Regulatory compliance in the automobile industry

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On **18 September 2015**, the US EPA served a Notice of Violation on **Volkswagen Group**

+/- 480,000 Volkswagen and Audi automobiles equipped 2-litre TDI engines with an emissions compliance “defeat device“.

The engine could identify the operating conditions of the certification test cycle and switch into low emissions mode during the test.

Reynaert and Sallee (2020)

Gaming, understood as finding a way to signal lower emissions than those occurring on-roads, has significantly increased in the automobile industry in the last 15 years possibly as a result of the implementation of increasingly stringent regulations

Literature

- Malik (1992), Heyes (2000): fines and monitoring set to incentivize firms to align their emission levels with the standards that are set.
- Macho-Stadler and Pérez-Castrillo (2006), Macho-Stadler (2008), Coria and Villegas-Palacio (2010 and 2014) : pollution taxes and emission permits in a context where emissions are self-reported.

- Malik (1990), Reynaert and Sallee (2021) and Reynaert (2021): consider cheating as a decision to install a cheating device.
- Yao (1988) and Puller (2006): strategic investment strategies when regulators revise standards.

Our contribution

- Objective: to further understand the factors that determine a firm’s decision to cheat.

  Specifically, how do investment in innovation, regulatory stringency and compliance costs, penalties, and sector competitiveness influence the firm’s decision-making?

- Setting: sequential game with two firms that can comply but face compliance costs.
  - Innovation (when successful) reduces part of these costs.
  - Gaming (when not detected) eliminates these costs.

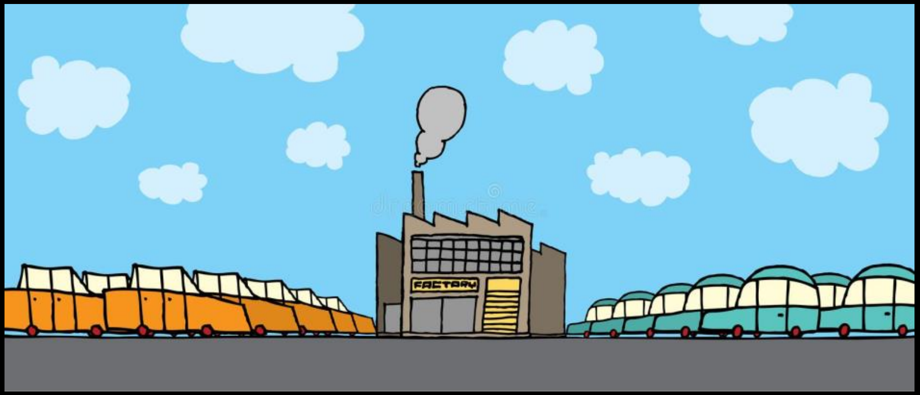
The model

- Two firms, 1 and 2.
- A regulator sets the target(s) that the firms should meet.
- Idiosyncratic compliance costs
  - c_i if the firm innovates with a new piece of emissions control technology
  - $(c_i + d_i)$ if the firm fails to innovate.
    - ↑ stringency means higher c_i
    - ↑ d_i means that the policy is more “technology forcing"
- Innovation is subject to uncertainty.
- The probability that firm i successfully innovates $P(\theta_i, I_i)$ depends on
  - Firm’s ability to innovate (positively)
  - Investment (positively)

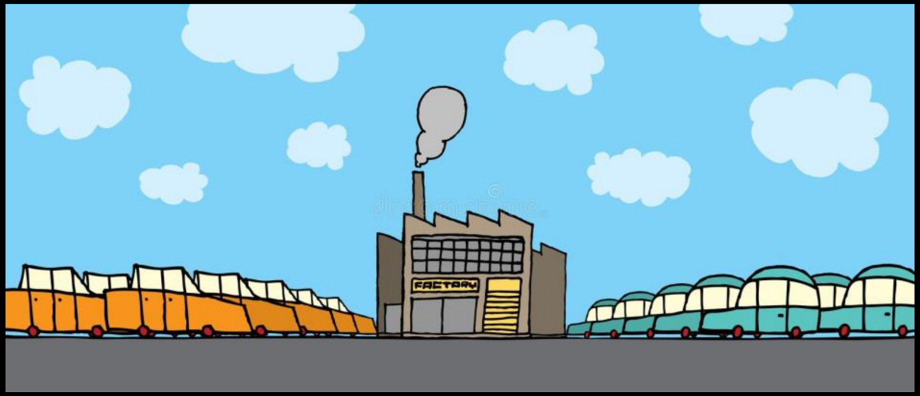
The Model: cheating

- Prior to investing in innovation, the firm can install a cheating device that signals that its fleet reaches the emission target.
- The firm can remove the device once the uncertainty about innovation is resolved.
- **The device is detected with probability $(1-\gamma)$ → penalty $F > 0$ in addition to compliance costs.**

