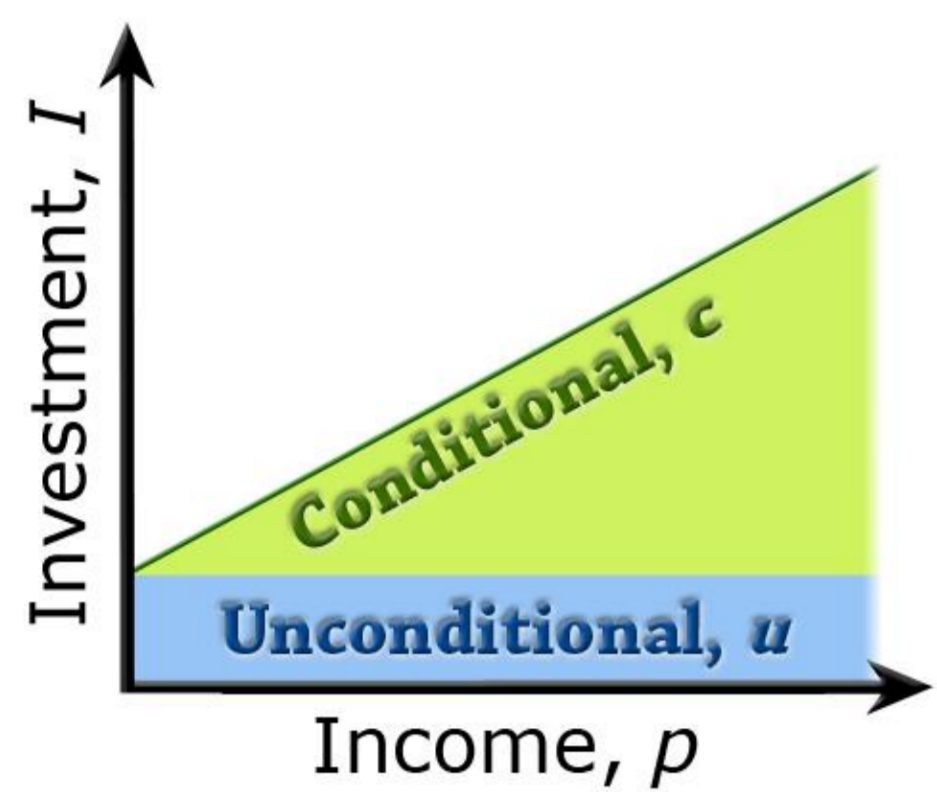


Systemic-risk Dilemmas Emerging from Reactive Investments

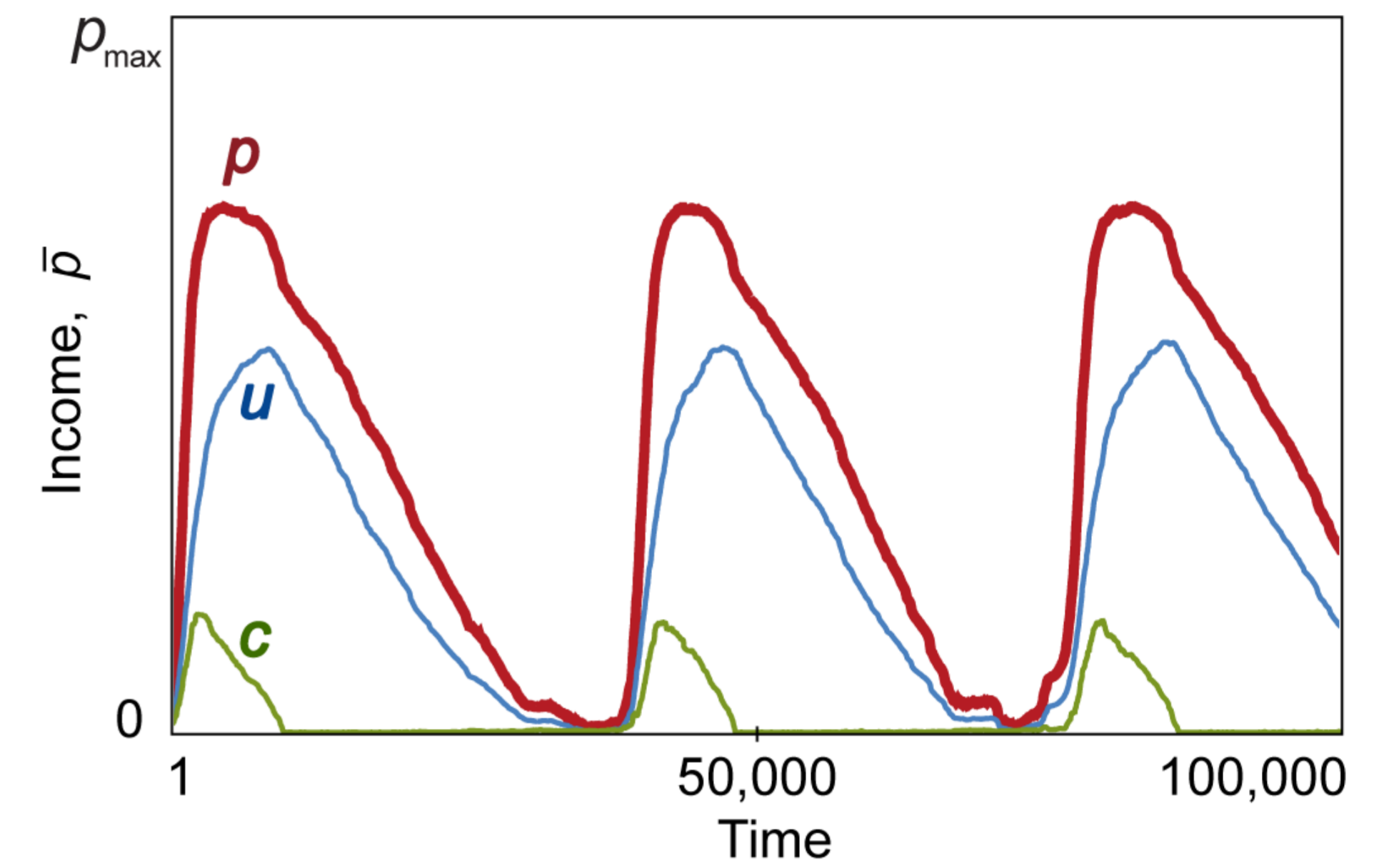
Gergely Boza (Evolution and Ecology Program & Risk and Resilience Program, IIASA)
 m Kun (Etvs University, Budapest, Hungary)
 Ulf Dieckmann (Evolution and Ecology Program, IIASA)
 Email boza@iiasa.ac.at

