Economic Models with Heterogeneous and Interacting Agents

Isabelle Salle*

Presentation at the ILO
March 2013

* University of Bordeaux, France & International Labour Office, Switzerland

Limits of the existing paradigm (DSGE models)

Unrealistic behavioural assumptions with weak empirical validation

- Representative agent assumption : same behaviour, same expectations.
  $\Rightarrow$ no coordination nor aggregation issues.
- Maximising agent framework:
  - Substantive rationality.
  - Forward-looking behaviour and rational expectations.
  - Complete information, the "whole picture" is available.

  $\Rightarrow$ Microfoundations (robust to the Lucas critique)

  $\nRightarrow$ Evidence in psychology, brain science, cognitive science, experimental economics (Kahneman & Tversky, Simon).
- A stationary environment with exogenous volatility and (near-) equilibrium analysis.

  $\nRightarrow$ No explanation of business cycles, no crisis.

The need to go a step further towards realistic modelling

- Colander 2006, Delli Gatti et al. 2009, Trichet 2010, Howitt 2012, De Grauwe 2012.
- Four attempts within macroeconomic models:
  - Econometric/statistical learning
    (Sargent (1993), Evans & Honkapohja (2001))
  - the **Heterogeneous Agent** literature
    (Brock & Hommes 1997, Branch & Evans 2010, De Grauwe 2011)
  - the **Evolutionary Algorithm** literature
    (Sargent 1993, Arifovic 1994-95, 2011, Vriend 2000, Noe et al. 2003, Vallée & Yildizoglu 2009)
  - the **Agent-Based** literature
    (Raberto et al. 2007-10-12, Delli Gatti et al. 2009, EURACE project, Dosi et al. 2012-13, Seppecher 2012, Lengnick 2013, Salle et al. 2013)

General Features of heterogeneous and interacting agent framework

- Agents cannot see the whole picture of the economy.
- No rational expectations based on the complete set of information.
- No representative agent: heterogeneous strategies, expectations.
- No maximisation under constraints: simple behavioural rules.
- No tractable model: numerical simulations.
- Microfoundations :
  - Either within a stylized macroeconomic model,
  - Or within a fully decentralized macroeconomic model (ABMs)
- Multiple objectives:
  - Empirical exercise.
  - Theoretical analysis of the implications of alternative assumptions.
  - Assessing convergence and coordination towards optimal behaviour.

The Heterogeneous Agent literature

Ingredients

- A or several group(s) of agents assumed to be heterogeneous (households, firms, investors...)
- A **finite set of available strategies** (behavioural rules or expectations):
  $\Rightarrow$ Usually two types (fundamentalists vs. chartists, pessimistic vs. optimistic, believers vs. non-believers...).
  $\Rightarrow$ A **time-varying proportion** of these types within the agent population.
- A measurement of strategy performances (forecast errors, utility...).
- A performance-based **evolutionary mechanism to switch** between the available strategies.
  $\Rightarrow$ Intuition: the highest performing strategy tends to attract the biggest proportion of agents at the expense of the less performing strategies.
- Endogenous volatility arising from these switches.

The Heterogeneous Agent literature

An example – De Grauwe (2012) model

- Framework: the baseline NK model (Woodford 2003):

$$x_t = \hat{E}_t(x_{t+1}) - (i_t - \hat{E}_t(\pi_{t+1}) - r_t^*)$$
$$\pi_t = \hat{E}_t(\pi_{t+1}) + \kappa x_t + u_t$$
$$i_t = r^* + \pi^T + \phi_x x_t + \phi_\pi(\pi_t - \pi^T)$$

- Main insights:
  - Endogenous waves of optimism and pessimism explain the volatility and persistence of macro variables. (animal spirits)
  - Reproduction of statistical properties of the output gap (non-normal distribution with fat tails).
  - Endogenous waves of credibility produce inflation variability.
  - More hawkish optimal monetary policy rule in face of imperfect credibility of the inflation target.

The Heterogeneous Agent literature

An example – De Grauwe (2012) model

- Two output gap expectations:
  - Optimistic: $E_t^{opt}(x_{t+1}) = g > 0$ in proportion α_t^{opt}
  - Pessimistic: $E_t^{opt}(x_{t+1}) = g < 0$ in proportion $\alpha_t^{pes} = 1 - \alpha_t^{opt}$
- Two inflation expectations:
  - Believers : $E_t^{tar}(\pi_{t+1}) = \pi^T$ in proportion β_t^{tar}
  - Non-believers: $E_t^{ext}(\pi_{t+1}) = \pi_{t-1}$ in proportion $\beta_t^{ext} = 1 - \beta_t^{tar}$
- Performance criterion:

$$U_t^i = -\sum_{k=1}^{\infty} \omega_k [x_{t-k} - E_{t-k-1}^i(x_{t-k})]^2 \ , \ i = \{opt, pes\}$$

- Switch routine:

$$\alpha_t^{opt} = \frac{\exp(\gamma U_t^{opt})}{\exp(\gamma U_t^{opt}) + \exp(\gamma U_t^{pes})}$$

The Evolutionary Algorithm literature

Ingredients

- A or several group(s) of agents assumed to be **heterogeneous**.
- A **pool of potential strategies**
  (finite or not, discrete or continuous, one- or multi-dimensional).
- A measurement of strategy performances (forecast errors, utility...).
- Exploration vs. exploitation of the strategy space:
  - **Exploitation**: diffusion of the highest performing strategies, disappearance of less performing ones.
  - **Exploration**: new strategies are constantly introduced.
- Performed through several genetic-based **operators**.
- Either **social** (population-based) or **individual** learning.

The Evolutionary Algorithm literature

Individual learning: an example (Yildizoglu et al. 2012)

Can consumers learn the (near) optimal buffer stock rule of consumption ?

