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Effects of investors' power correlations in the power-based game on networks

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HIGHLIGHTS

- Effects of investors' power correlations in the power-based game on networks are studied.
- The power correlations is measured by the assortativity coefficient r.
- The expected payoff of a cooperator is more than that of a defector as the level of assotativity is high enough.
- An increment of assortativity coefficient raises the average payoffs of cooperators and boosts cooperations.
- As the market efficiency α swings, the density of cooperators will be higher and more stable on the network with the larger r.

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ABSTRACT

With the consideration of the heterogeneity of investors, an investors' power-based game is proposed (Xu et al., 2018), where payoffs of defectors depend on the efficiency of market and the related-power against cooperators. Directed by the special structure of the power-based game, effects of investors' power correlations in the power-based game on networks are studied in this paper. The power correlations, also called the degree correlation in the traditional theory of graph, is usually measured by the assortativity coefficient r. Firstly, we theoretically show that the expected payoff of a cooperator is more than that of a defector as the level of assotativity is high enough. Meanwhile, our simulation results show that, an increment of assortativity coefficient raises the average payoffs of cooperators and boosts cooperations, verifying the theoretical inference. Furthermore, as the market efficiency α swings, the density of cooperators will be higher and more stable on the network with the larger r. As the network of investment in real world may possess both of the properties of BA scale-free networks and assortative networks, the findings may be helpful in managing the emergence of cooperative behaviors.

1. Introduction

Network is applied to economic researches widely [1–5]. Network science helps the economic scholars describe the interactions among economic agents, which is characterized by small distance [6], high clustering [7,8], unequal distribution of links [9,10] and high assortativity [11]. In what follow, networks is incorporated in more economic researches, such as the labor markets [12,13], international trades [14,15], financial markets [16,17], and cooperate finance [18–20]. Totally, the effect of networks, representing the relationships among the agents, should not be neglected.

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Game theory, a tool to dissect the behaviors of interactions [21], is remarkably promoted by Nash [22] who believed a large number of repeated interactions from networks could form the equilibrium. With this inspiration, Axelrod and Hamilton [23] presented the groundwork on repeated games. The spatial prison dilemma game is firstly studied by Nowak and May [24]. In this way, the prison dilemma game (PDG) [25–30] and the snowdrift game (SG) [31,32] are attractive for academics. Perc and Szolnoki make a comprehensive review on evolutionary classical games in recent years [27]. Comprehensively, several papers consider the influence of the dilemma strength, or values of parameters to the equilibrium in theory [33–35]. Another case is that, the networked games are studied on networks with special structures [36–38]. Perc et al. [39,40] considers the prisoner's dilemma on the scale-free networks, in which the complex mechanisms in the real world are participated, such as distinguished players. Generally, the strategies of agents in games, such as cooperation and defection, are similar to people's behaviors in society, which are applied to explained many phenomena [41–52]. This common framework of evolutionary game will be adopted in our research.

Under the framework of neoclassical economics, most assumptions in economic papers are far away from reality, one of which is agent's perfect rationality [53–56]. However, agents in the evolutionary game is only required to be bounded rational, which is coincident with the real world [57,58]. On the other hand, markets in neoclassical economics are always efficient [59]. But it is always suspected by the practical researchers, because there is not enough efficiency in actual markets [60–62]. The efficiency of markets should be regarded as a key parameter in our economic model.

An investors' power-based game has been proposed by Xu et al. [63]. Investors will win-win and receive the same reward that equal to 1 if both of them cooperate. However, a defector can capture $(d_i/d_j)^\alpha$ versus a cooperator, where d_i, d_j denote the power or the degree of the defector i and the cooperator j respectively. Meanwhile, α measures the efficiency of market, varying in $[0, 1]$. The previous result show that an improvement of efficiency benefits for the cooperation fundamentally. Besides, the payoff structure, especially for defector's gain $(d_i/d_j)^\alpha$ vs. cooperators, implies that the power correlation or degree correlation may influence the dynamic process.

Assortativity is another property of social and economic networks [11]. Small et al. [64] offer another proof to illustrate the assortativity of social and economic networks by reporting a physically motivated algorithm to generate scale-free networks with a high level of assortativity. Assortativity, the synonym of degree correlation, measured by the assortativity coefficient in graph theory. The behaviors of players on networks are affected by the assortativity. Tanimoto's findings [65,66] reveal that the assortativity have a simultaneous effect on the emergency of agents' behaviors. Zimmerman, Eguiluz and other scholars' studies [27,67–69] validate this point. As the classical studies, Rong et al. [70] , Fu et al. [71] make a discussion about how the assortativity affects cooperative behaviors in the networked prison dilemma game (PDG) and snowdrift game (SG) respectively. Meanwhile, the evolution of cooperative behaviors in the public goods game on assortative networks are investigated by Rong and Wu [72]. Inspired by the works above, the effect of assortative linkings on dynamic networks [73] and multilayer networks [74] are studied. Unlike the traditional models where only learning agents exist, Tanimoto proposes a new coevolutionary model where the teaching and learning agents coexist. Importantly, the assortativity of strategies of teaching and learning agents are introduced [75]. Recently, Bandyopadhyay and Kar [76] have summarized the relationship between the co-evolution of cooperation and network structure including assortativity. Bilancini et al. [77] also detect action-assortativity for the emergence of cooperation in theory.

Motivated by these references, we explore the behaviors of investors against the background of investment markets. Especially, the effect of investors' power correlation , or degree correlation in power-based game on networks is concerned about. The power-based game will be exhibited in Section 2. Section 3 gives the rule of strategy updating in evolutionary process. Under power correlation, the investor's expected payoff when adopting different strategies is compared theoretically in Section 4. The evolutionary dynamics of power-based game on networks with different assortativity coefficient are examined in Section 5. Finally, Section 6 concludes.

2. Power-based game

Degree is used to measure the power of nodes in the traditional theory of graph. In the networks formed by investors, investors with higher degrees, i.e. with formidable connections, always have more powers because of their richer sources of messages [78–83]. However, the effect of investors' powers on payoffs is ignored in the original game model, such as the prisoner dilemma game (PDG). According to Xu et al. [63], the power-based game is presented in a rescaled payoff matrix:

$$\begin{array}{cc} & \begin{array}{cc} C & D \end{array} \\ \begin{array}{c} C \\ D \end{array} & \begin{pmatrix} 1 & 0 \\ (d_i/d_j)^\alpha & 0 \end{pmatrix} \end{array}$$

where d_i, d_j are the degree of the defector i and the cooperator j respectively. α measures the efficiency of market, which lies between 0 and 1. Two cooperative investors will receive the same reward that equal to 1. Even for maximizing the individual payoff, given the cooperated rival, defection is not sure to be dominant for the other investor, whose optimal action is depended on the comparison of their powers.

We try to consider the effect of investors' power correlation in power-based game on networks intuitively. On the assortative network, investors are surrounded by other investors that possess similar powers. At this time, cooperating with each other are the best strategies for investors. In fact, on the one hand, because of their similar powers, the investor gets $(d_i/d_j)^\alpha \approx 1$ when defecting the cooperators perhaps. Approximately, what the defector get equal to what the cooperator