The Model: competitive pressures



$\Delta\pi$



Does not cheat
AND
Does not innovate

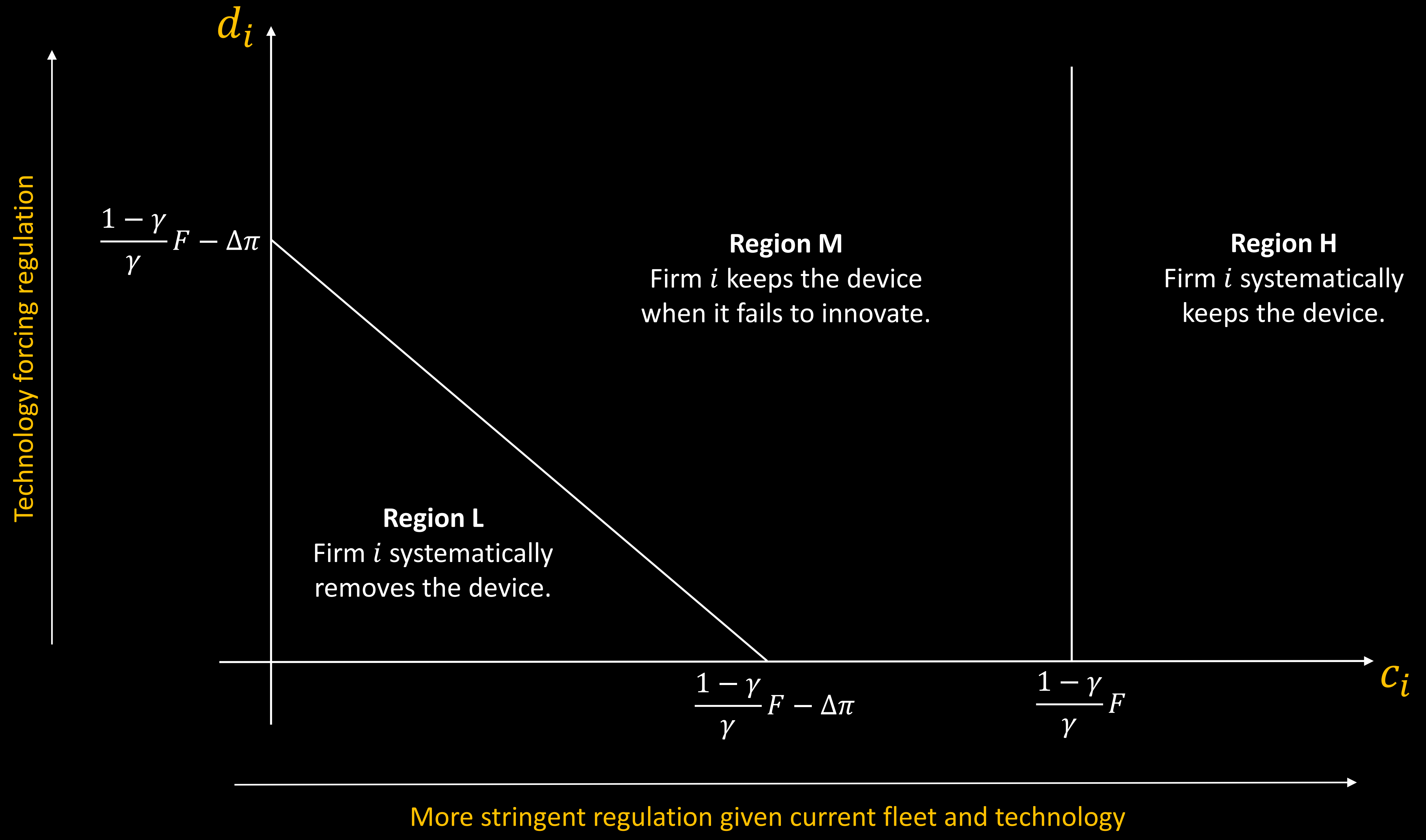
Cheats and not caught
OR
Innovates

Timing

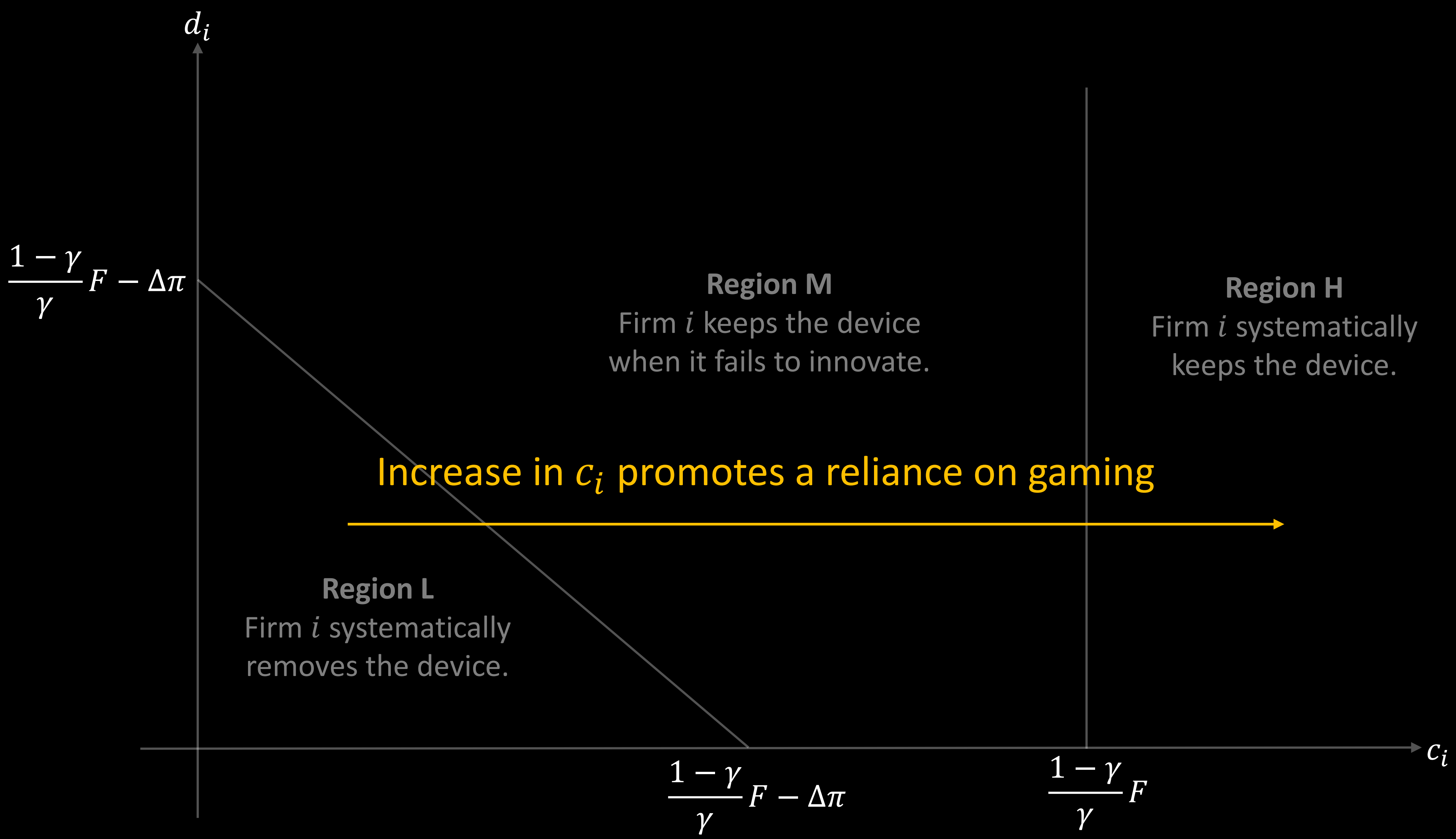
- Nature sets the firms' types (θ_1, θ_2).
- The regulatory agency announces the new emission targets which determine the costs c_i and $d_i, i = 1,2$.
- The firms decide simultaneously and non-cooperatively whether to cheat.
- The firms decide simultaneously and non-cooperatively how much to invest in R&D and Nature decides whether they succeed or fail.
- Based on the innovation outcome, the firms decide simultaneously and non-cooperatively to remove or to leave the device (if installed).

