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HUMAN RATIONALITY, ENVIRONMENTAL CHALLENGES AND EVOLUTIONARY GAME THEORY

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Abstract: In recent years, game theory is more often applied to analyse several sustainable development issues such as climate change and biological diversity, but the explanations generally remain within a non-cooperative setting. In this paper, after reviewing important studies in this field, I will show that these methods and the assumptions upon which these explanations rest lack both descriptive accuracy and analytical power. I also argue that the problem may be better investigated within a framework of the evolutionary game theory that focuses more on the dynamics of strategy change influenced by the effect of the frequency of various competing strategies. Building on this approach, the paper demonstrates that evolutionary games can better reflect the complexity of sustainable development issues. It presents models of human – nature and human – human conflicts represented by two-player and multi-player games (with a very large population of competitors). The benefit in these games played several times (continuously) will be the ability of the human race to survive. Finally, the paper attempts to identify and classify the main problems of sustainable development on which the game theory could be applied and demonstrates that this powerful analytical tool has many further possibilities for analysing global ecological issues.

Keywords: . rationality, sustainability, game theory, evolutionarily stable strategy

Introduction

In the introduction to their book, Eigen and Winkler wrote the following in 1975: "It's time for us to understand that humans are not nature's mistakes; however, nature is not destined to "care about" human survival automatically and self-evidently. Humans are participants in a Big Game where the outcome is open even for them. Humans have to evolve their skills and capacities in their entirety to become "Players" instead of the "Playthings of Chance" (Eigen–Winkler, 1981, p.18).

The most crucial and urgent task for humans in the 21. Century is to avert the global economic crisis. Human behaviour, i.e. the types of behavioural strategies people pursue in certain (economic, social) situations and their ecological consequences, constitutes an intrinsic element in the interaction of human society and physical laws in nature. Several researchers argue that we are on the brink of a global ecological catastrophe. At present, political decision-makers are in a tight corner, as they have to face a much more alarming, long-term danger while recovering from a serious global crisis (Karcagi-Kováts–Kuti, 2012).

In our days, societies in western civilization, in terms of financial, economic, fertility etc. data are in an instable state and but the most threatening crisis might endanger them in terms of traditional values. Having a look at global summits held by the UN about environmental issues and sustainability reveals that the chances of joining forces in favour of common interests are rather low. Nevertheless, the time factor and increasingly alarming changes highlight the necessity of shifting towards sustainability in an increasingly urgent way.

The most false myth in the XX. Century regarded man to be a rational being, a homo eoconomicus. All sociological, psychological analyses express explicitly that human decisions are not rational and cannot be rational, as the majority of decisions are formed in the sub-conscious and not in the rational part of the brain. Elliot Aronson, the greatest "social-psychologist" of the XX. Century states that humans are not rational, but rationalizing beings, i.e. they bring some decision and try to give reasons why it was logical subsequently (Aronson, 2008). This mechanism is not only dangerous because it is capable of exerting a negative influence on social-economic processes, but because people insist on their bad decisions for a long time. As for environmental ethics and environmental psychology, this fact is of incredible significance.

In relation to the crisis, currently several renowned economists argue that mainstream economics and methods of analysis applied there have failed and a new way is to be sought. Many claim that game theory as an analytical tool is the new avenue. My paper argues that the application of evolutionary game theory, a relatively young area of game theory is the most suitable method to examine how and with the adoption of what kind of behavioural strategies a process of transformation is to be realized where communities obey the laws of Nature and thus they can achieve a quasi stable state again.

