Dynamic games applied to common resources: modeling and experimentation

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Dynamic games applied to common resources: modeling and experimentation - preliminary analysis

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Motivation

- Without regulation, Common Pool Resources (CPR) are subject to overexploitation (Hardin, 1968)
- Ex : forest, earth, groundwater, fish stocks.
- To correctly anticipate the effect of regulation, we need to understand how agents take decisions

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Objectives

- Clarify some ambiguities between discrete and continuous time, and the time horizon chosen for lab experiments
- What type of behavior will the experimental subjects exhibit : feedback, myopic, open-loop or social optimum ?
- Continuous time can be approched by discrete time $\Rightarrow$ confront theory with experimentation

Outline

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Literature

- Theoretical article : Rubio & Casino (2003) $\Rightarrow$ continuous time, infinite horizon
- Lab experiment : Janssen & al. (2010) $\Rightarrow$ spatial aspect
- Theoretical with lab experiment :
  - Herr & al. (1997) $\Rightarrow$ discrete time, finite horizon
  - Oprea & al. (2014) $\Rightarrow$ compares continuous and discrete time
  - Tasneem & al. (2017) $\Rightarrow$ continuous time, infinite horizon

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Model

- Infinite horizon framework
- Study the exploitation behavior of a renewable groundwater table by 2 identical and symmetrical farmers $\Rightarrow$ optimal control and game
- the **continuous time** problem :

$$\max_{w_i(t)} \int_0^{\infty} e^{-rt} \left[\underbrace{aw_i(t) - \frac{b}{2} w_i(t)^2}_{Gross\ profit} - \overbrace{\underbrace{c_t(H(t))}_{Unitary\ cost}\ w_i(t)}^{Total\ cost} \right] dt \tag{1}$$

$$\text{st} \begin{cases} \dot{H}(t) = R - \alpha w_i(t) : \textit{the optimal control} \\ \dot{H}(t) = R - \alpha \sum w_i(t) : \textit{the game} \\ w_i(t) \geq 0 \\ H(t) \geq 0 \end{cases}$$

$$H(0) = H_0, \ \textit{and} \ H_0 \ \ \textit{given}$$

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Model

- Calibration :
  $a = 2.5; b = 1.8; \alpha = 1; R = 0.56; c_0 = 2; c_1 = 0.1; r = 0.005; H_0 = 15$

- The unitary cost is such that :

$$c_t(H(t)) = \begin{cases} (c_0 - c_1 H(t)) & \text{if } 0 \leq H(t) < 20 \\ 0 & \text{if } H(t) \geq 20 \end{cases} \Rightarrow \begin{cases} (2 - 0.1 H(t)) & \text{if } 0 \leq H(t) < 20 \\ 0 & \text{if } H(t) \geq 20 \end{cases}$$

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illustrations : extraction behaviors