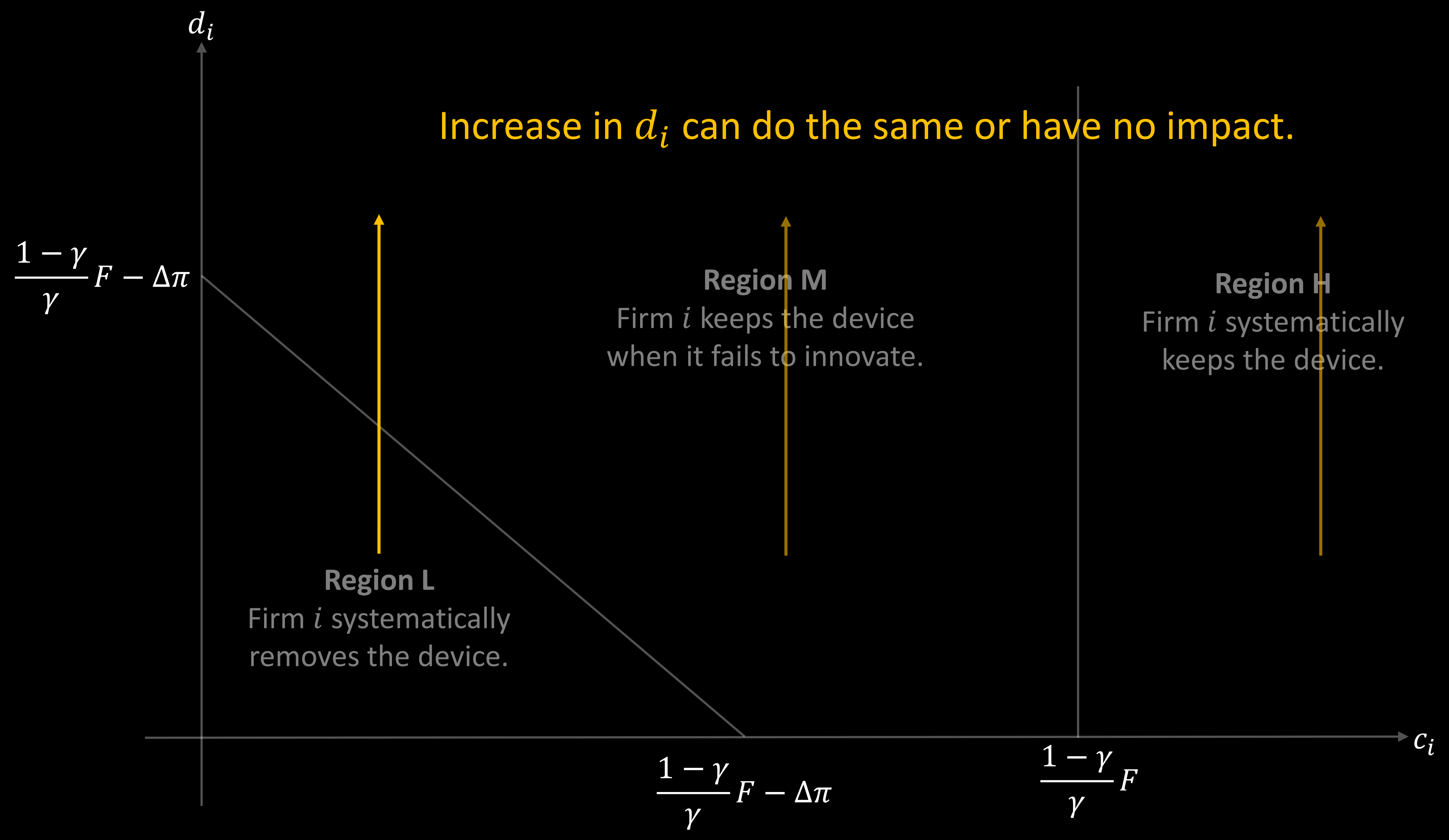
Last stage: keep or remove the defeat device?