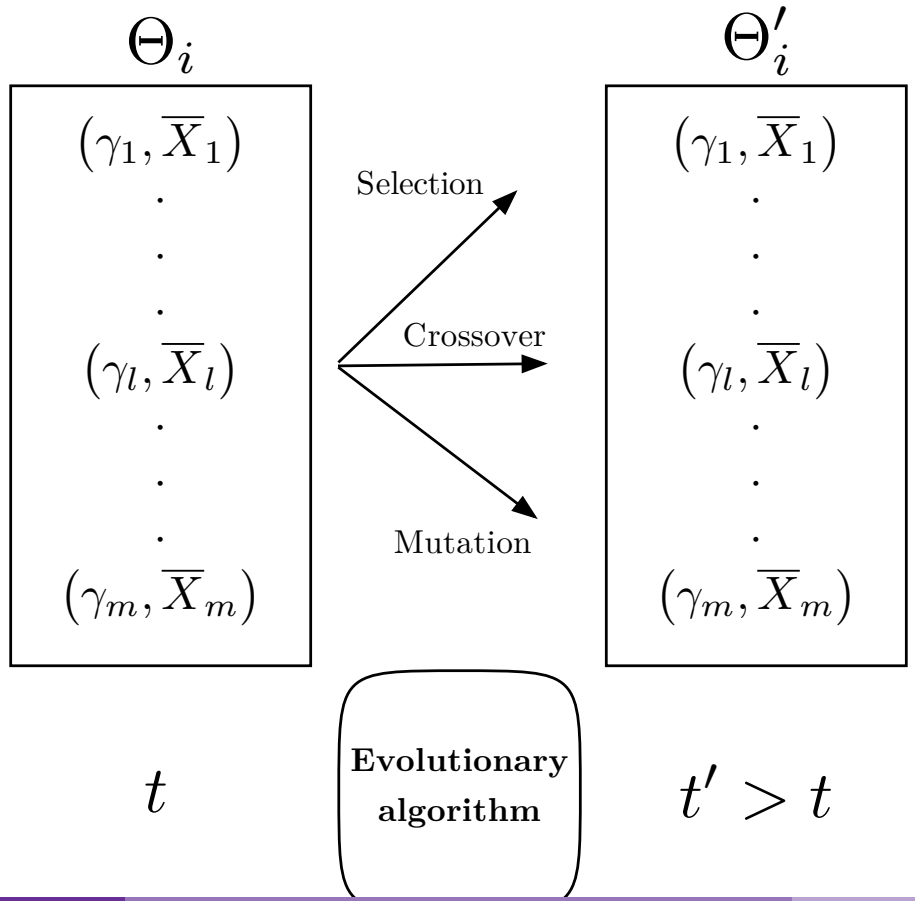
$$C^*\left(X_t\right) = 1 + \gamma^* \cdot \left(X_t - \overline{X}^*\right)$$

The Evolutionary Algorithm literature

Individual learning: an example (Yildizoglu et al. 2012)

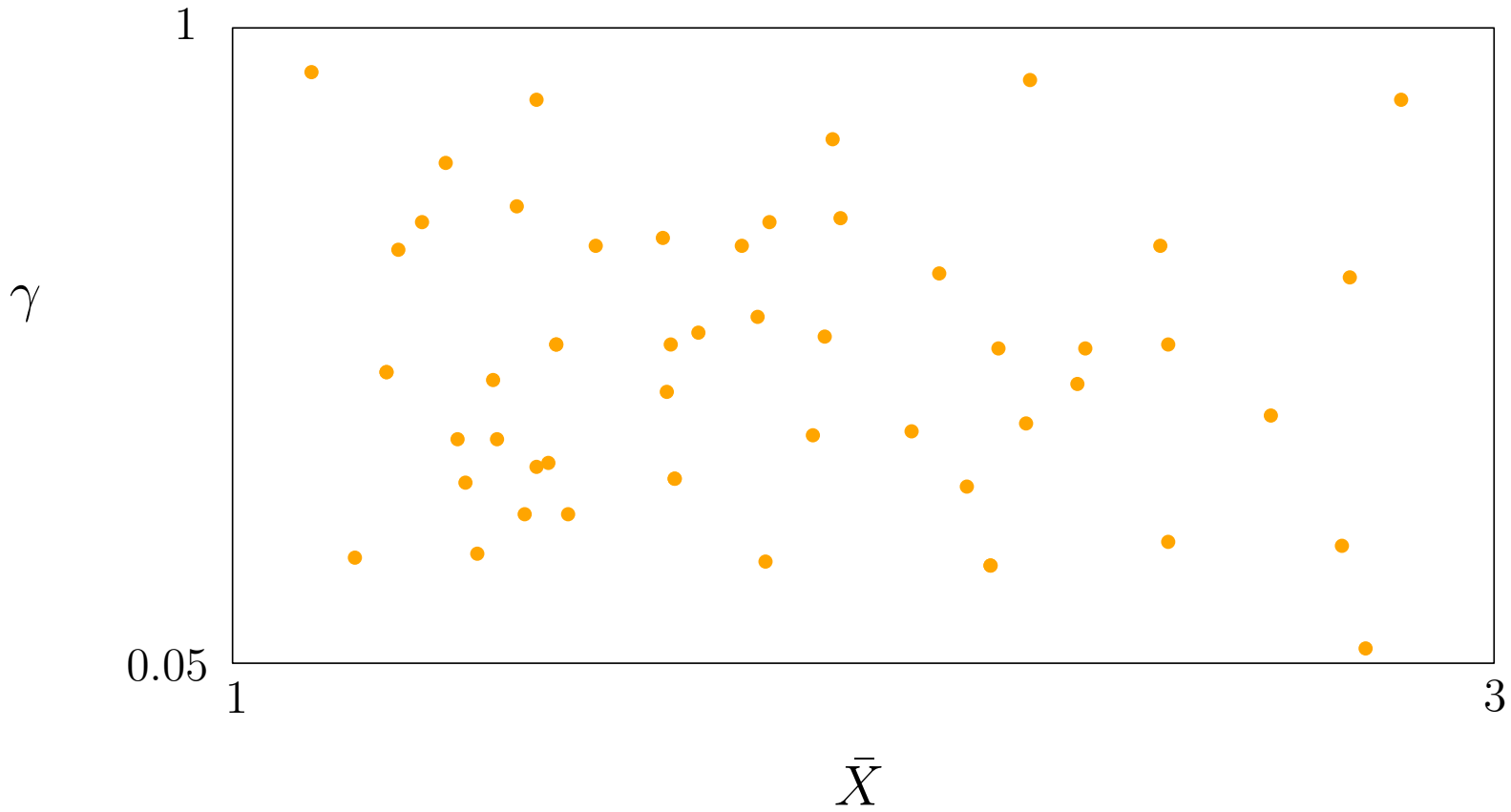
Can consumers learn the (near) optimal buffer stock rule of consumption ?