Some words about the game theory

Game Theory – GT is an abstract discipline engaged in the study of rational decisions, the theory of abstract decisions which studies rational decisions in situations where the strategy of individual participants (players) depend on the expected strategy of the other participants. The founding father of game theory was John von Neumann with his work published in 1928 (Theory of Parlour Games), where he used mathematical tools to analyse parlour games and proved the so-called MiniMax theorem claiming that in a given game the best strategy minimizes the possible maximum loss. In fact, the game theory was conceived in 1944 when the book written jointly by John von Neumann and the Austrian economist, Morgerstern, was published entitled "Theory of Games and Economic Behaviour. Their theory was based on their studies on various kinds of parlour games, therefore a vast number of technical expressions were taken over from everyday life and later applied in game theory (e.g. game, player, payoff, etc.). As for their fundamental assumption, "players are selfish (all of them want to maximize their own benefits) and intelligent, i.e. they are aware of all the possible decisions and the related quantifiable gains. Players' intelligence covers the ability to identify the best solution, if there is any, while they do not forget about their counterparts' similar skills either" (Szabó, 2009, p.118). Neumann and his co-author wanted to support economists in the analysis of diverse economic and market situations, strategic problems. However, widespread application of their book had to wait. The main reason was that the Neumann-Morgenstern theory describes game complete information, which means that all players know the payoff function of the other players, their strategic objectives and faculties as well.

The early 50s represented the next turning point. The theory of n-player non-cooperative games and Nash-equilibrium is linked with the name of John Nash, and it describes an equilibrium where none of the players have anything to gain by changing their own strategies as long as other players' strategies remain unchanged. John Harsányi expanded Nash equilibrium to those cases when players do not have a thorough knowledge of other players' strategies and utility functions. Harsányi realized that in reality or in economic life players can only understand others' goals and potentials insufficiently or not at all. His model is grounded on Bayes' theorem, where the main point is that once a player is involved in a game with another player about whom he has only deficient information or no information whatsoever, the best way to select the rational strategy is to allocate probabilities to various possibilities and use them as starting points. Economists started the application of game theory in the mid-70s. Later, this new theory as a new analytical tool emerged in other areas of social sciences (e.g. psychology, sociology, political science.).

A new branch of game theory, the Evolutionary Game Theory (EGT) was born in the early 70s. In 1973 John Maynard Smith and George Price evolution biologists realized that the fundamental ideas of game theory are suitable for the precise description of interactions among living creatures and formalized the key conception of evolutionary game theory, the evolutionarily stable strategy (ESS). This strategy argues that the state of a population where players "play" an evolutionary stable strategy is regarded stable if rare mutants are not capable of spreading (Smith–Price, 1973). Evolutionary games differ from traditional game theory models in several crucial issues. The payoff here is that the given species possesses its survival (propagation) ability (fitness), and the players are not intelligent and rational, meaning that they do not calculate the results of their possible decisions. A whole population is engaged in these games, i.e. it is a multi-player game and while the basic game is played repeatedly, players have the opportunity to modify their strategies, causing modifications in the group itself. Darwinian selection applies in the course of these modifications, i.e. members of a certain population take over the strategy of the most successful player (with the greatest) individual fitness.

The conception of biological evolution is concealed behind evolutionary games, i.e. entities follow this or that strategy in a biologically determined way and their survival probabilities will have varying degrees in line with certain individual strategies. To give an economic example, players of economic life learn from certain events and correct their behaviour accordingly. Today the most vivid example for this may be drastic mood changes on borrowing in the past couple of years. Evolutionary games use three fundamental concepts: mutation, selection and heredity. Mutation means a problem in a system and this is significant in terms of evolutionary stability, as a strategy is ESS if it is played by a satisfactorily large population; mutants in this case are not able to spread in this population, suggesting that an evolutionary stable state is immune to mutation (Szabó, 2003). Selection favours those entities who employ high payoff strategies. To date, there has been no clear-cut standpoint about the fundamental units of natural selection. Followers of group selection claim that the fundamental unit of selection is a large group or species, while the majority argue that the theory of genetic selection serves as the basis of natural selection (Dawkins, 2011), i.e. selection exerts an effect on the survival of a single behaviour. "As for the world concept arising from the theory of group selection, nature wisely provides for expedient cooperation among entities within certain species and thus about the development of the given species…. As for the world concept arising from the selfish gene theory, the world is conducted exclusively by the short-sighted interests of genes without any superior goals, and development is at best the seeming product of perfection through the methods of selfish genes" (Mérő, 2007 p.187). Darwin himself "considered the appearance of morality the most vital evolutionary factor in the origin of humans and assigned its emergence to the effect of group selection" (Csányi, 1999, p.14).