Dominant strategy equilibrium

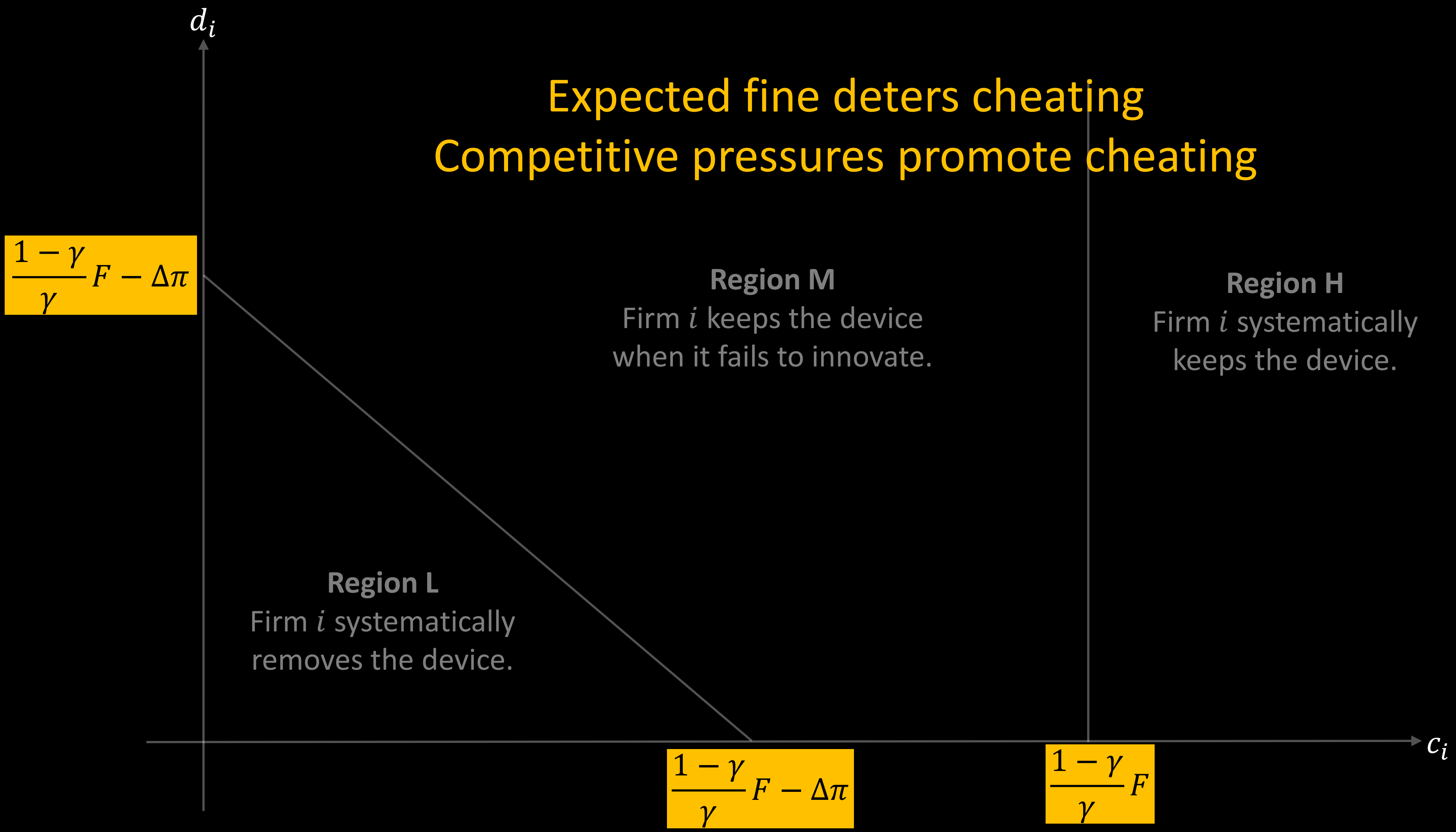


d_i
Technology forcing regulation
$\frac{1-\gamma}{\gamma}F - \Delta\pi$
Region M
Firm i keeps the device when it fails to innovate.
Region H
Firm i systematically keeps the device.
Region L
Firm i systematically removes the device.
$\frac{1-\gamma}{\gamma}F - \Delta\pi$
$\frac{1-\gamma}{\gamma}F$
c_i
More stringent regulation given current fleet and technology


d_i
$\frac{1-\gamma}{\gamma}F - \Delta\pi$
Region M
Firm i keeps the device
when it fails to innovate.
Region H
Firm i systematically
keeps the device.
Increase in c_i promotes a reliance on gaming
Region L
Firm i systematically
removes the device.
c_i
$\frac{1-\gamma}{\gamma}F - \Delta\pi$
$\frac{1-\gamma}{\gamma}F$


Increase in d_i can do the same or have no impact.
d_i
c_i
$\frac{1-\gamma}{\gamma}F - \Delta\pi$
$\frac{1-\gamma}{\gamma}F - \Delta\pi$
$\frac{1-\gamma}{\gamma}F$
Region L
Firm i systematically removes the device.
Region M
Firm i keeps the device when it fails to innovate.
Region H
Firm i systematically keeps the device.

Expected fine deters cheating
Competitive pressures promote cheating



Intermediate stage: investing in innovation.

The investment (I) is proportional to what the firm stands to gain.

Investment is deterred when the firm plans to rely on a device that is very difficult to detect.

- If the firm does not cheat or plans to remove the device systematically, I^L solves

$$\frac{\partial P}{\partial I_i}(d_i + \Delta\pi) - 1 = 0.$$

- If the firm plans to keep the device, I^H solves

$$\frac{\partial P}{\partial I_i}[(1-\gamma)(d_i + \Delta\pi)] - 1 = 0.$$

As $(1-\gamma) \rightarrow 0$ there is no reason to invest.

The variable c_i has no impact on investment because its occurrence is not contingent on innovating.