$$C^*(X_t) = 1 + \gamma^* \cdot (X_t - \overline{X}^*)$$



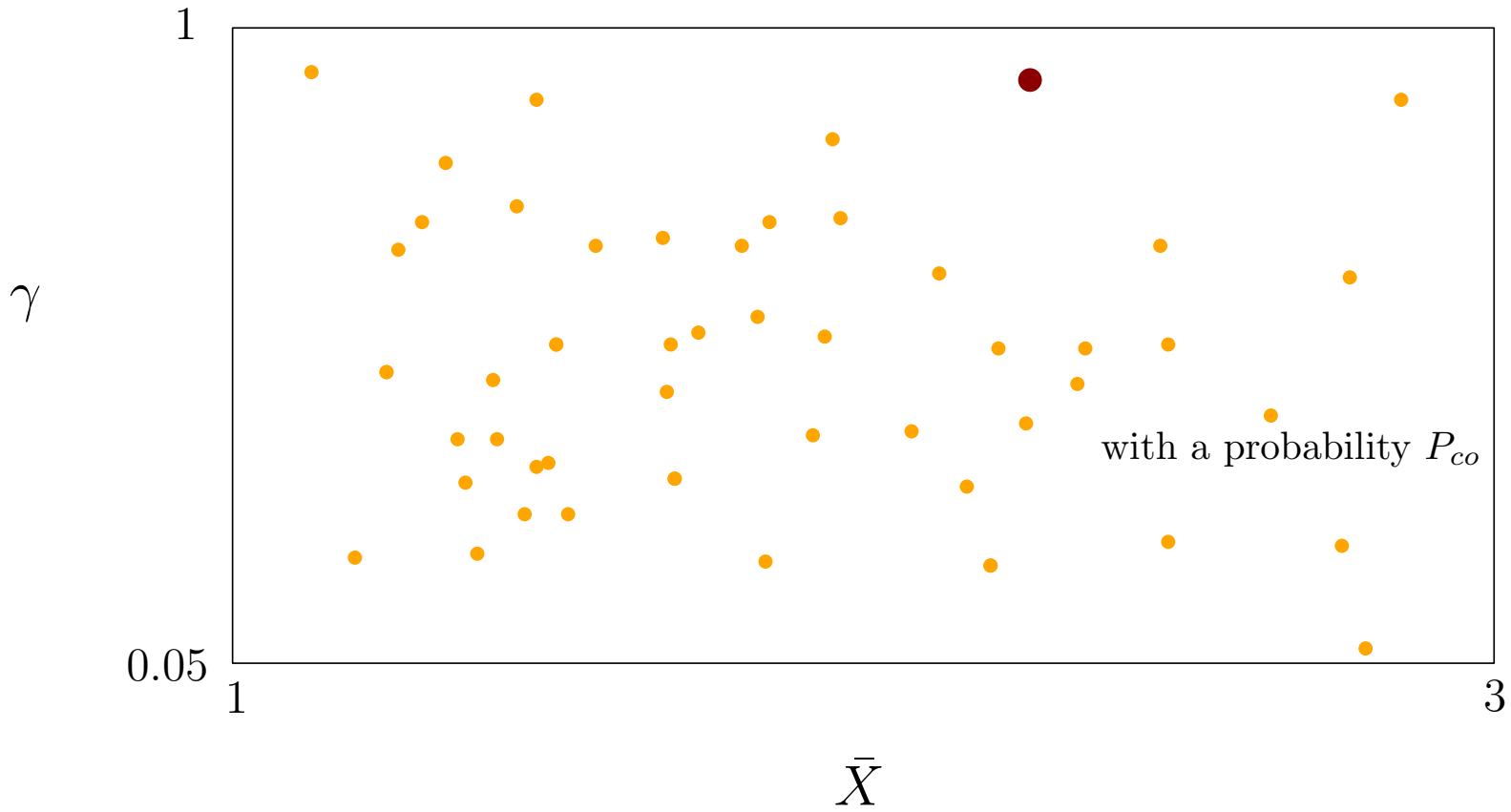
The Evolutionary Algorithm literature

Social learning: an example (Salle & Seppecher 2013)



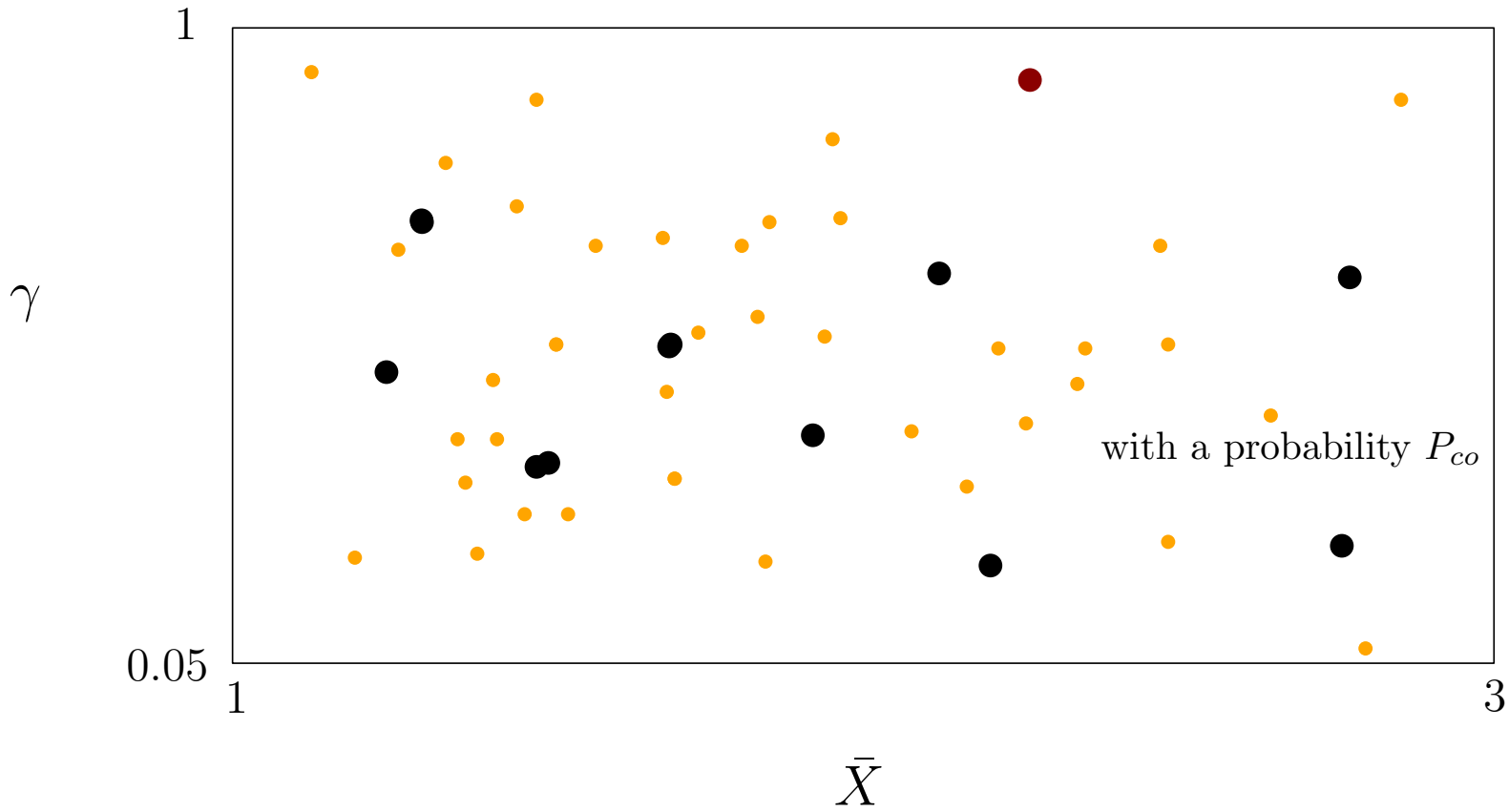
The Evolutionary Algorithm literature

Social learning: an example (Salle & Seppecher 2013)