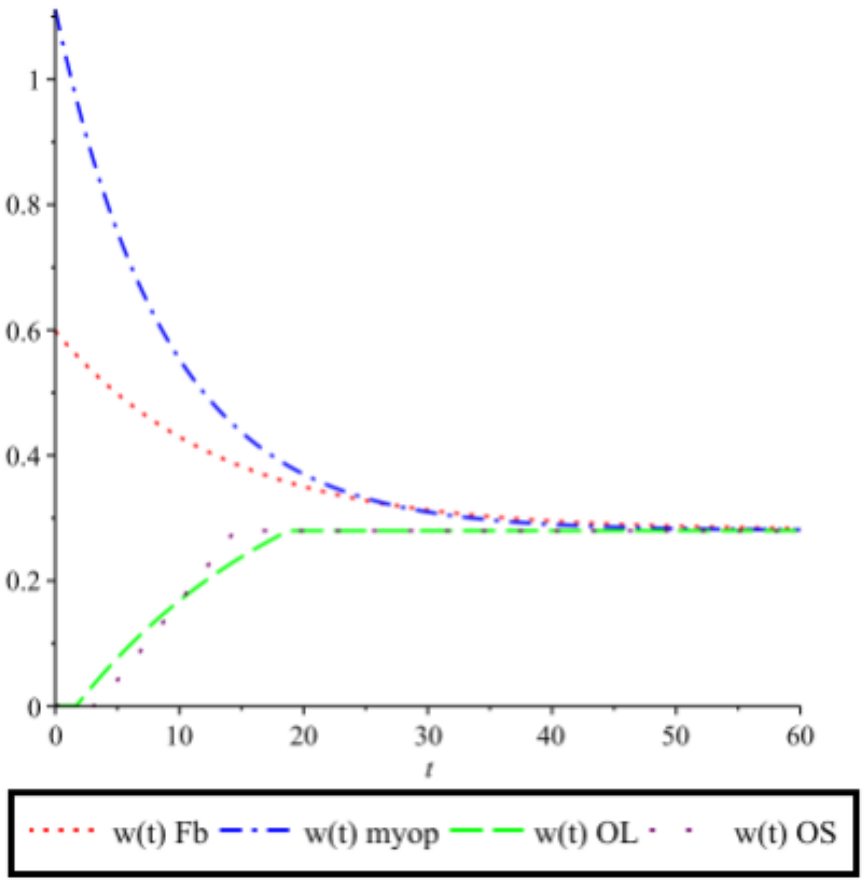

FIGURE – ***The game : feedback, myopic, open-loop and social optimum***

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Model

- the **discrete time** problem :

$$\max_{w_{i\,n}} \sum_{n=0}^{\infty} \underbrace{(1-r\tau)^n}_{\beta^n} \left[a w_{i\,n} - \frac{b}{2} w_{i\,n}^2 - c_n(H_n) w_{i\,n} \right] \tau \tag{2}$$

$$\text{st} \begin{cases} H_{n+1} = H_n + \tau \left(R - \alpha w_{i\,n} \right) : \textit{the optimal control} \\ H_{n+1} = H_n + \tau \left(R - \alpha \sum w_{i\,n} \right) : \textit{the game} \\ w_i(t) \geq 0 \\ H(t) \geq 0 \end{cases}$$

$$H(0) = H_0, \ \textit{and} \ H_0 \ \ \textit{given}$$

- Continuous & discrete time : availabilty of all formulas for the optimal control and the game

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illustrations : continuous and discrete time comparison

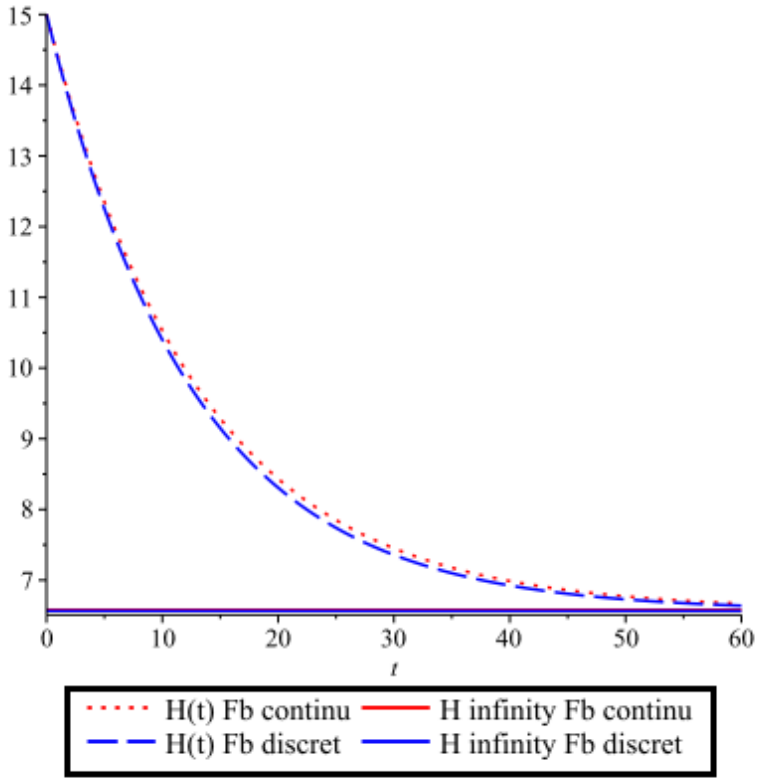

FIGURE – ***Feedback : groundwater table*** $H(t)$ ***convergence for*** $\tau = 1$

