Dynamic games applied to common resources: modeling and experimentation : preliminary results

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Motivation

Motivations :

- Without regulation, Common Pool Resources (CPR) are subject to overexploitation (Hardin, 1968)
- To correctly anticipate the effect of regulation, we need to understand how agents take decisions

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 with discrete time $\Rightarrow$ confront theory with experimentation

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Outline

1. Introduction
   - Motivation
   - Literature
2. The theoretical model
   - Infinite horizon modeling
     - The optimal control
     - The game
3. Theory and experimentation
   - Experimentation
     - The optimal control
     - The game
4. Econometric analysis
   - Preliminary analysis
   - Preliminary results
5. Concluding remarks

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

- We study the behavior of two identical and symmetrical farmers, exploiting a renewable groundwater table in infinite time
- The optimal control and the game
- the continuous time problem :

$$\max_{w_i(t)} \int_0^{\infty} e^{-rt} \left[\underbrace{a w_i(t) - \frac{b}{2} w_i(t)^2}_{Gross\ profit} - \underbrace{\overbrace{\left(c_0 - c_1 H(t)\right)}^{Unitary\ cost} w_i(t)}_{Total\ cost} \right] dt \qquad (1)$$

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

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

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Model

- the discrete time problem :

$$\max_{w_{i\ n}} \sum_{n=0}^{\infty} \underbrace{(1 - r\tau)^n}_{\beta^n} \left[a w_{i\ n} - \frac{b}{2} w_{i\ n}^2 - (c_0 - c_1 H_n)\, w_{i\ n} \right] \tau \tag{2}$$

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

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

Model

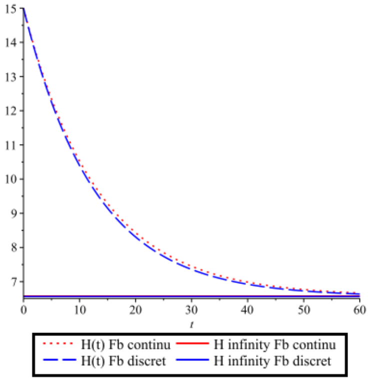
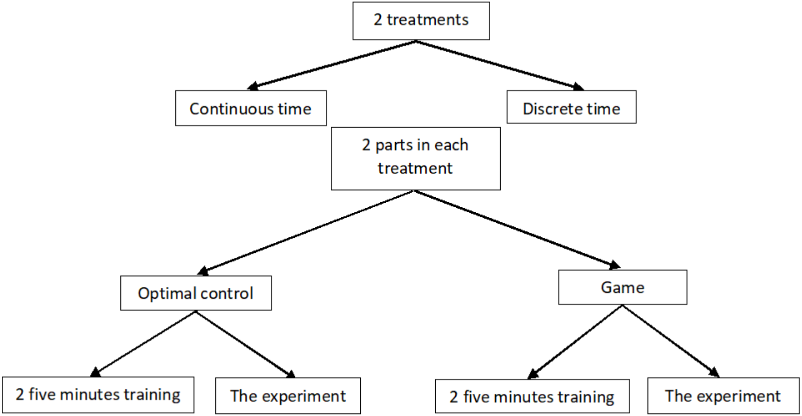


FIGURE – ***Feedback : groundwater table*** $H(t)$ ***convergence for*** $\tau = 1$

Experimental design



Experimental design

- 40 subjects in the optimal control and 20 groups for the game
- Between subject design : different subjects for each treatment
- 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 dynamics of the resource :

$$\begin{cases} H_{t+1} = H_t + 0.56 - w_{it} : \textit{the optimal control} \\ H_{t+1} = H_t + 0.56 - (w_{1t} + w_{2t}) : \textit{the game} \end{cases}$$