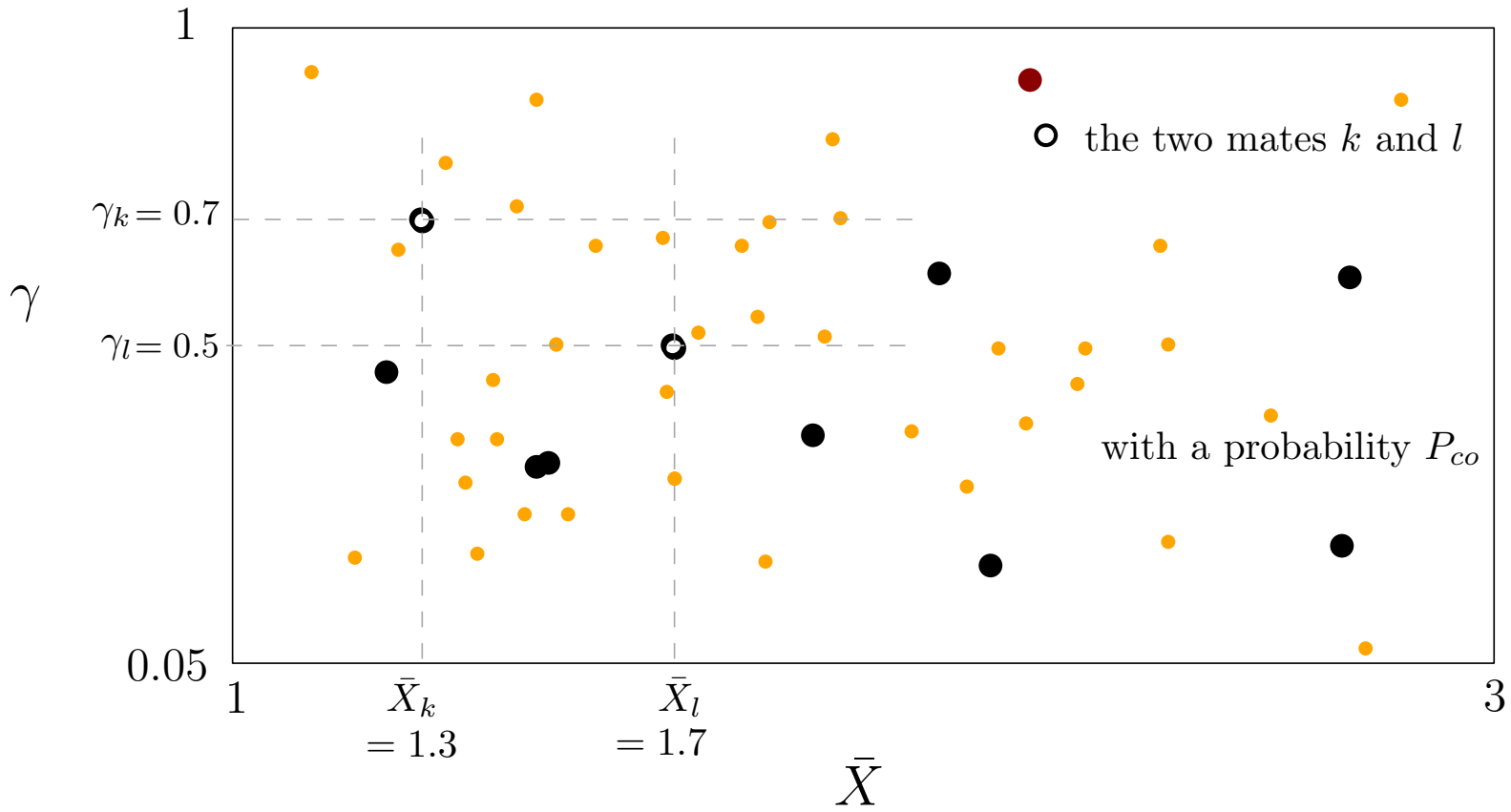
The Evolutionary Algorithm literature

Social learning: an example (Salle & Seppecher 2013)



