Game Theory Applications to Socio-Environmental Studies, Development Economics, and Sustainability Research

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Abstract: The present investigation elaborates on the level of game theory application for the applied and theoretical analyses of climate change and development studies. This editorial shows that the common good character of global climate alongside the increasing internalization of environmental externalities through national regulations and international environmental treaties jointly result in the increasing congruence between the context of climate change problems and the game theoretical method. Furthermore, the adoption of the Paris Accord by the overwhelming majority of developing countries as well as the disproportionate vulnerability of the Global South have led to an increasing shift in focus with regard to international development cooperation, from poverty alleviation and economic growth to green growth and circular economy solutions, within developing countries. The underutilization of game theory in the context of development studies is not satisfactory. This paper underlines the importance of implementing an impetus to researchers for scholarly discussions and applications of game theory in a discourse on the following topics: 1. economic growth; 2. climate change mitigation and adaptation; and 3. a broader socioeconomic development.

Keywords: game theory; climate change; development; industrial organization

1. Introduction

Game theory is a study of mathematical models that focus on the interaction and patterns among rational agents. Despite the fact that game theory emerged only in the last century as a unique discipline, many attempts to advance the use of mathematics in the explanation of human interactions and conflict management had already taken place in the sixteenth century. The works of Italian polymath Gerolamo Cordano—particularly his treatise *Liber de ludo aleae* (*Book of Games of Chance*) written in 1564—already sketched the basic ideas of modern game theory. In the seventeenth century, Blaise Pascal and Christiaan Huygens put forward game-theoretic foundations for the calculus of chances and the concept of expectation on the reasoning of game model structures [1,2]. Since then, there have been a number of attempts in the mathematical modeling of human interaction, and many of them merit attention. However, without underestimating the contribution of other noteworthy scholars, we would also like to mention the work of Antonie Augustin Cournot, written in 1838, on strategic interaction patterns within a duopoly, whereby he also provides a solution to the game, which is in line with the Nash equilibrium [3].

With the publication of John von Neuman's seminal article *On the Theory of Games of Strategy* in 1928 and his and Oskar Morgenstern's *Theory of Games and Economic* Behavior in 1944, game theory emerged as a separate field of research [4,5]. The focus of game theory

since then has mostly been on economics. Since the onset of the discipline, industrial organization followed by political economy were the main fields of application of the game theory. However, it has to be mentioned that in the realm of industrial organization, game theory applications are more sophisticated and applicable than in the field of political economy and political science [6]. It is also worth mentioning that the most noteworthy innovations in the field of game theory have been emanating from the studies on industrial organization itself. In particular, monopolistic, oligopolistic, and monopsony relations are disproportionately researched and advanced by means of game-theoretic modeling approaches.

The present editorial focuses on the applications of game theory in the fields of climate and development. To this end, based on the brief literature analysis and an assessment of the contemporary problems of economic development, the authors try to develop a perspective on the potential use and necessity of game theory solutions in approaching issues of economic development and climate action, both on the theoretical level and in terms of applied problem solutions.

2. Games as a Method for the Problems of Socio-Environmental Sustainability

The scholarly discussion on environmental issues in the context of socioeconomic development dates back to the year 1972, when the *Limits to Growth* of the Club of Rome was published and the first UN Conference on environmental problems in Stockholm took place [7]. However, it took quite a while until the scholarly community started using game theory in the realm of environmental economics and sustainability studies. This evidence is not astonishing because the critical consideration of environmental amenities as scarce natural resources, as well as sustainable production processes as viable ways of saving costs, developed naturally only with an increasing emphasis on environmental regulations and energy policies that envisage the surge of renewable energy sources, in addition to the internalization of environmental externalities.

The years between 1994—when the Conference of Parties (COP) in Kyoto adopted the Kyoto Protocol—and 2015—when the majority of countries worldwide adopted the Paris Accord—were decisive in this regard. The corresponding climate policies were supposed to counteract climate crisis by internalizing environmental externalities, which are expressed in the words of the Nobel Prize winner in the field of environmental economics, William Nordhaus, and Nicholas Stern from the London School of Economics and Political Science, as the *"biggest market failure in human history"*. The environmental policies, such as carbon tax, emission trading schemes, and feed-in tariffs for renewables, targeted the commodification of environmental externalities and provided them with a more tangible economic character [8].

