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Anmina Murielle Djiguemde, Dimitri Dubois, Mabel Tidball, Alexandre Sauquet

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

Murielle Djiguemde, Dimitri Dubois,
Mabel Tidball and Alexandre Sauquet

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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 approached with discrete time \Rightarrow confront theory with experimentation

Outline

- 1 Introduction
 - Motivation
 - Literature
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 - 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

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 :

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

$$\text{st } \begin{cases} \dot{H}(t) = R - \alpha w_i(t) : \text{the optimal control} \\ \dot{H}(t) = R - \alpha \sum w_i(t) : \text{the game} \\ H(0) = H_0, \text{ and } H_0 \text{ given} \end{cases}$$

Model

- the discrete time problem :

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

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

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

Model

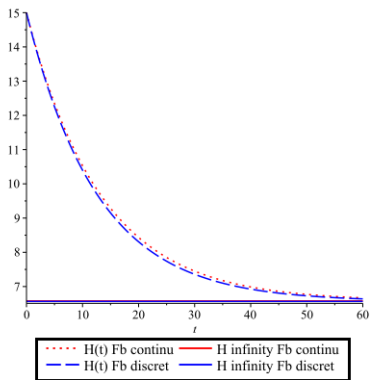
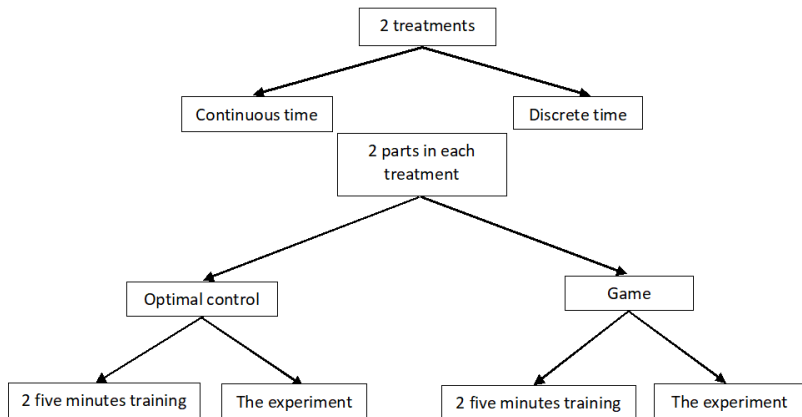


FIGURE – *Feedback : groundwater table $H(t)$ convergence for $\tau = 1$*

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 :

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

Experimental design

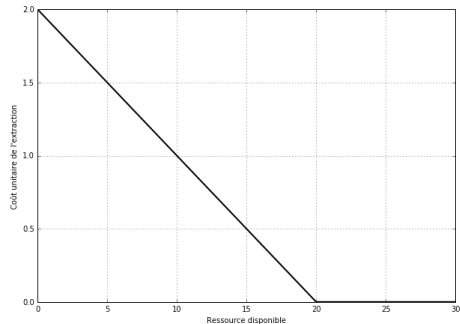
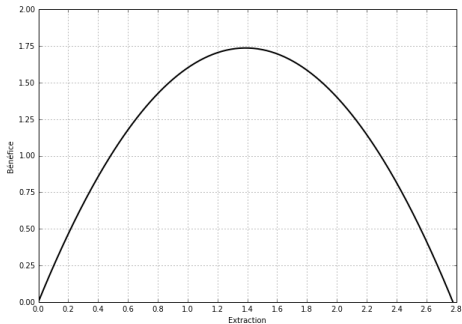


FIGURE – Information on gross profit and unitary cost

Continuous time : optimal control interface



Preliminary analysis

Different types of behavior : $\overbrace{\text{feedback, open – loop, myopic, social optimum}}^{\text{The game}}$
 $\underbrace{\hspace{15em}}_{\text{Optimal control}}$

- OLS regression :

$$E_t^{expe} = \alpha + \beta E_t^{theor} + \varepsilon_t \quad (3)$$

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

Preliminary results

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

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

Illustrations

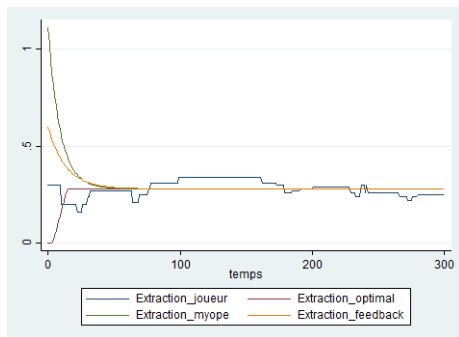
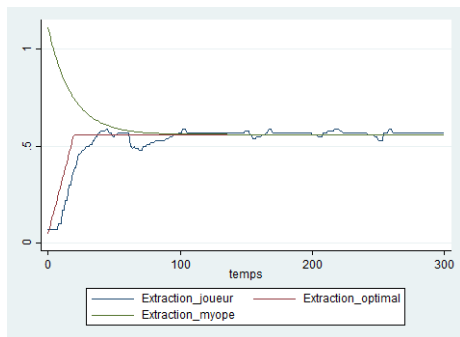


FIGURE – Comparing a player's behavior : optimal control and game

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 :
 - Discrete time lab experiment
 - Experimentation : continuous time vs discrete time model
 - Test the game without the optimal control
 - Modify the given information

Thank you for your attention!