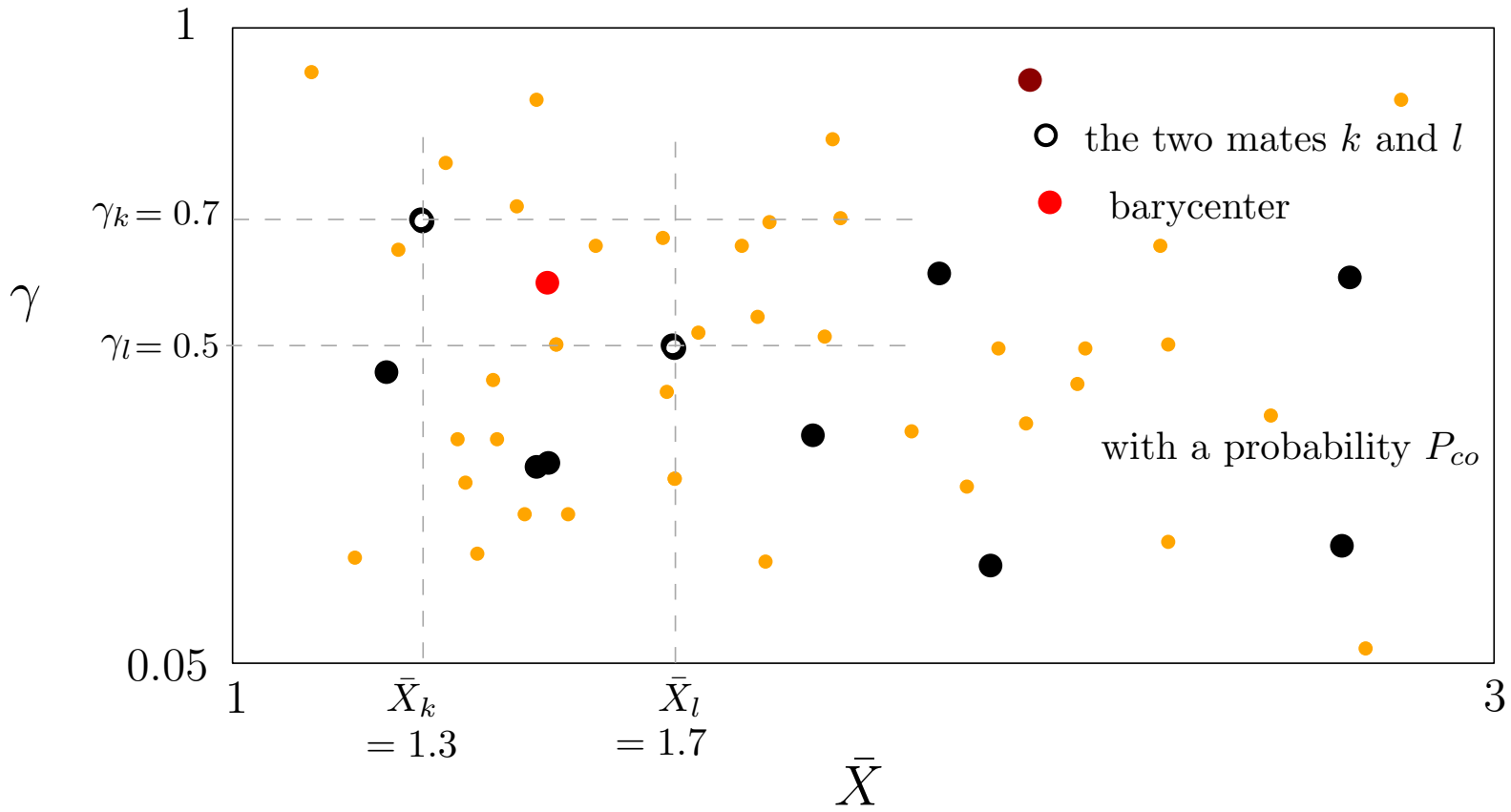
The Evolutionary Algorithm literature

Social learning: an example (Salle & Seppecher 2013)



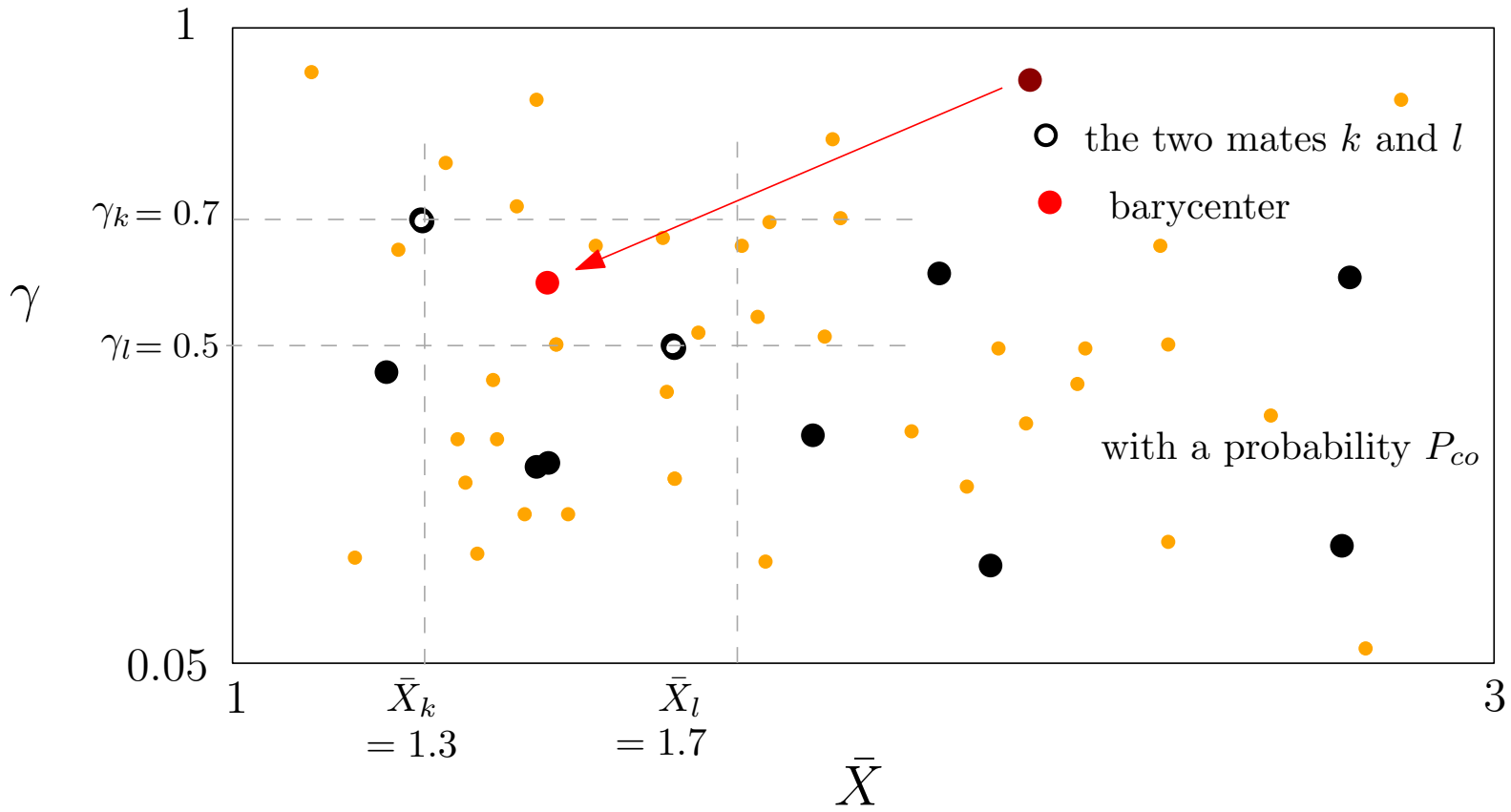
The Evolutionary Algorithm literature

Social learning: an example (Salle & Seppecher 2013)