- The firm plans to remove the device only when it innovates.
  - Gains from innovation are $(d_i + \Delta\pi) + (1 - \gamma)F$
  - Gains that the firm forgoes by innovating $\gamma(c_i + d_i + \Delta\pi)$

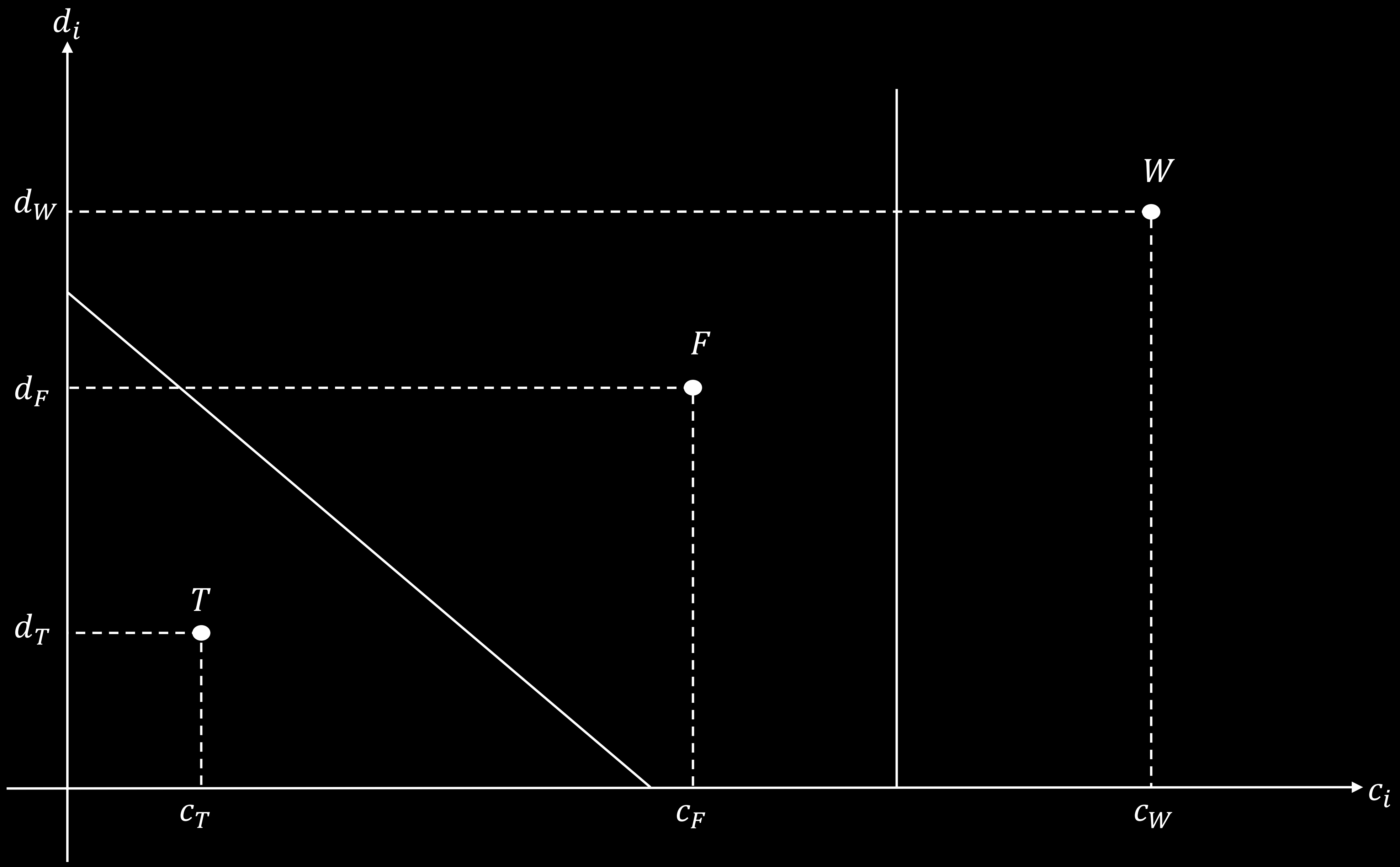
→ I^M solves

$$\frac{\partial P}{\partial I_i}[(1-\gamma)(d_i + \Delta\pi + F) - \gamma c_i] - 1 = 0.$$

(Note: in region M, $(1-\gamma)(d_i + \Delta\pi + F) - \gamma c_i > 0$)

- For a given d_i, the investment is non-increasing in c_i.
  - As we move horizontally from region L to H, the firm intends to rely more and more on the device and reduces its investment
- For a given c_i, investment is increasing in $(d_i + \Delta\pi)$.

c_i and d_i exert countervailing forces → those who rely the most on gaming could also be those investing the most.



