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An agent-based model of delegation relationships with hidden-action:

On the effects of heterogeneous memory on performance

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Resume

- Patrick Reinwald
  - **Phd student**
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Motivation 1

- The standard hidden-action model:
  - Describes a delegation relation between a principal and an agent
  - It covers a situation where exactly one task is delegated
  - The agent selects an effort which is not observable by the principal
  - The outcome is a product of the chosen effort and the exogenous factor
  - Both the principal and the agent individually try to maximize their utility
  - The principal tries to align the agent's goal with her goal

(Holmström 1979)

Motivation 2

- Principal-agent theory makes some rather restrictive assumptions about information, individual behaviour and capabilities, e.g.,
  - Full rationality
  - Information asymmetry for specific types of information
  - Information processing capabilities
  - Limited power to explain empirical phenomena
- Our agent-based model variant of the standard hidden-action model
  - Less “gifted” and heterogeneous agents (cognitive capacity)
  - Limited availability of information regarding the exogenous factor

(Axtell 2007)

Hidden-action model

The standard hidden-action model

- Makes specific assumptions about individual behaviour and about the information available for the principal and the agent
- The optimal solution can be found in one time step (second-best solution)

Principal (P)

$$U_P(x,s) = x - s(x)$$

$$\max E(U_P(x,s))$$

$$s.t.\ E\big(U_A(s,a)\big) \geq \overline{U}$$

$$a \in \arg\max E\{U_A(s,a')\}$$

P's utility function is defined by the outcome and A's compensation

P maximizes her expected utility subject to

- Participation constraint
- Incentive compatibility constraint

Agent (A)

$$U_A(s,a) = V(s) - G(a)$$

$$\max E(U_A(s,a))$$

A's utility function is defined by utility from compensation minus disutility from exerting effort

(Holmström 1979)

Research agenda

The standard hidden-action model

- Makes specific assumptions about individual behaviour, the information available for the principal and the agent and their cognitive capacity
- The optimal solution can be found in one time step (second-best solution)

Agent-based model variant: adaptions

- Relax assumption regarding information of exogenous factor
  - Distribution of exogenous factor is unknown
  - P and A are able to individually learn about the exogenous factor
  - Different levels of cognitive capacity (memory)
- P can adapt the parameterization of the incentive scheme over time
- A reacts to the parameterization based on his state of information (via the selected effort levels)

Transferring the hidden-action model 1

STANDARD MODEL		AGENT-BASED MODEL
P's information • A's characteristics $(U_A, \overline{U})$ • Observed outcome (x) • Entire 'action space' (A)	=	P's information • A's characteristics $(U_A, \overline{U})$ • Observed outcome (x) • Entire 'action space' (A)

• Distribution of exogenous factor	≠	• Limited information about the environment
		• P endowed with
		  • Learning capabilities
		  • Different levels of cognitive capacity (memory)

Transferring the hidden-action model 2

STANDARD MODEL		AGENT-BASED MODEL
A's information • Observed outcome (x) • A's private information: selected action, realized exogenous factor	=	A's information • Observed outcome (x) • A's private information: selected action, realized exogenous factor

• Distribution of exogenous factor	≠	• Limited information about the environment
		• A endowed with
		  • Learning capabilities
		  • Different levels of cognitive capacity (memory)

Scenarios 1

- Benchmark scenario
  - Results derived from the standard hidden-action model are used as the benchmark scenario (second-best solution)

- Agent-based model parameterization
  - Principal
    - Linear utility function
  - Agent
    - Exponential utility function (risk-averse)
    - Reservation utility normalized to 0
  - Environment
    - Normal distributed
    - Standard deviation relative to optimal outcome x^* either $0.05x^*$or $0.45x^*$ (mean always set to 0)