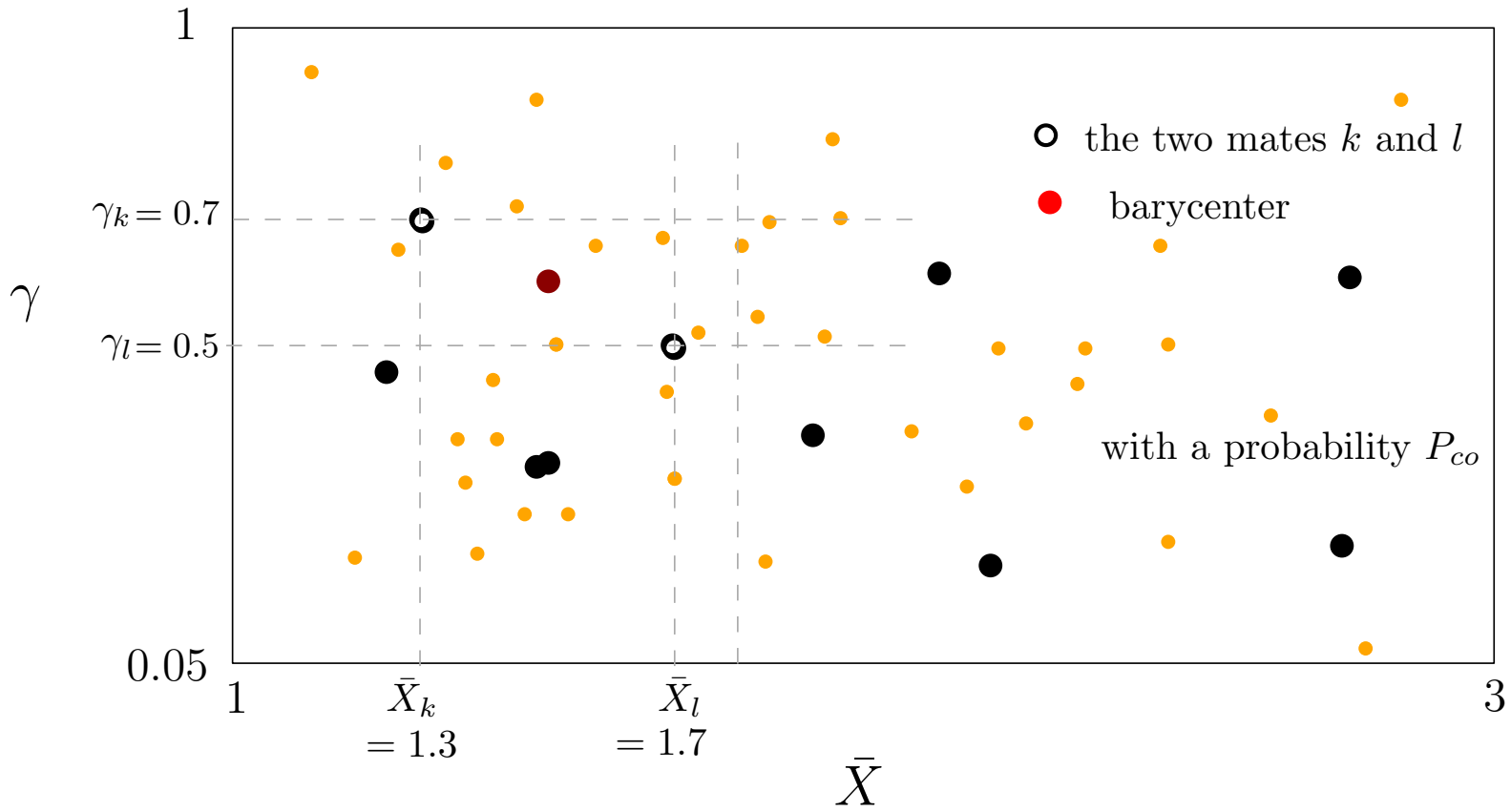
The Evolutionary Algorithm literature

Social learning: an example (Salle & Seppecher 2013)



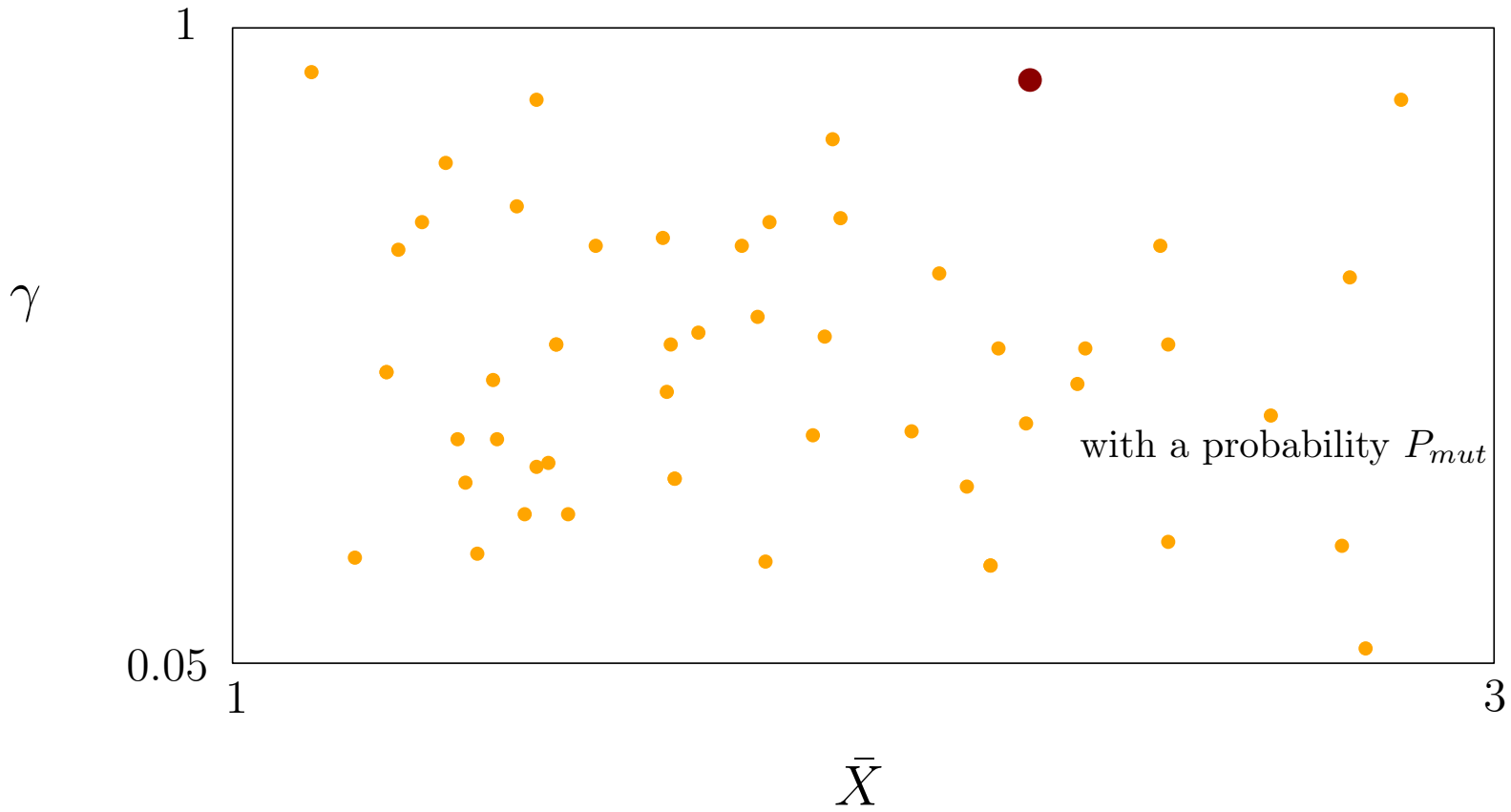
The Evolutionary Algorithm literature

Social learning: an example (Salle & Seppecher 2013)