The success story of evolutionary game theory started with John Maynard Smith's famous hawk-dove game. In the past couple of decades, this example was used in almost every field of social sciences, just like the Prisoner's Dilemma. In the hawk-dove game Smith characterises the population of a given species, where players fight to obtain a certain resource with the restraint that entities in the population can follow merely two strategies: hawks always fight and when they are confronted with hawks, the fight is always brought to an end by a serious injury. However, doves only threaten and pose if they meet other doves and escape when confronted with hawks. We might think that a community reaches the highest total gain if all the members are doves. But this behaviour is instable evolutionarily, as the appearance of a single hawk is enough for doves to take over the strategy of the hawk reaching the highest payoff and thus they start to proliferate rapidly. In the end, the proportion of hawks and doves in a given population will be determined by the values of the payoff matrix, providing the evolutionary stable state of a population (Szabó, 2003). In the evolutionary version of the multi–step game "Prisoner's Dilemma" hallmarked with the name of Robert Axelrod, the strategy of the worst payoff was replaced with the best one at the end of each competition cycle, leaving the former extinct and the latter with a new offspring. The outcome was the development of two evolutionarily stable states. In one of them, each player behaved selfishly without any cooperation whatsoever, leading to the extinction of the given population. As for the other strategy, most players pursued the Tit-for-Tat strategy, as this strategy promised the highest gains (Szabó, 2003).

Analysis of certain issues of sustainability by game theory models to date

Several scientific articles seek to study certain issues of sustainability by using game theory models. Most of them focus on the depletion of resources, i.e. free riding behaviour under non-cooperative conditions. They also analyze potential shifts to tackle climate change, certain negotiation processes and the probability of coalition development by cooperative game theory tools. Below, I present a non-exhaustive list of environmental areas already examined by game theory methods.

Bhat's paper seeks to explore potential methods for the conservation of biodiversity, where two Players compete for the same resource on the resource market. The result is Hardin's the Tragedy of the Commons. However, he emphasises that if the game is cooperative, there are probabilities to avoid depletion and to maintain resources in the long run (Bhat, 1999). Similarly, Acre studies the question of biodiversity and environmental protection as global public goods and uses the evolutionary game theory to explore global public assets. He claims that scientific, economic and political conditions not necessarily lead to the Prisoner's Dilemma. He also argues that international environmental protocols may be improved by collaboration and cooperation, but this massively depends on the proportion of participants employing certain strategies in the group of negotiators (Acre, 2000). Palmini's article uses comprehensive game theory tools, such as the MiniMax theorem and the lottery game for the analysis of hazardous problems with uncertain outcome for the description of environmental problems, and underlines the significance of the selection of risk-averse strategies (Palmini, 1999).

Liu et al. focus on the potentials of the establishment of a closed economic system with zero emission in the Western-Qaidam region, China by a game theory bargaining model (Liu et al., 2012) It means that similarly to symbiosis in wildlife, farmers may cooperate in a mutually beneficial way in material (waste) and energy management, i.e. industrial systems should be developed in the same way as natural ecosystems as these cycles do not generate waste and environmental pressure.

Jaehn and Letmathe analyse the volatility of the CO2 quota trading system by game theory tools (Jaehn–Letmathe, 2010).

Soroos makes a comparison between military and environmental safety. He uses the Prisoner's Dilemma to describe the process of striving after environmental safety and enhances that in negotiation efforts to curb the growth of the ozone hole the Prisoner's Dilemma has not taken a central stage. He claims that this fact vividly demonstrates that we can surpass our narrow-minded, selfish selves and negotiating partners might recognize the necessity of cooperation to support sustainability instead of aggravating international conflicts and unfairness (Soroos, 1994). Courtois and Tazdait also analyse the processes of environmental change negotiations to find the methods for the development of a cooperative coalition. Their model comprises persuasion, dissuasion, revocation and imitation as well. Among others, they found that the distribution of unfavourable effects among players (negotiating parties) significantly boosts propensity for cooperation (Courtois–Tazdait, 2007). Dutta and Radner also write about climate change and make a distinction between national and international possibilities. They emphasize that on international level, climate change is equivalent with the tragedy of common pastures where the game is ruled by dominant states and the laws of Nature. Their model also includes population growth and players' inter-temporal preferences (Dutta–Radner, 2006).