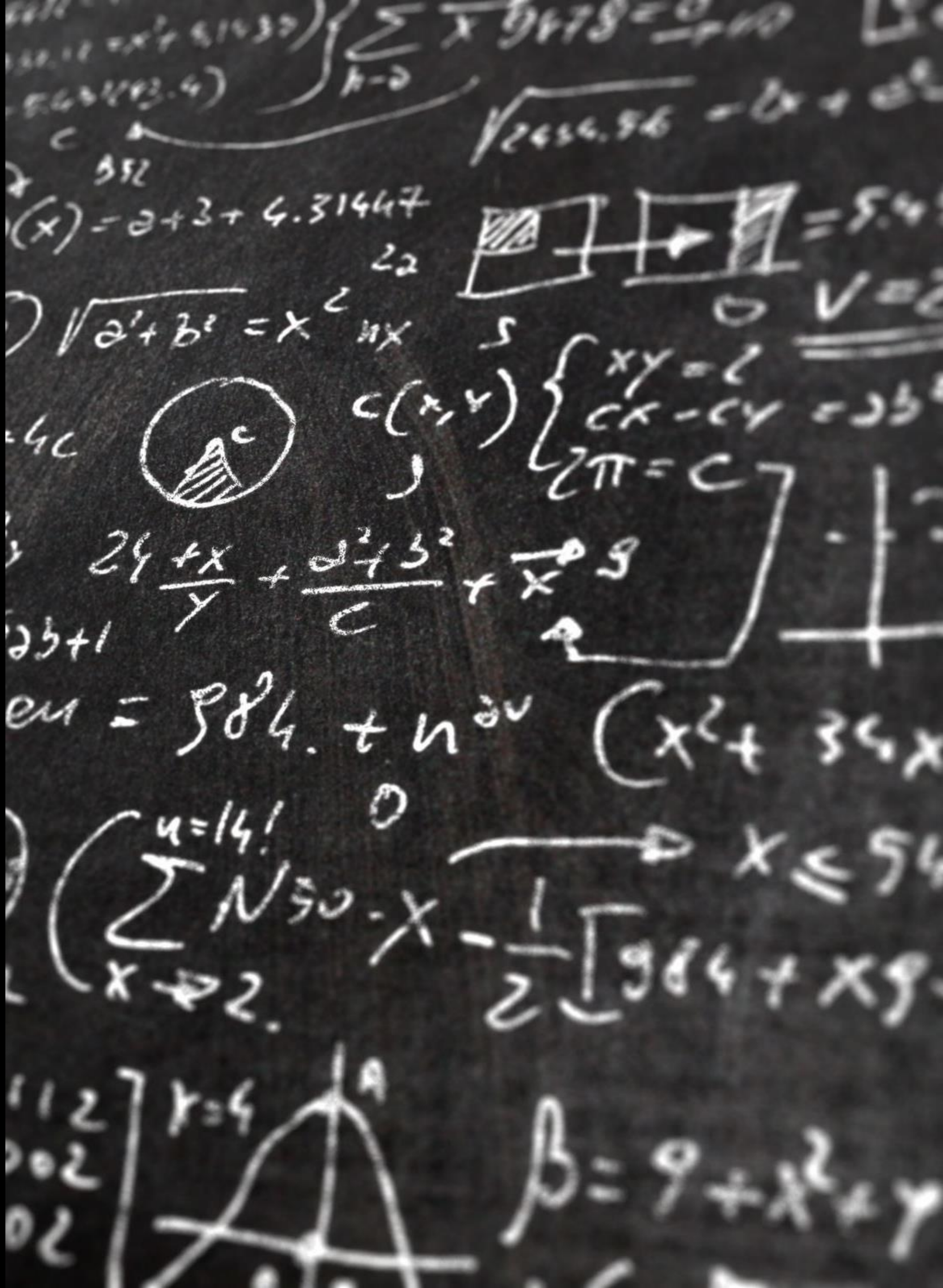
Requirement to lower NOx emissions imposed to three manufacturers with very different fleet.

The initial cheating decision

Solving for a subgame perfect equilibrium

In the paper we…

- Define the strategies
- Characterize the best reply functions
- Use them to identify the equilibria
- Complete the analysis with some comparative statics



Strategies and elimination of non-credible threats

- $s_i = NC$ *“No cheating and investing* I_i^L*”*
- $s_i = CH$ *“Cheat, invest* I_i^H*, and keep the device”.*
- $s_i = CM$ *“Cheat, invest* I_i^M*, and remove the device if innovation is successful”*

- A firm with costs in region L perfectly anticipates that it will systematically get rid of the device. Therefore, it relies on strategy NC. This decision is independent of its rival’s strategy at this stage.
- A firm facing a rival with compliance costs in region H anticipates that, initially, the rival will either select strategy NC or strategy CH. Strategy CM is non-credible.
- A firm facing a rival with compliance costs in region M anticipates that, initially, the rival will either select strategy NC or strategy CM. Strategy CH is non-credible.

Main findings

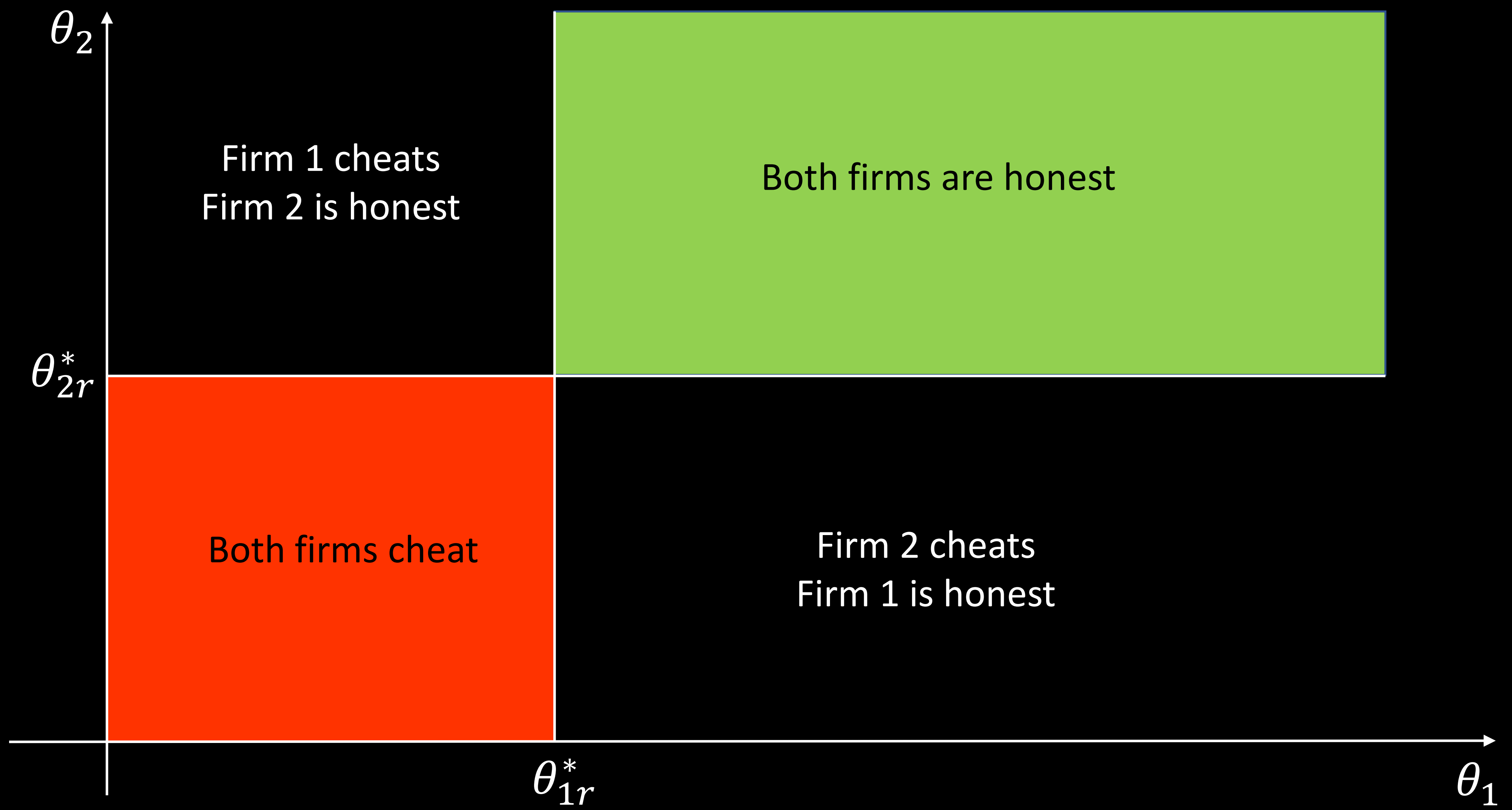
- Since the firm have the ability to remove the device post-innovation, the initial cheating decision reflects their willingness to prioritise investment.
  - Best-reply strategy consists in installing the device when θ low
  - Gaming forms an equilibrium when the firms have a low ability to innovate.
- Competitive pressures promote both, cheating and investment.
- Gaming can form a sub-optimal dominant strategy equilibrium, a prisoner’s dilemma outcome, as competitive pressures increase.