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Experimental design

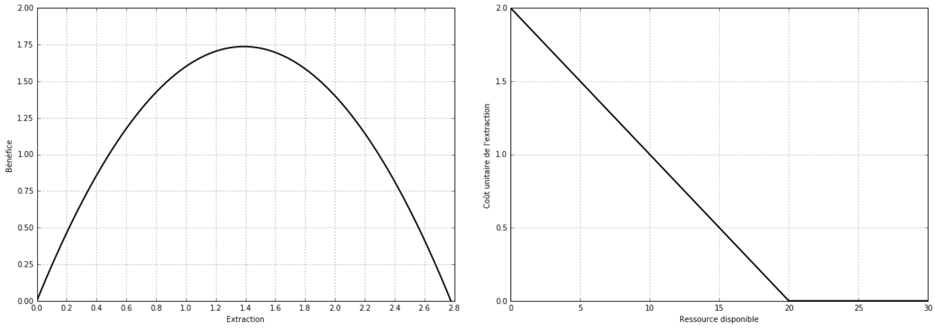
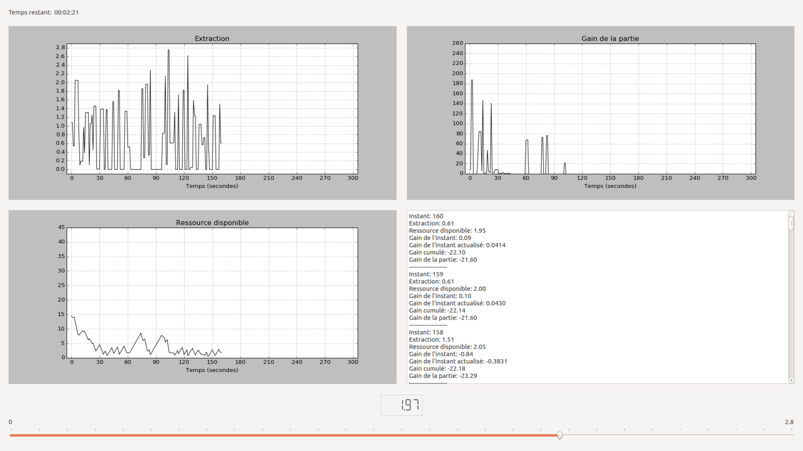


FIGURE – ***Information on gross profit and unitary cost***

Continuous time : optimal control interface



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Preliminary analysis

$$\text{Different types of behavior : } \overbrace{feedback, open - loop, \underbrace{myopic, social\ optimum}_{Optimal\ control}}^{The\ game}$$

- OLS regression :

$$E_t^{expe} = \alpha + \beta E_t^{theor} + \varepsilon_t \tag{3}$$

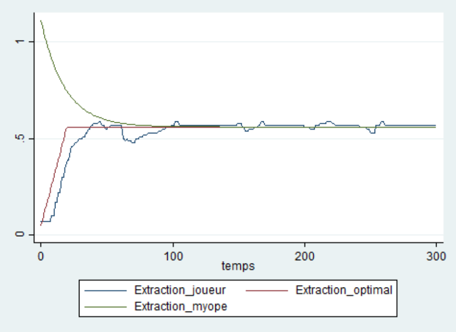
- Classification of behaviors according to the highest R^2
- Limits to take into account

Preliminary results

Optimal control	Game: Feedback	Game: Myopic	Game: Optimal	Total
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***

Illustrations



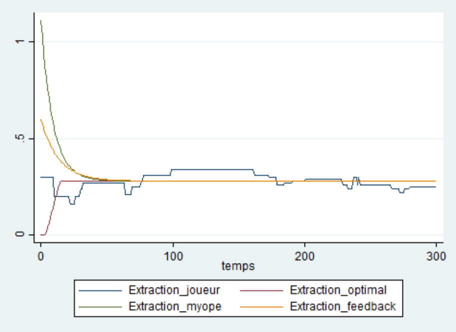


FIGURE – ***Comparing a player's behavior : optimal control and game***

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Conclusion

- Continuous time treatment : subjects were more myopic in the optimal control than in the game
- Econometric analysis not complete $\Rightarrow$ correct time-series treatments
- Some extensions :
  - Dicrete time lab experiment
  - Experimentation : continuous time vs discrete time model
  - Test the game without the optimal control
  - Modify the given information

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Thank you for your attention !