Rocha argues for the application of evolutionary game theory in the analysis of competition among companies producing homogenous products on a quasi-competitive market. His model comprises social responsibility, environmental sensitivity, environmental benchmarking by the state and also social responsibility and environmental performance sensitive consumer boycott. He finds EGT the most suitable tool of analysis because the result to be achieved depends not only on payoffs, but also on the proportion of certain behaviour strategies (e.g. supporters of socially responsible companies or environmentally sensitive ones) within the given population (Rocha, 2013).

A matrix which offers the multifaceted evaluation of individual decision alternatives provides a comprehensive picture about a situation in social decision-making. With the payoff matrix used in game theory, Constanza demonstrates what results are to be expected if humanity, the player trusts the omnipotence of technology or it follows in the footsteps of technological pessimists, where the other player is the Earth,

Table 1. Payoff matrix for techno-optimistic and pessimistic strategies, source: Costanza, 1993

		The real state of the world	
Actual policy		optimistic version	pessimistic version
	techno-optimistic approach	HIGH	CATASTRO-PHE
	techno-pessimistic approach	MODERATE	SUSTAIN-ABLE

Table 1. Payoff matrix for techno-optimistic and pessimistic strategies, source: Costanza, 1993

suffering insignificant or significant injuries as a result of human intervention. The left side of Table 1. presents ongoing, alternative political strategies of technological optimism and pessimism, while we can see the real life situation of the world above.

The intersections are labelled with the results of the combinations of policies and the states of the world. For example, if we pursue the optimistic policy and the world really does turn out to conform to the optimistic assumptions, then the payoffs would be high. This high potential payoff is very tempting and this strategy has paid off in the past. It is not surprising that so many would like to believe that the world conforms to the optimist's assumptions. If, however, we pursue the optimistic policy and the world turns out to conform closer to the sceptical technological assumptions, then the result would be "Disaster." The disaster would come because irreversible damage to the ecological life support system would have occurred (like ozone depletion and global warming) and technological fixes would no longer be possible. If we pursue the sceptical policy and the optimists are right, then the results are only "Moderate." But if the sceptics are right and we have pursued the sceptical policy, then the results are "Sustainable." Within the framework of game theory, this simplified game has a fairly simple "optimal" strategy. (Assuming a "risk averse" player, which global society as a whole must certainly be in this case.) If we really do not know the state of the world, then we should choose the policy that is the maximum of the minimum outcomes (i.e., the MaxiMin strategy in game theory jargon). In other words, we analyse each policy in turn, look for the worst thing (minimum) that could happen if we pursue that policy, and pick the policy with the largest (maximum) minimum. In the case stated above, we should pursue the sceptical policy because the worst possible result under that policy ("Sustainable") is a preferable outcome to the worst outcome under the optimist policy ("Disaster") (Constanza, 1993). In real terms, Constanza presents the precautionary principle by game theory tools in his article.

In 2006 the World Bank published 3 studies analysing the competition for natural resources (e.g. fish stock, forests etc.), the distribution of resources, difficulties arising from the free rider problem and especially the issues of aboveground and underground waters, using the tools of Cooperative Game Theory (CGT) (Parrachino et al., 2006a, 2006b; Zara et al., 2006).