Equilibria when $\Delta\pi = 0$.

Several equilibria emerge, all are in dominant strategies.

1. When both firms have low compliance costs located in region L, they do not install a cheating device, and this forms the unique equilibrium.
2. When (c_i, d_i) is in region L and (c_j, d_j) is in region M or H, there are two dominant strategies equilibria. In each of these firm i does not install a device and firm j installs one if and only if $\theta_j < \theta_{jr}^*$ $(r = M, H)$.
3. When neither of the firms has compliance costs in region L, four dominant strategy equilibriums arise depending on their ability to innovate.

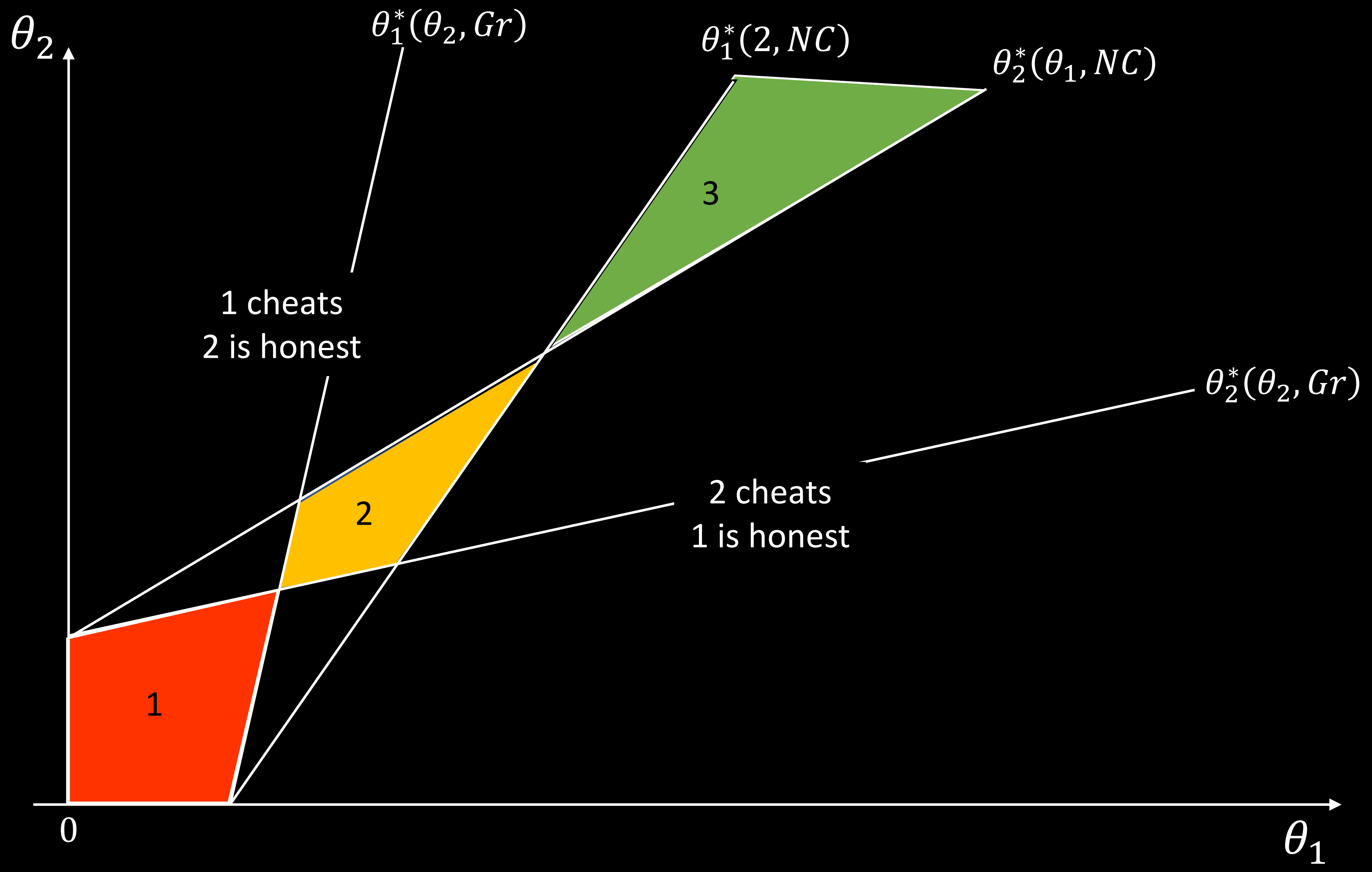
In equilibrium, the sum of profits is maximized.