INVESTMENT CYCLES

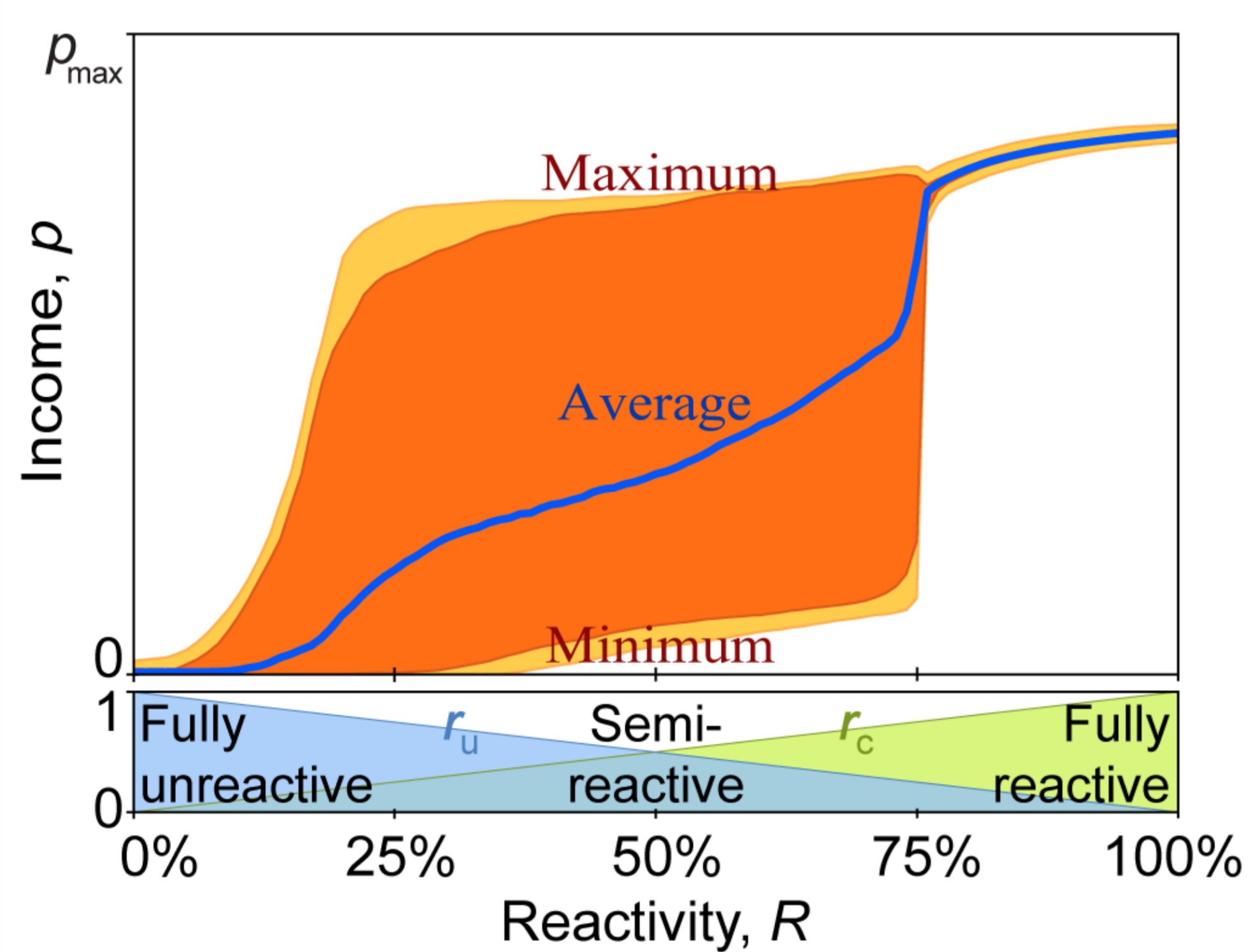


We study the evolution of **reactive investment strategies** in agent-based models with iterated, pairwise interactions and social learning. Reactive strategies allow agents to continuously reevaluate and adjust their investments according to their income obtained from a partnership following the initial, unconditional investment.

The coevolution of such strategies can induce systemic risk in the form of **investment cycles**.



We present four ways to mitigate such boom-bust cycles:



REACTIVITY R defines the balance between the non-reactive or **unconditional** (r_u) and the reactive or **conditional** (r_c) investment components, so that:

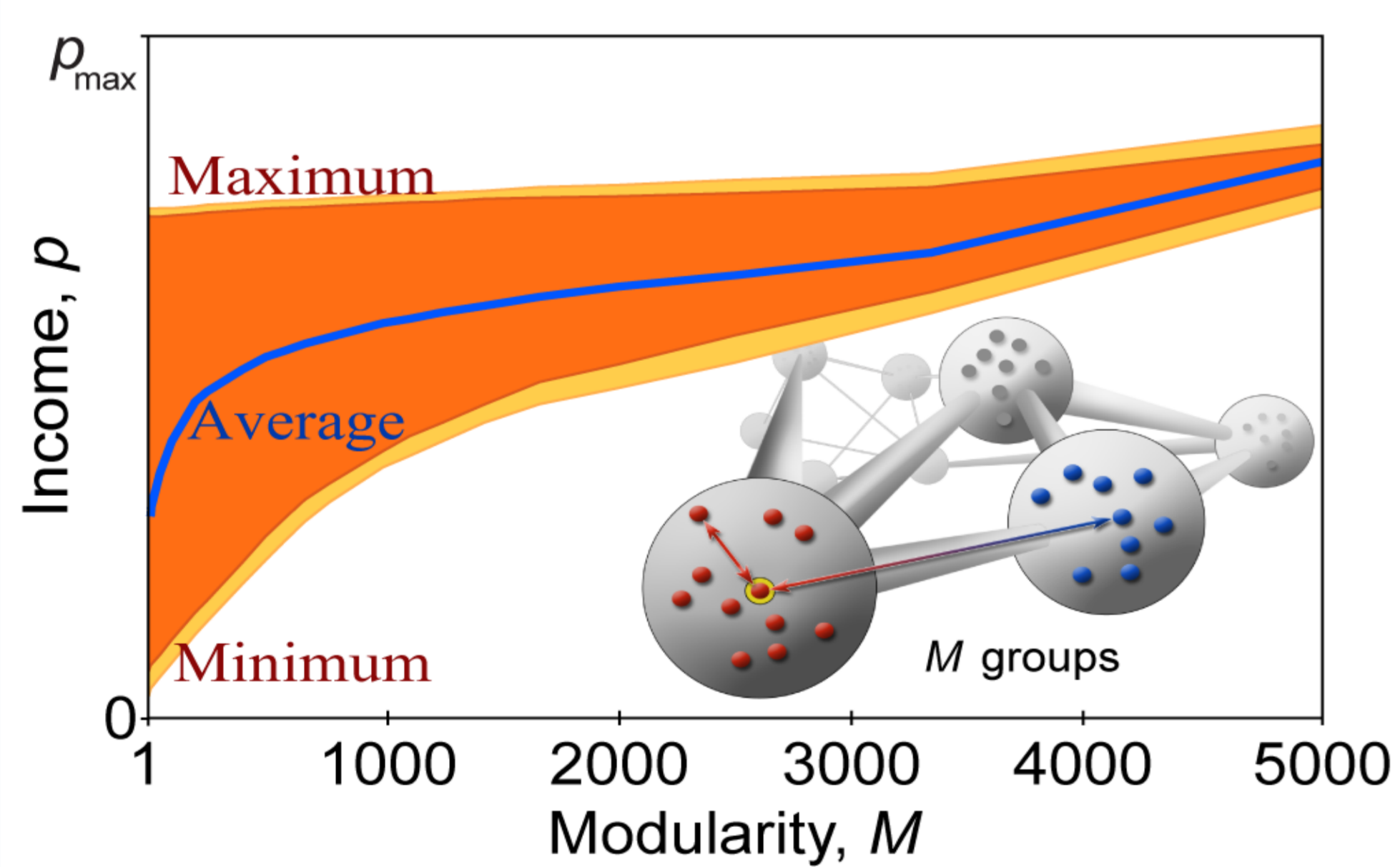
- ▶ At full reactivity ($R = 100\%$), investments are resumed only for positive incomes obtained from the previous iteration of an interaction.
- ▶ At low reactivity ($R = 0\%$), unconditional investments can be made during the interaction even when the previous income is zero.

At a **low reactivity**, when the conditional component plays a lesser role in investment decisions, **no investment** is the only stable state, and investments can increase only temporarily; hence, **investment cycles** appear (orange shaded area).

However, at **full reactivity**, when the conditional component gains importance for large investments, cycles cease and **investments become stable**.

DIVERSITY of investment strategies emerges when the strategy innovation rate I is increased, measuring how fast agents try out slight variations of their strategies, thus increasing strategy polymorphism.

High strategy diversity can stabilize high investment levels, dampening the boom-bust cycles that appear at low reactivity in monomorphic populations.

