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Modelling the Triple Helix of university-industry-government relationships with game theory: Core, Shapley value and nucleolus as indicators of synergy within an innovation system

Eustache Mêgnigbêto[a,b,*]

[a] University of Antwerp, Faculty of Social Sciences, B-2000 Antwerp, Belgium
[b] Bureau d'études et de recherches en science de l'information, 09 BP 477 Saint Michel, Cotonou, Benin

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ABSTRACT

The Triple Helix of university-industry-government relationships is a three-person cooperative game with transferable utility. The core, the Shapley value and the nucleolus are suggested as indicators to measure the synergy between innovation actors. The core is the expression of actors' interests and constraints exerted on them; it measures the extent of the synergy. The Shapley value indicates actors' strength to lead to and create synergy; and the nucleolus determines the power of coalitions to maintain synergy. The Triple Helix games of the South Korean and the West African innovation systems are studied, based on bibliographic data collected from Web of Science over a ten-year period (2001–2010). Results show that the core of South Korea is larger than that of West Africa, meaning that synergy occurs more within the South Korean innovation system than in the West African one. University has more power to lead to and create synergy and coalitions involving government work in order to maintain synergy.

1. Introduction

The Triple Helix concept introduced by Etzkowitz and Leydesdorff (Etzkowitz & Leydesdorff, 1995; Etzkowitz, Webster, Gebhardt, & Cantisano Terra, 2000) is one of the variants of the nonlinear model of innovation (Etzkowitz et al., 2000; Leydesdorff, 2012; Meyer, Grant, Morlacchi, & Weckowska, 2014). The model postulates that the interactions between university, industry and government create synergy that leads to innovation (Leydesdorff & Etzkowitz, 2001). The theory has gained attention since it was developed, as illustrated by an increasing number of papers, as registered in the Web of Science (Meyer et al., 2014). Its geographic audience is very broad compared with that of other variants of the linear model of innovation like the Mode 2 (Shinn, 2002, p. 603). The Triple Helix idea has led to a genuine research school with an empirical and conceptual agenda (Shinn, 2002, p. 611). National and international research funding institutions (like the North Atlantic Treaty Organisation, the European Union, National Science Foundation (USA), the Centre National de Recherche Scientifique (France), etc.) are interested in this idea, and researchers from the Third World have contributed to the development and the implementation of the theory; evidence could be established from the nationalities of participants to the annual Triple

* Correspondence address: University of Antwerp, Faculty of Social Sciences, B-2000 Antwerp, Belgium.
E-mail addresses: eustache.megnigbeto@uantwerpen.be, eustachem@gmail.com

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Helix conferences and authors of papers presented at the conferences (Mêgnigbêto, 2016a, p. 36). Furthermore, innovation programmes have been developed under this paradigm[1] (Park, 2014). As Le Coadic (1994) stated about information science, the Triple Helix is becoming a separate discipline because it has an epistemology (a specific concept, models, methods, etc.), societies (e.g. the Triple Helix Association), journals (e.g. Triple Helix Journal) and scientific events (e.g. the Triple Helix Annual Conference). The Triple Helix is being investigated by researchers from various domains such as sociologists, economists, informetricians, etc.

However, the Triple Helix community is still seeking indicators to measure the synergy between innovation actors. According to Meyer et al. (2014), some papers proposed indicators of science-technology interaction like patent citations or inventor/author analysis, publications counts, patents counts, citations, co-authors and related indicators; others are concerned with measuring information flows especially through entropy measures. The mutual information (Leydesdorff, 2003) or mutual redundancy (Leydesdorff & Ivanova, 2014) and the transmission power (Mêgnigbêto, 2014c), based on information theory, were proposed. They have been used in the literature to analyse various innovation systems, for example, Kwon, Park, So, and Leydesdorff (2012), Khan and Park (2011), Ye, Yu, and Leydesdorff (2013) and Leydesdorff and Sun (2009) who studied mutual information and Ivanova, Strand, and Leydesdorff (2014) and Mêgnigbêto (2014b, 2014c, 2015) who studied transmission power.

Innovation systems are complex systems (2016, Katz, 2006). The university-industry-government relationships constitute a complex system (Leydesdorff, 2003) that can be analysed with techniques and tools from cybernetics, information theory, game theory, decision theory, topology or mathematics of relations or factorial analysis (von Bertalanffy, 1973). Informetric studies having used game theory techniques and tools are scarce: Tol (2012) and Karpov (2014) resorted to Shapley values, the former for assessing research production and impact of schools and scholars, and the latter for allocating publication credit to co-authors; Hayes (2001, 2003) modelled decision-making in library cooperation with cooperative games theory; Schubert and Glänzel (2008) showed that ternary diagram could serve to study research collaboration and citations. Some papers introduced game theory in the study of either innovation systems in general (Baniak & Dubina, 2012 gave a review of them) or the Triple Helix in particular. Carayannis and Dubina (2014) on the one hand, and Dubina and Carayannis (2015) on the other hand, demonstrated that game theory could help in understanding the behaviour of innovation actors; Dubina (2015a, 2015b) modelled the Triple Helix relationships with game theory; however, the scope of his reflection was limited to project funding. Not only did he not deal with publications, but he did not either propose any indicator to measure the synergy within the Triple Helix framework also. As he wrote, it was a "first attempt to formalize the concept of the Triple Helix of university-government-industry interactions in innovation activities with game theory" (Dubina, 2015a, p. 33; 2015b, p. 40).

The objective of this paper is twofold: i) analyse the Triple Helix relationships using game theory principles, methods and techniques, and, ii) develop indicators to measure the synergy within an innovation system. The article intends to answer the following research questions: i) What are the rules of the Triple Helix game? and, ii) How can the synergy be measured with game theory indicators? It is structured as follows: the second (next) section, gives a background information on game theory; the third section determines the rules of the Triple Helix game, the fourth proposes the core, the Shapley value and the nucleolus as indicators to measure the synergy within a Triple Helix innovation system; the fifth section gives an application to bibliographic data quoted from relevant Triple Helix studies; the last two sections are devoted to the discussion of the findings and the conclusion of our paper.

2. Basic information on game theory

Game theory is a branch of mathematics that deals with how economic actors interact for their interests. Modern game theory and its application in economy originate from von Neumann and Morgenstern (1944). Nowadays, game theory's techniques are used to understand economic, social, political, and biological phenomena (Jackson, Leyton-Brown, & Shohan, 2016; Osborne, 2004). It is concerned with the actions of decision makers who are conscious that their actions affect each other; it "is not useful when decisions are made that ignore the reactions of others or treat them as impersonal market forces" (Rasmusen, 2000, p. 30). According to Aumann (1985), game theory can be applied to all situations where peoples' actions are both utility maximizing and interdependent.

Game theory defines a game by four elements: the players, the actions, the payoff and the information (Rasmusen, 2000). Players are the individuals who make decisions. An action is a choice made by a player; usually, there is a set of actions a player can choose from. A payoff means either the utility a player receives after the game has been played out; or the expected utility. An information set at any particular point of the game is the reading a player gets from the actions the other players have taken or will take. Once a game is defined, one is interested in the strategies each player elaborates to maximize its utility. Game theory distinguishes two branches: noncooperative games and cooperative games. Noncooperative games focus on the strategies of individual players while cooperative games focus on how players behave mainly by the means of coalitions.

[1] Shapiro (2007) qualified the Triple Helix as a paradigm.