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Doves and hawks in economics revisited: An evolutionary quantum game theory based analysis of financial crises

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ABSTRACT

The last financial and economic crisis demonstrated the dysfunctional long-term effects of aggressive behaviour in financial markets. Yet, evolutionary game theory predicts that under the condition of strategic dependence a certain degree of aggressive behaviour remains within a given population of agents. However, as a consequence of the financial crisis, it would be desirable to change the "rules of the game" in a way that prevents the occurrence of any aggressive behaviour and thereby also the danger of market crashes. The paper picks up this aspect. Through the extension of the well-known hawk–dove game by a quantum approach, we can show that dependent on entanglement, evolutionary stable strategies also can emerge, which are not predicted by the classical evolutionary game theory and where the total economic population uses a non-aggressive quantum strategy.

1. Introduction

Economic developments often have been compared to biological evolutionary processes, as they converge to equilibria in an evolutionary manner (e.g. Refs. [1–3]). Actually, the conceptual ideas behind evolutionary theory were borrowed from early economic works, especially Malthus [4] (see e.g. Ref. [5]). Due to inter alia the application of evolutionary game theory, whose origin lies in biology [6,7], evolutionary concepts came back into economics and organisational theory. Applications in respect to biological systems [8–14] and socio-economic systems, e.g. "public good" games [15,16], cultural or moral developments [17,18], the evolution of languages [19], social learning [17], the evolution of social norms [20,21] and the evolution of social networks [22–28] have been addressed in several research articles. One major topic in this evolutionary research field is the optimality of aggressive versus non-aggressive or cooperative behaviour (see e.g. for the tension of cooperative and non-cooperative behaviour [20]). In an economic context the notion of aggressive behaviour can be translated to the short-term-oriented maximisation of individual utility without looking after others, while cooperative behaviour comprises a more interactive and long-term-oriented behaviour considering long-term, individual and/or group utility maximisation. The possible positive effects of the mentioned aggressive behaviour on economic welfare have been discussed since the earliest days of economics [29]: the idea was that if each economic individual tries to maximise his/her utility without caring about other individuals, the whole welfare will also be maximal.

One instrument to analyse the long-term effects of this assumption is evolutionary game theory. Analogous to the classical game theory it introduces the concept of strategic dependence among agents in an economic context. In such a situation the expected utility of one agent depends on the decisions of other agents. Evolutionary game theory provides

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an equilibrium in which the ratio of aggressive to non-aggressive agents is stable and that depends on the expected losses and gains of utility induced by the agents decisions. For example, if the expected losses are high for two meeting aggressive agents, most members of the economic population – but not all of them – will behave in a non-aggressive, cooperative way [30]. Hence, also in situations where severe losses are expected, if two aggressive agents meet, an economic population always will contain a certain degree of aggressive agents.

In economic reality, exactly this aspect can be observed, for example in the recent financial crisis: each participant of financial transactions knew that highly risky financial products would increase the risk of the whole market portfolio and thereby augment the probability of a market crash resulting in huge losses. Nevertheless, several participants continued selling and buying these products in order to maximise their own, short-term utility resulting from high selling premiums and investment returns. Hence, these individuals followed an aggressive strategy. However, as the occurrence of the financial crisis exhibited, this behaviour can result in severe problems for the whole economic population. So, the question rises, whether there is a possibility to change the rules of the game in a way that protects populations from these severe problems by inhibiting the occurrence of aggressive behaviour.

To answer this question the classical concept of evolutionary game theory shall be extended by another game theoretical development that is currently discussed: quantum games. The discussion of quantum games started with the work of Meyer [31] and Eisert et al. [32]. Meyer analysed the "penny flip" game and showed, that a player who selects a quantum strategy always wins this game. Eisert et al. [32] concentrated on the prisoner dilemma and demonstrated that the players of this game could escape this dilemma if the entanglement of the prisoners wave function is above a certain value. Since these leadoff articles several further applications of quantum games have been published. Marinatto & Weber [33] applied quantum games to the "battle of sexes" showing that entangled strategies will lead to a unique solution of this game. R.V. Mendes analysed the "quantum ultimatum game" and Hogg et al. investigated the quantum treatment of several different games, namely the "quantum treatment of public good economics" [34], the "quantum coordination game" [35] and "quantum auctions" [36]. Benjamin & Hayden [37] amplified the quantum game approach to a situation of multiple players. Piotrowski & Sladkowsky [38] used quantum games to examine market behaviour. In 2001 the first quantum game was realised on a quantum computer [39] (see also Refs. [40]). The application of quantum game theory to social experiments and experimental economics [41–45] and several review articles [46–52] followed. Hanauske et al. [53] based the analysis of the open access publishing behaviour in different scientific communities on a quantum game approach (see also Ref. [54]).

The combination of this quantum game approach and evolutionary game theory has been applied by Refs. [55–58]. We add to this existing research a practical application of this type of game theory. Our results show that dependent on entanglement, also evolutionary stable strategies can emerge, which are not predicted by the classical evolutionary game theory: the analysis exhibits the existence of a new, payoff dominant evolutionary stable strategy (ESS), where the whole economic population uses the non-aggressive quantum dove strategy. We interpret entanglement in this context as the objective influence of socio-economic context factors, while the application of quantum strategies exhibits the degree to which decision makers incorporate these factors into their decisions. This interpretation allows the derivation of consequences and shows the linkage of our study to other game theoretical analyses that also highlight the importance of the socio-economic context to the outcomes of games. For example, Sally [59] discusses the notion of sympathy, a feeling that occurs when players get to know each other and that can lead to increasing cooperation in prisoners' dilemma games. Platkowski [60,61] generalises the classical evolutionary game theory by implementing additional parameters, which describe the complex personality profiles similar to Max Weber's ideal types of social actors. Analogically to this study additional evolutionary stable strategies have been found for specific parameter ranges.

The paper is structured as follows: we pick up the recent financial crisis as an example for the fruitful application of evolutionary quantum game theory. In order to do so, we have to select a group of participants in the financial transactions that finally lead to the crisis. We have chosen the group of inventors and sellers of the highly risky financial products. Their behaviour can be interpreted as the in theory well-known hawk–dove game [7,62,7,62]. Hence, in Section 2 we develop a model that is based on this game type and comprises the relevant parts of the behaviour of these constructors and sellers to mirror the starting conditions of the financial crisis. In Section 3 we transfer this model into a classical evolutionary game. Section 4 is dedicated to the quantum version of this game, while Section 5 comprises the evolutionary quantum version. In Section 6 we draw some conclusions from our findings. The paper closes with a summary in Section 7.

2. The financial crisis as hawk–dove game

Financial crises in general and the last one especially, have their origin in highly speculative behaviour of market participants. In our analysis we focus on a specific population of market participants, who had a great part in the last crisis: constructors and sellers of financial products with different degrees of risk. They played an important role in the last crisis as follows.

This crisis grounded especially on the housing market in the United States. Based on the idea of continuously increasing prices for real estates, loans were also provided to borrowers, who actually could not afford buying a house. But under the premise of increasing house values, providing loans to these people seemed to be rational as they were backed by increasingly valuable real estates. Yet, these loans did not remain with the lending credit institutes but they were bundled to portfolios together with loans of higher solvency. These portfolios then were sold to other banks as investment products. The idea behind these products is to spread risk among banks. Moreover, papers of higher risk also promise a higher return, which