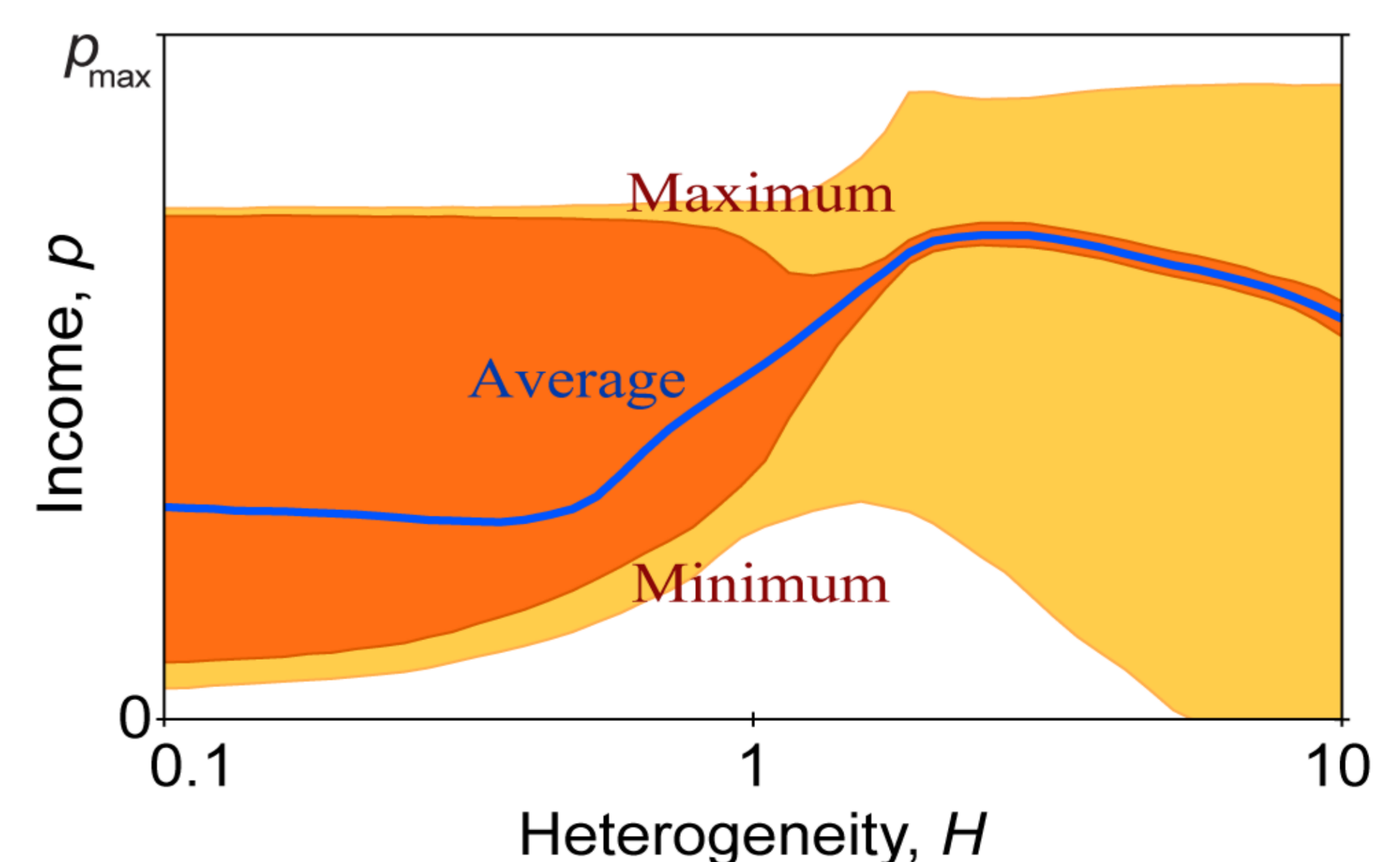
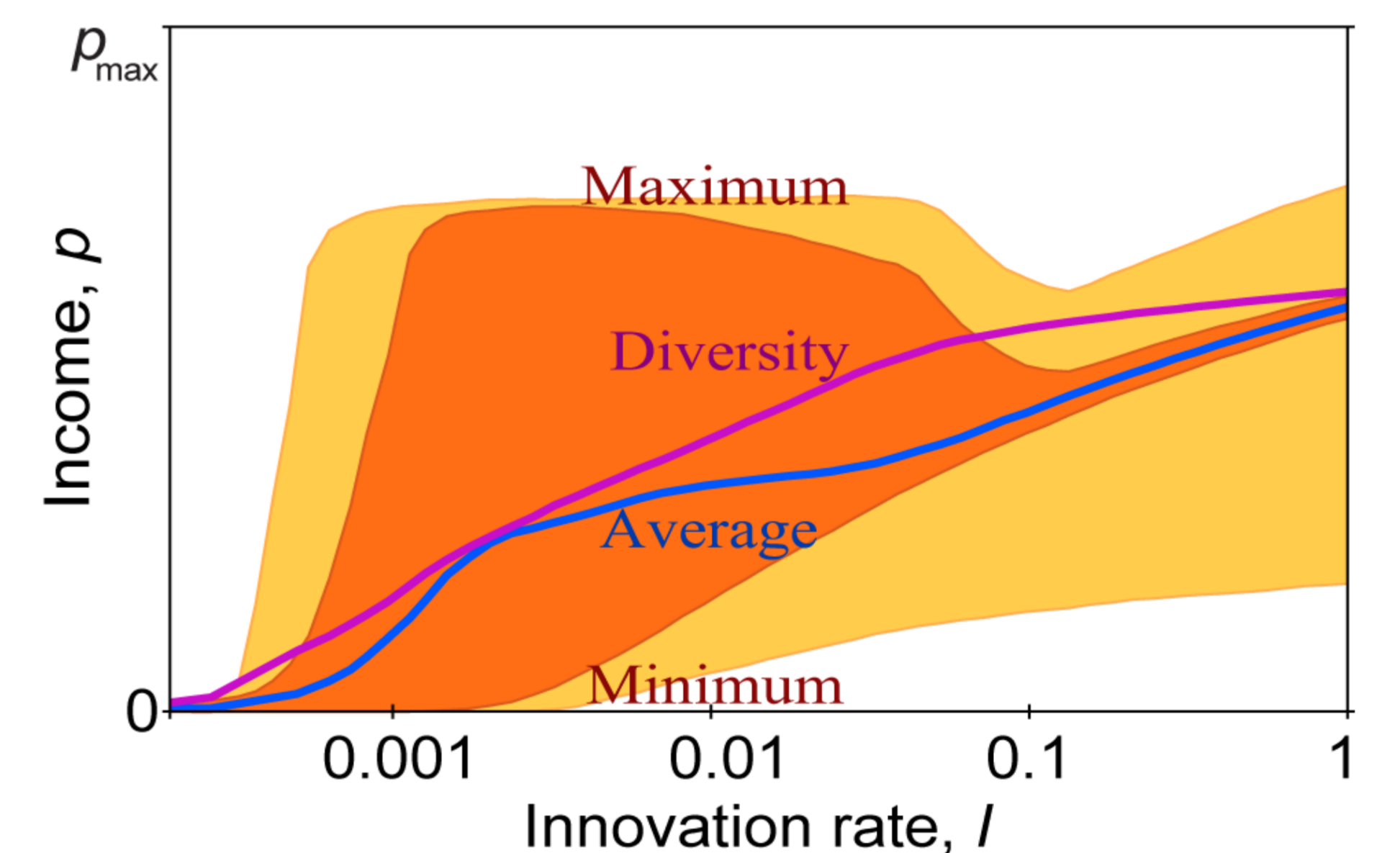


MODULARITY M results from social interaction structure, through which agents are divided into small communities, with sparse interactions between the resultant modules.

With modular social structure, systemic risk is reduced, as boundaries between modules act as barriers. Investment decisions are **decoupled** across the society, the spread of exuberant or non-investing strategy types is restrained, and strategy diversity is maintained, providing an efficient countermeasure against boom-bust cycles.

HETEROGENEITY H is introduced as a difference in the attributes of modules, such as differences in the cost of investment, in module size, in innovation rate, and in the pace of social learning.

A medium level of heterogeneity facilitates the emergence and stability of high investment levels by **enhancing the polymorphism** of investment strategies, **decoupling** investment decisions across the population, and restraining the spread of exuberant or non-investing strategy types even in cases of low modularity.



COUNTERACTING SYSTEMIC RISK

Countermeasures against income loss, such as reactive investment decisions, are crucial for maintaining high and stable investment levels in a society. In our pairwise, reciprocal investment game, such strategy evolution typically leads to **investment cycles**. We thus find that what seems to be rational at the individual level elevates systemic risk at the society level. However, when **reactivity** – **diversity** – **modularity** – **heterogeneity** are employed, separately or combined, stable investment levels can replace boom-bust cycles and stabilize investments and incomes at high levels.