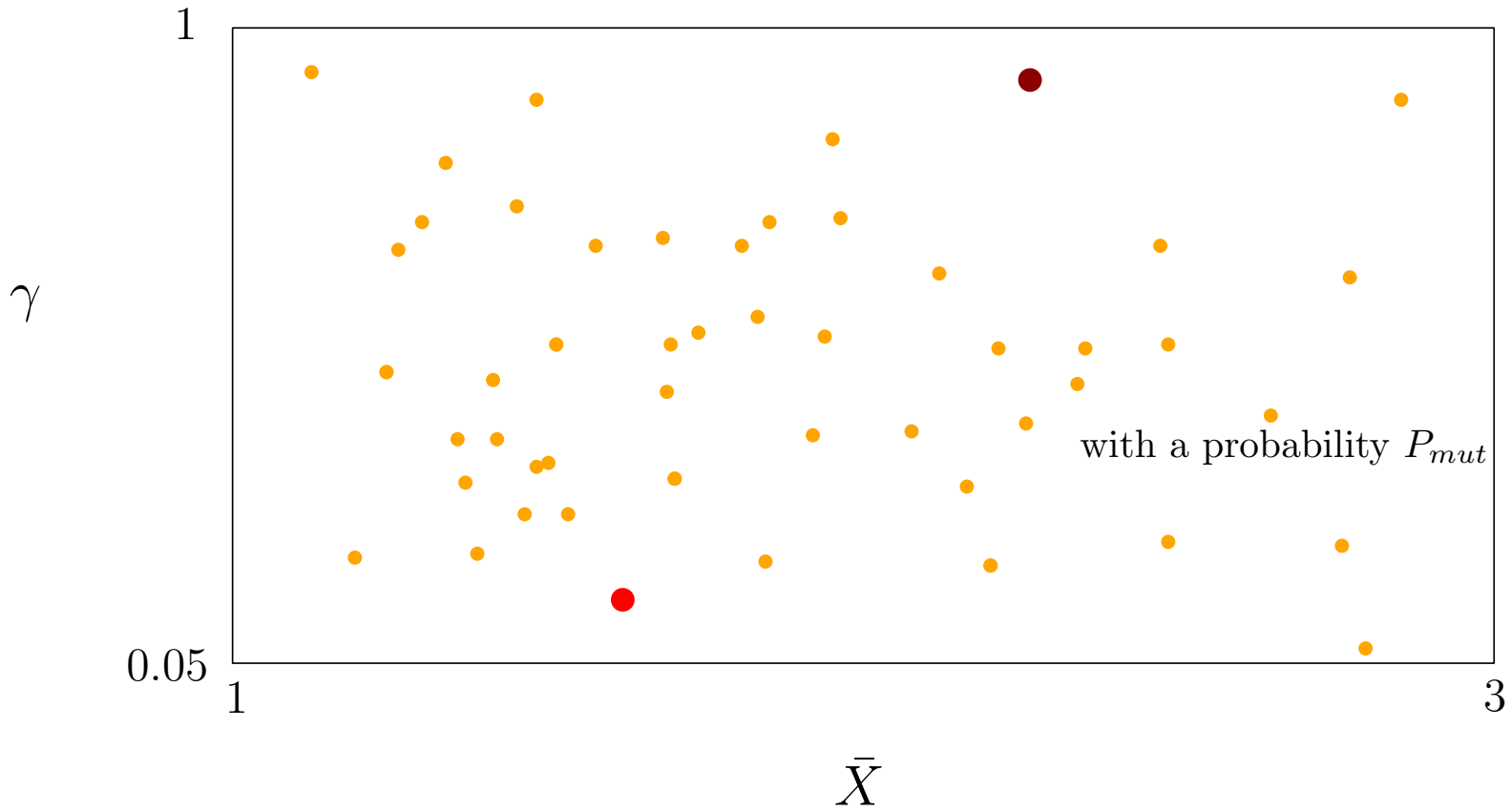
The Evolutionary Algorithm literature

Social learning: an example (Salle & Seppecher 2013)