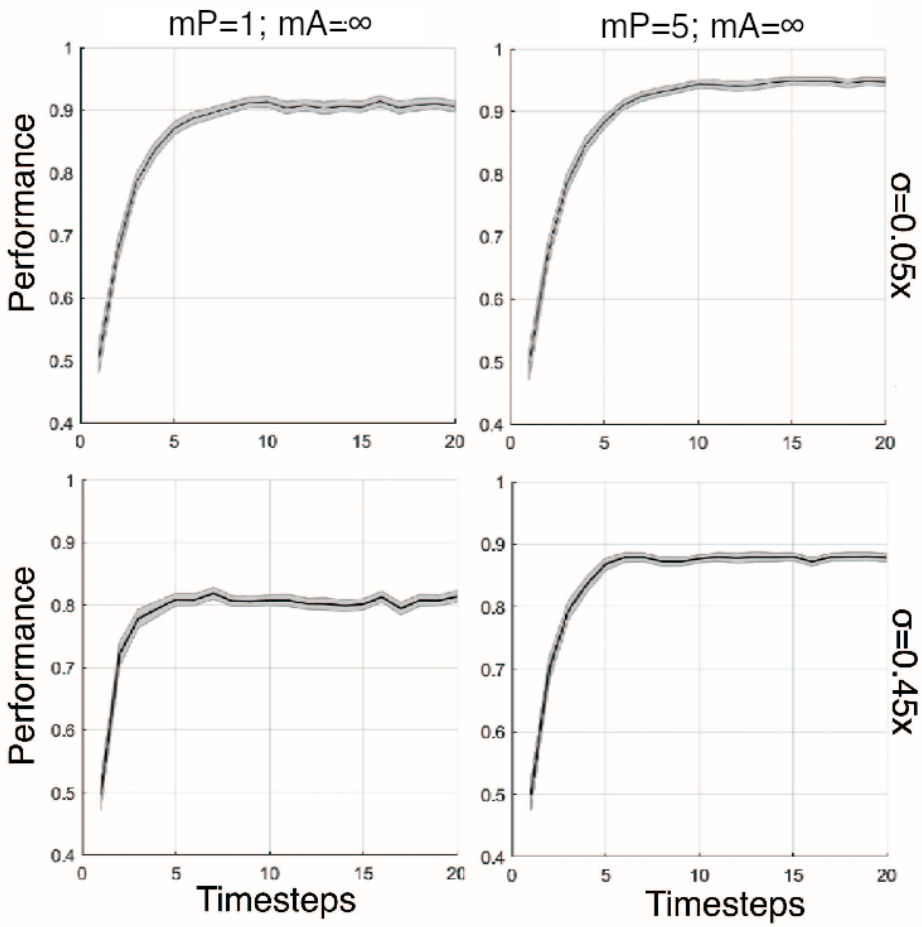
Scenarios 2

- Levels of cognitive capacity for principal and agent
  - Limited cognitive capacity: 1 period
  - Moderatly limited cognitive capacity: 5 periods
  - Unlimited cognitive capacity: all historical data
- Further parameters
  - Simulation runs per scenario: 700
  - Periods per time path: 20
- Performance measure:

$$\phi_t = \frac{1}{R} \sum_{r=1}^{r=R} \frac{a_{tr}}{a*}$$

- a^* = 'second-best' action derived from the standard model
- t = timesteps;
- r = simulation run; R = total number of simulation runs
- a_{tr} = action selected by the agent in timestep t and simulation run r

Advantage in information for A

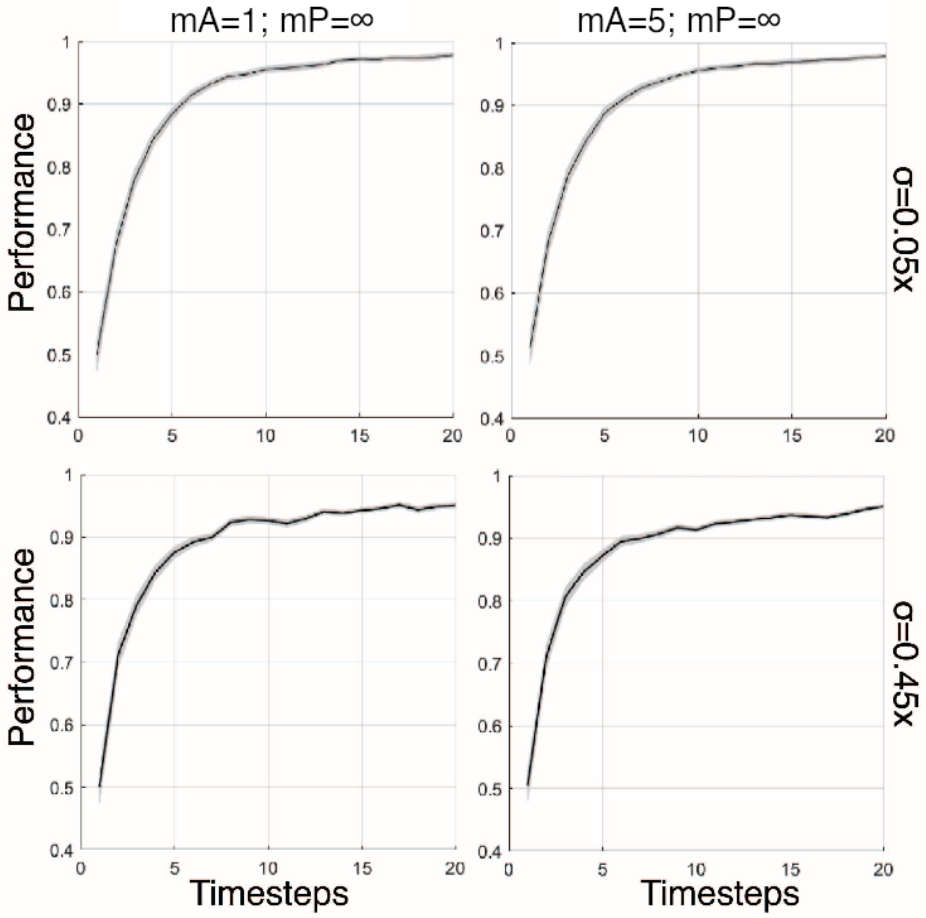


Results:

- Increase in environmental turbulence **decreases** the overall performance
- Increase in principal's memory
  - **increases** overall performance
  - **increases** the number of timesteps to reach a stable solution
  - **decreases** the variance of the exerted efforts (only in unstable environments)

mA = Agent's memory
mP = Principal' s memory

Advantage in information for P



Results:

- Increase in environmental turbulence **decreases** the overall performance
- Increase in agent's memory
  - **does not increases** overall performance
  - **decreases** the number of timesteps to reach a stable solution
  - **decreases** the variance of the exerted efforts

mA = Agent's memory
mP = Principal' s memory

Summary

- The results suggest that:
  - Gathering information about the environment is a good strategy for the principal to increase his utility
  - In turbulent environments, increasing the memory of both the principal and the agent always reduces the variance of the results -> reduces the risk of extreme deviations from the performance measure.
  - In stable environments, this effect can only be seen by increasing the agent's memory
  - Environmental turbulence has a positive effect on stability, so that a stable solution emerges earlier in turbulent environments

Limitations and future work

- Some assumptions are carried over from the standard hidden-action model
  - P and A can process information without error
  - Availability of information about the agent for the prinicpal
- Future work
  - Deeper investigate the effects of heterogeneous memory in the hidden-action setting
  - Include cognitive biases when characterizing the principal's and the agent's cognitive capabilities
  - Limit the principal's knowledge about the characteristics of the agent

Thank you for your attention

For any questions or comments, please contact me:

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