The leverage of sustainable environmental management practices presents a substantial impetus for an enhancement of the toolkit utilized in the analysis of purely economic problems. This is not surprising considering the fact that environmental regulations target the internalization of costs. Hence, it is plausible that game theory approaches serve increasingly as methodological frameworks for the analysis of climate-related problems that intensify in an economic manner.

Additionally, the fact that global climate has the characteristics of the global commons leads to the risk of tragedy occurring within the commons in the framework of international environmental treaties, such as the Paris Agreement [9,10]. Aside from the free rider problem, the free driver issue in the context of climate-related interactions raises new concerns and questions. Daniel Heyen reveals that in the issues related to climate geoengineering in particular, free driver problems are a real risk that could lead to climate conflicts and further aggravate the ongoing climate crisis [9].

Nevertheless, a substantial lack in the applications of game theory solutions in the context of international development has become evident. There are works that successfully translate the problems of underdevelopment—especially poverty alleviation, microfinance, inferior institutional quality, and even culture-related issues—into the language of game

theory [11,12]. These studies, however, provide a relatively bird's eye perspective on development issues. Only a few studies make use of game theory—especially differential games—for the applied analysis of natural resource use and climate-related problems in developing countries [13,14].

The fact that the countries of the Global South are already disproportionately affected by global warming and the shift in development policies from poverty alleviation to climate-aligned poverty alleviation, green growth, and circular economy solutions speaks volumes in support for more game theory applications in the field of development [11,12,15]. In addition, there is a growing body of literature that negates the Environmental Kuznets Curve conjecture that was deemed to be the dominant pattern of a long-term income–environment nexus [16]. This is a clear plea for increased environmental action in the Global South. This gap, whereby the game theory is underutilized in development studies, is more than unsatisfactory and has to be closed by pertinent research projects.

3. Conclusions and Perspectives

We are currently experiencing several multi-layered global crises that call for enhanced cooperation. Severe multidimensional, complex phenomena such as the COVID-19 outbreak and global climate change have dramatically changed our lives and our relationship with our work, nature, and interactions, affecting entire populations. Adverse events and shocks risk causing enormous ecological, societal, economic, and governance impacts, endangering mankind [17].

Game theory offers an array of rigorous analytical tools to settle noteworthy issues and possibly offset the anthropogenic impact on society, environmental quality, and the sustainable use of natural resources, proposing resilience policy and solutions [17]. There is a sizeable body of game theory applications for monopolistic and oligopolistic interaction patterns within the framework of the economics of natural resources. A growing body of theoretical and empirical literature offers strategic perspectives on environmental and development economics and sustainable development [18].

The relevance of game theory for the analysis and optimization of the interaction between sizeable groups of states is palpable, especially within international environmental agreements such as the Paris Agreement or the European Green Deal [19,20]. Against this backdrop, the theory of global common-pool resource governance plays a central role in the assessment and optimization of international and global climate action. This is even more pertinent for the exploration of fisheries in the mesopelagic zone, which drives the biological carbon footprint and yet also acts as a potential source of food for the growing number of people worldwide [21,22].

The adoption of the Paris Agreement by the overwhelming majority of developing countries, the increasing environmental awareness of the population in developing countries, and the increasing vulnerability of the tropics and sub-tropics to the climate crisis have led to the shift in focus with regard to international development cooperation programs and projects from only poverty alleviation and economic growth toward green growth and circular economy solutions in the developing country settings. The underutilization of game theory in the context of development studies is no longer acceptable. As a result, there is a grave need for implementing an impetus to the applications of game theory in diverse settings. In particular, we ought to observe the ongoing and forthcoming discourse on the following topics: 1. economic growth; 2. climate change mitigation and adaptation under the umbrella of a broader notion of development; and 3. diverse issues related to development, shocks, and grand challenges.

Conflicts of Interest: The authors declare no conflict of interest.

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