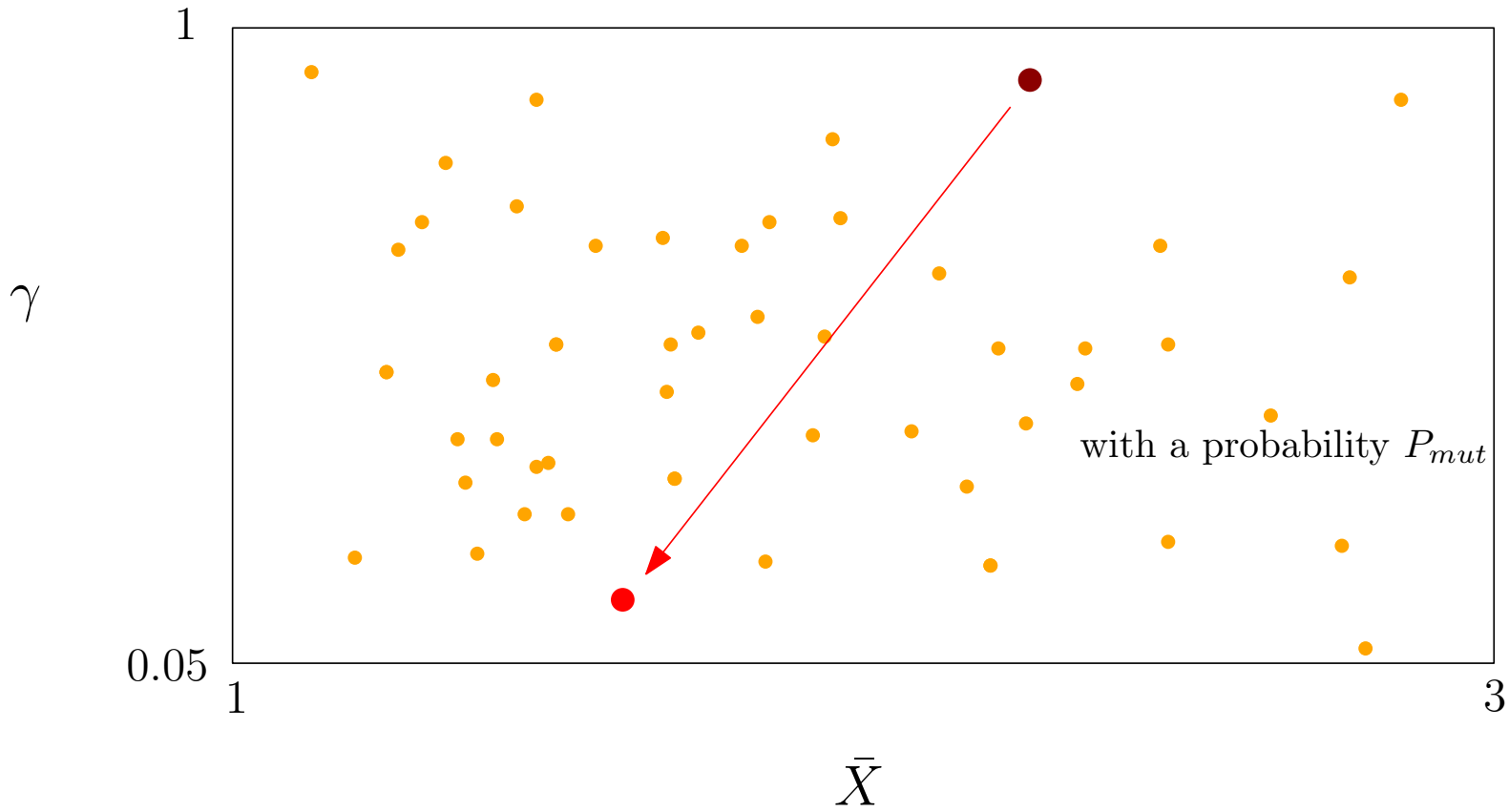
The Evolutionary Algorithm literature

Social learning: an example (Salle & Seppecher 2013)



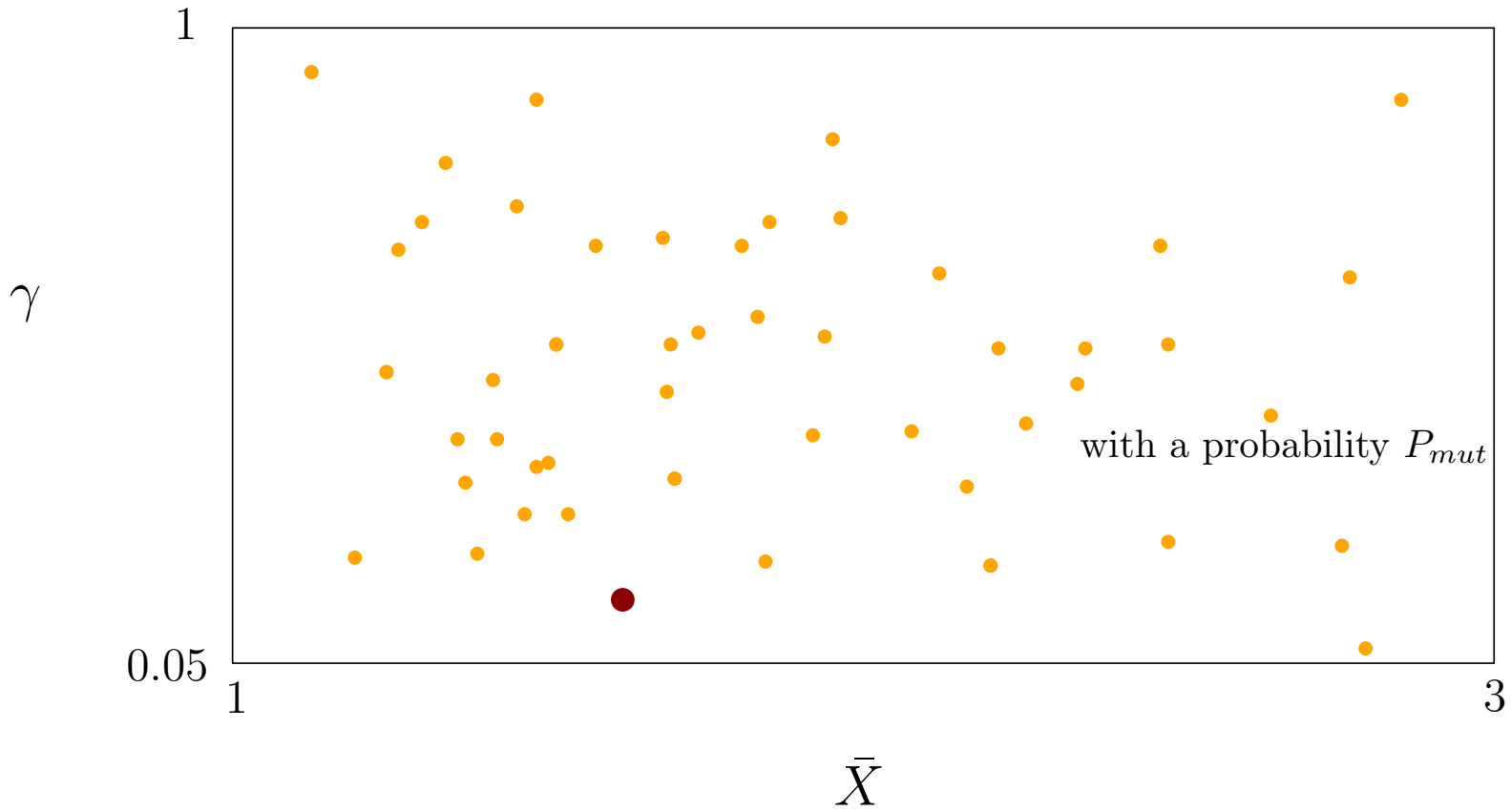
The Evolutionary Algorithm literature

Social learning: an example (Salle & Seppecher 2013)



The Evolutionary Algorithm literature

Social learning: an example (Salle & Seppecher 2013)



Agent-Based Macro Modelling

Ingredients

- Object-oriented programming:
  - Each group of agents consumers, firms, bank..) has specific behavioural rules (reservation wage setting, production plan setting, ...)
  - Each agent has his own attributes (employed or not, amount of consumption, reservation wage...)
- Agents **interact** on the basis of the prescribed behavioural rules, in a **sequential** order (no auctioneer, no Walrasian market).
- Numeric simulations (no simultaneous solution, non-linearity, path dependency).
- Coordination failure may arise (non-clearing markets, disequilibrium dynamics, bankruptcy...).
- Aggregation is the sum of individual components (consumption, investment, labour...).

Agent-Based Macro Modelling

Pitfalls and Appealing Features

- Strong empirical validation.
- Many degrees of freedom:
  - Flexibility (no tractability or closed-formed solution constraint)
  - but disciplinary device needed.
- Complexity:
  - Interdependence, coordination issue, disequilibrium, lower degree of abstraction
  - but "black box"

Thank you for your attention

Any question ?