θ_2
Firm 1 cheats
Firm 2 is honest
Both firms are honest
θ_{2r}^*
Both firms cheat
Firm 2 cheats
Firm 1 is honest
θ_{1r}^*
θ_1

When $\Delta\pi$ increases the game becomes complex as decisions become interdependent.

Points 1 and 2 remain valid.

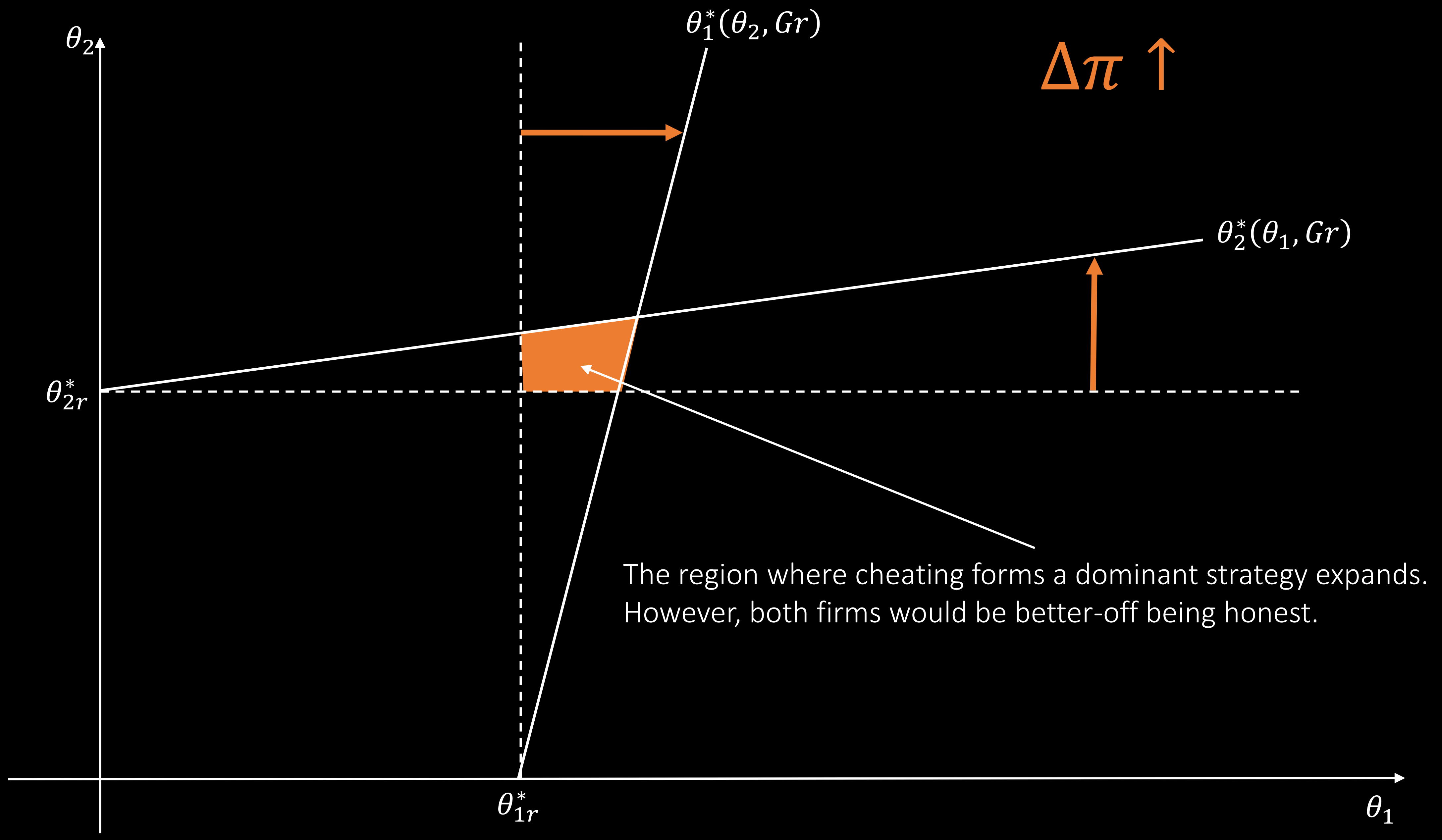
But when neither firm has costs in region L more outcomes arise



In region 1: both cheat (Dom. Strat)

In region 3: both are honest (Dom. Strat.)

In region 2: two asymmetric equilibria where one firm cheats and the other is honest


θ_2
$\theta_1^*(\theta_2, Gr)$
$\Delta\pi \uparrow$
$\theta_2^*(\theta_1, Gr)$
θ_{2r}^*
θ_{1r}^*
θ_1
The region where cheating forms a dominant strategy expands.
However, both firms would be better-off being honest.

Interesting comparative statics

- A greater F discourages cheating (region 3 expands) BUT the impact of γ is not obvious!

- The parameter γ captures the ability to get away with cheating.
  - One would expect that cheating is more prevalent when γ increases.
  - This would be the case provided

$$\underbrace{F(c_i, d_i, \ldots)}_{+} + \Delta\pi\left(P_j - P_i\right) > 0$$

Interesting comparative statics

When $\Delta\pi(P_j - P_i)$ is positive or not too negative, an increase in γ promotes cheating.

When $\Delta\pi(P_j - P_i)$ large and negative, an increase in γ deters cheating.

- When γ=1, the situation is "static" as everyone appears to be compliant. No firm can get $\Delta\pi$.
- When $\Delta\pi$ is large and a firm is confident that it is more likely to innovate than its rival, an increase in γ can lead the firm to behave honestly. It is a commitment to focus on innovation.

Conclusions

- The decision to install a device is typically taken by firms who have low confidence in their ability to innovate.
- The decision to keep the device post-innovation is typically linked to higher unavoidable costs.

On behalf of the three of us

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