBI policy:
  - Place the riskiest λ = 57% of exports in high group and inspect those shipments with certainty (ρ_H = 100%).
  - Inspect medium group with a probability of ρ_M = 28%.
  - Reduces the number of EAIS by 1/5.
- Caveat: group threshold to announce (z_λ) is sensitive to heterogeneity in exporters.