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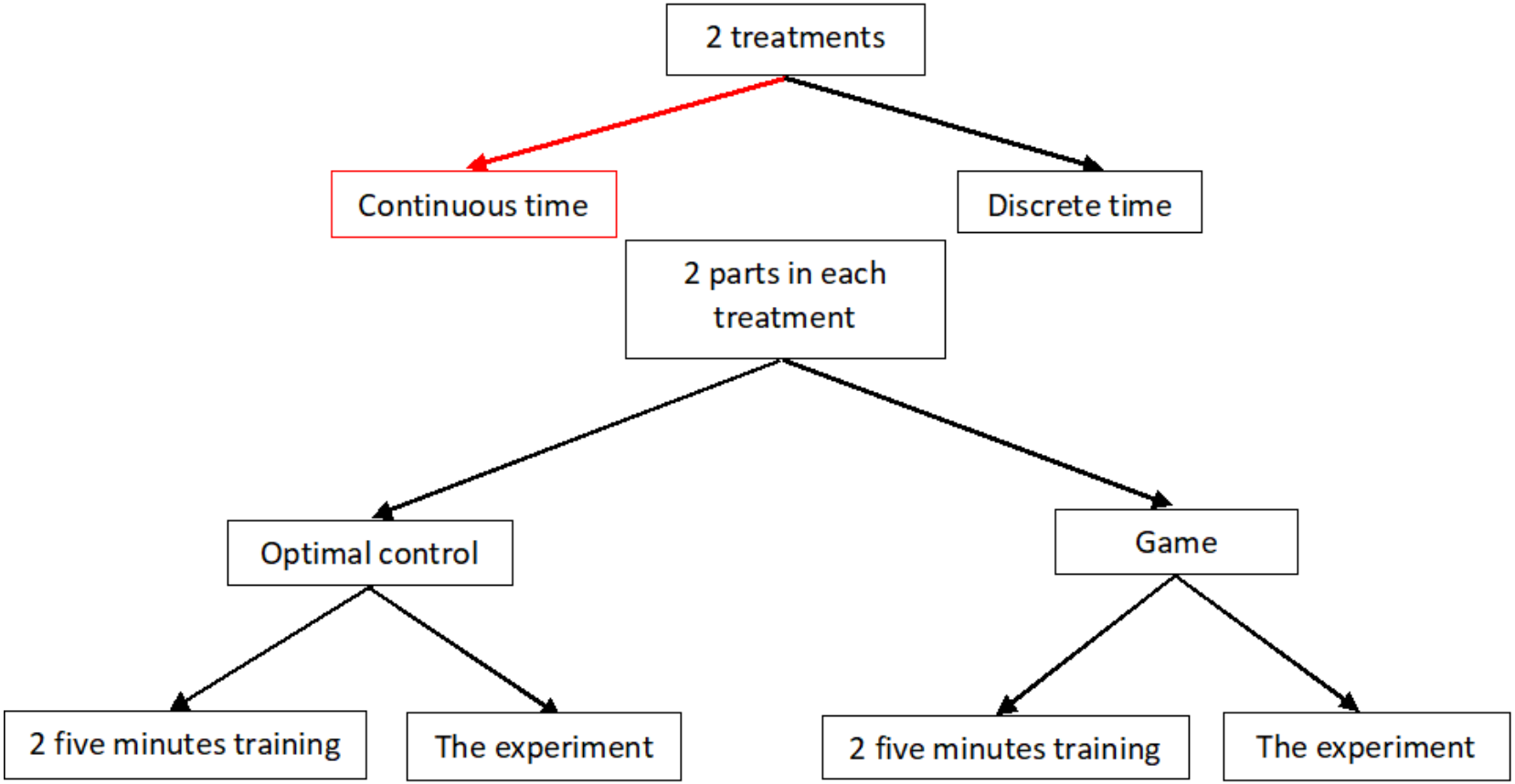
Experimental design



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Experimental design

- No contextualization
- common knowledge experimentation with full information

Subject were informed that...

« You initially have 15 resource units. At any time, you can take a quantity between 0 and 2.8 resource units, with a precision of two decimal places. You are free to choose the quantity you want to take, namely 0, 0.01, 0.02. . . 2.79, 2.8 »

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Preliminary results - continuous time

		Game		
	Type	Feedback	Myopic	Optimal	Total
Optimal control	Other	0	0	1	1
	Myopic	19	2	5	26
	Optimal	7	1	5	13
	Total	26	3	11	40

FIGURE – ***Behavior in the optimal control and the game***

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Discussion and conclusion

We found that :

- Continuous time model $\equiv$ discrete time model when $\tau \to 0$
- But $\tau = 1$ also works $\Rightarrow$ easy to understand in experimentation

The question is...

Which model best represents the reality ?

- Subjects who were myopic in optimal control mostly played feedback in the game
- Econometric analysis not complete $\Rightarrow$ correct time-series treatments

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Further works

First of all :

- Dicrete time lab experiment
- Experimentation : continuous time vs discrete time model

Then :

- Test the game without the optimal control
- Modify the given information $\Rightarrow$ dynamics of the resource vs dynamics of costs

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