Exploring Emergent Topological Properties in Socio-Economic Networks through Learning Heterogeneity

, Chanuka Karavita[1], Zehua Lyu[2], Dharshana Kasthurirathna[1*], Mahendra Piraveenan[2*]

[1]Faculty of Computing, Sri Lanka Institute of Information Technology, Malabe, Sri Lanka.
[2]School of Computer Science, Faculty of Engineering, The University of Sydney, Sydney, NSW, Australia.

*Corresponding author(s). E-mail(s): dharshana.k@sliit.lk; mahendrarajah.piraveenan@sydney.edu.au;
Contributing authors: chanuka.k@sliit.lk; zlyu0064@uni.sydney.edu.au;

Abstract

Understanding how individual learning behavior and structural dynamics interact is essential to modeling emergent phenomena in socio-economic networks. While bounded rationality and network adaptation have been widely studied, the role of heterogeneous learning rates—both at the agent and network levels—remains underexplored. This paper introduces a dual-learning framework that integrates individualized learning rates for agents and a rewiring rate for the network, reflecting real-world cognitive diversity and structural adaptability. Using a simulation model based on the Prisoner's Dilemma and Quantal Response Equilibrium, we analyze how variations in these learning rates affect the emergence of large-scale network structures. Results show that lower and more homogeneously distributed learning rates promote scale-free networks, while higher or more heterogeneously distributed learning rates lead to the emergence of core-periphery topologies. Key topological metrics—including scale-free exponents, Estrada heterogeneity, and assortativity—reveal that both the speed and variability of learning critically shape system rationality and network architecture. This work provides a unified framework for examining how individual learnability and structural adaptability drive the formation of socio-economic networks with diverse topologies, offering new insights into adaptive behavior, systemic organization, and resilience.

Keywords: Socio-Economic Topologies, Bounded Rationality, Learning Heterogeneity