Evolutionary game theory and sustainability

For several reasons, evolutionary game theory can be regarded a suitable method to set up models for the characterization of social transformations. Vilmos Csányi wrote that human ethology "assumes that human behaviour is the result of evolution, the outcome of the adaptation of humans to their environment" (Csányi, 1999, p.7). My paper focuses on the question, how to set up models to illustrate evolutionary processes, where developed national economies switch over to a lifestyle which takes ecological restraints into consideration. However, the analysis of the problem raised several difficulties. One of them is that the interactions and time related changes of a highly complex system (environment-society-economy) should be described. The other one is that scientific knowledge of this system is very uncertain, "answers" from life-support systems, gains (rather losses) are delayed in time, and therefore switching to a new strategy is also delayed. The human factor must also be calculated, as the free rider behaviour is crucial: for a short time, excessive consumption and production leaving behind environmental pollution will provide higher payoff. But Nature's answer, the "slap in the face" will hit everybody, leaving borders and behavioural strategies out of consideration.

Neumann's MiniMax theorem is a theory for minimizing loss. This is true as long as available results are not temptingly high. At this time, however, humans become risk-takers, possible losses shrink into insignificance in the shadow of potential alluring gains (Kahneman, 2013). This is the attitude we adopt when it comes to environmental issues, when we bring decisions about patterns of production and consumption. In environmental terms, sustainable consumption and production would require us to sacrifice temporary pleasures and higher profits. Our behavioural strategies are induced by the probability of potential growth, while our greediness prevents us from calculating serious long-term losses. Human psyche works in the way that long-term perils are either not sensed at all or we think that they can happen only to others, or elsewhere and we play down what happens to the next generation. In economic theory, starting from Keynes, renowned think-tanks always ended up discussing human nature. The model of environmental game theory is suitable for the description of temporally changing processes and for sketching various scenarios while forecasts are prepared.

If the whole planet is considered to be a common pasture, our previous behavioural strategies will certainly lead to the tragedy of Hardin's Commons, which demonstrates the conflict of public good and self-centred behaviour. In the evolutionary competition, if the free rider's gain is too high, only the parasites will survive as long as the total income for the community drops to a minimum in the final phase, i.e. natural resources get depleted. If, however, the rules of the game provide advantages for those players who adopt strategies subjected to the rules of Nature, parasites will disappear from the population and hopefully, as a result of social evolution, our attitude to nature and natural environment will change and we break off with Bacon's "knowledge is power" concept.

The definition of the payoff function becomes problematic from two viewpoints in the analysis of the game against Nature. The first is that the payoff is determined by the rules of nature, there is no possibility to bargain and potential losses are unknown. The second is that results, i.e. the slap in the face from Nature is delayed in time, so it is questionable whether we can learn from our mistakes in time. Two German sociologists, Wolfgang Krohn and Georg Krücken introduced the concept of evolutionary risk, denoting a new type of risk which is treacherous and hiding, lurking with uncertain time and way of occurrence and when it takes place, it affects everybody, independently of their previous behavioural strategies (Krohn–Krücken).

There are several behavioural forms that we humans learn, whereas our genes lead us to actively select our environment, the space where we can adopt other behavioural patterns (Csányi, 1999).

Evolutionary game theory affords possibility for the players to take their place in space and for setting up models to describe their possible local relations and their effects. According to the rules of evolution, players take over the successful “neighbour’s” strategy and thus the proportion of individual strategies within a community constantly changes until – if everything turns out well – the population gets into an evolutionary more stable state.

Conclusions

Game theory tools have been widely used to explore several sub-problems of sustainable development. Most papers use non-cooperative games and analyse mostly the depletion of scarce resources, focusing on selfish human behaviour, leading to Hardin’s Tragedy of the Commons. Cooperative games are primarily applied for analysing the possible outcomes of environmental negotiations. So far there have only been a few studies to set up sustainability models with evolutionary game theories, perhaps because evolutionary game theory is a young branch of game theory. Most of these writings analyse the changes of biological diversity by evolutionary game theory models. I am convinced that in the analysis of sustainability as a global ecological problem, evolutionary game theory is a suitable tool to illustrate uncertainties and processes altering in time, originating in our insufficient body of knowledge and the inherent nature of the system, and to provide forecasts focusing on the dynamism of changes in human strategies, the topology of players and therefore the potential meeting points among players; adoptable, learnable and hopefully, from the viewpoint of sustainability, positive behavioural patterns.

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