Have Quadruple and Quintuple Helices Emerged? Metaphors, Project Titles, and Empirical Research

Helen Lawton Smith | ORCID: 0000-0002-5950-9931
Department of Management, Birkbeck University of London, UK
Corresponding author
h.lawton-smith@bbk.ac.uk

Loet Leydesdorff | ORCID: 0000-0002-7835-3098
Department of Communication Studies, Amsterdam School
of Communication Research (ASCoR), University of Amsterdam,
Amsterdam, The Netherlands
loet@leydesdorff.net

Abstract

In the original Triple Helix model (Etzkowitz and Leydesdorff 1995), the three "helices" of Universities, Industry and Government and the (3-way) interactions among and between them were proposed as a basis for looking at how entrepreneurship comes into being. Since the original article, other "helix-based" models have been proposed. Some vary the triple and others propose higher numbers of helix – with 4 and 5as the most typical extensions. In the article "Triple, Quadruple, and Higher-Order Helices: Historical phenomena and (neo-)evolutionary models," Leydesdorff and Lawton Smith (2022) developed an Information-Theory based approach to look more formally at the need for higher-order helices.

In the case of two helices, processes of mutual shaping can generate historical trajectories that could have been otherwise: other options providing possible states, which have not yet historically been realized (Petersen et al., 2016). Adding a third helix makes a substantive change from an information point of view: a Triple Helix model is not just the sum of three sets of 2-way interactions. However, once this number has been reached further additions can be decomposed into sets of triads (Batagelj et al., 2014; Simmel, 1902). This leads to the suggestion that higher-dimensional helix structures potentially add little to discourse.

Four (sets of) authors were asked by the Editors of the *Triple Helix* to respond to Leydesdorff and Lawton Smith (2022). Many insightful and interesting points were

raised including convenience, presentation and the need to allow a more unified theory model. These are discussed in this article's "responses to just criticism" (Shostakovich, 1937). It continues the debate on triple and higher-order helices by summarising and responding to the points made by those commentators. What may be the status of triple and/or higher-order helices?

Keywords

Lewontin – Quadruple – Quintuple helices – Simmel's triad – Triple Helix

1   Introduction

In our article entitled "Triple, Quadruple, and Higher-Order Helices: Historical phenomena and (neo-)evolutionary models," Leydesdorff & Lawton Smith (2022) challenged the validity of the inference of this triple-helix metaphor to quadruple and higher-order helix models. Whereas a Triple-Helix synergy indicator could be developed in the last two decades, the research programs of those using higher-order helix models have hitherto largely tended to stagnate in terms of empirical results. One repeats the articulation of models in policy debates using anecdotal evidence. For example, Carayannis and Campbell (2022) proposed an "emerging unified theory of helix architectures, EUTOHA." These authors, however, did not specify how a quadruple or quintuple helix contributes to innovations other than perhaps programmatically.

Networks are constructed bottom-up first by agents relating to one another. Links can operate upon one another and generate a second-order dynamics of communications on top of the dynamics of carrying agents. The two sub-dynamics of knowledge production (by agents) and diffusion (by texts) can reinforce each other, co-evolve, or disturb each other. As the networks become increasingly populated with links and nodes, structure is further developed (Archer, 1982). Structure is not the sum of the links but a consequence of a configuration of realized and missing links. A network has an architecture that cannot be reduced to the sum of the links. The difference can also be considered as the redundancy of the network.

From this perspective, the first-order dynamics can be considered as a production dynamics; the second as diffusion. The production dynamics generates variation whereas the diffusion dynamics operates as selective feedback. Such a "reaction-diffusion dynamics" can bifurcate and generate internally an additional dimension (Rashevsky, 1940; Turing, 1952). A three-dimensional system

can proliferate beyond control (Ulanowicz, 1997). The next-order overlay feeds back selectively and against the arrow of time on the historical (forward) pattern of development. Feedbacks may have the opposite sign and can therefore also be considered redundancy.

In the case of two helices, processes of mutual shaping can generate historical trajectories that could have been otherwise: other options providing possible states, which have not yet historically been realized (Petersen et al.., 2016). Shannon (1948) defined redundancy as the part (percentage) of the information capacity which is not used. Redundancy – the availability of not yet realized options – can also be measured.

As noted, we challenged the validity of the inference of this triple-helix metaphor to quadruple and higher-order helix models (Leydesdorff and Lawton Smith, 2022). In our opinion, the research programs of those using higher-order helix models have hitherto stagnated in terms of empirical results. One repeats the articulation of steering-models in policy debates using anecdotal evidence. For example, Carayannis and Campbell (2022) proposed an "emerging unified theory of helix architectures, EUTOHA." These authors, however, did not specify how a quadruple or quintuple helix contributes to innovations other than programmatically. Where can applications be found?

Does a claver-four exist? If quadruplets and quintuplets exist, they are rare events whereas dyads and triads are empirically common in networks. Can one expect that quintuplets teach us about trends in social processes above a single-case anecdote? If so, what may be the surplus? "Responsible innovation" which is "sustainable in smart regions" or other Eurocratic abbreviations and metaphors? Is it possible to count, for example, whether and how frequently a quintuplet decays into a triplet plus a dyad (3 + 2 = 5)? How would this decomposition relate to sociological theorizing and social network analysis?

2 Contributions

The basic Triple Helix model is of three spheres in co-evolution. The challenge is to model, measure, and analyse, for example, innovation systems. Theoretically, Leydesdorff and Lawton Smith (2022) have drawn particular attention to Simmel's (1902) triads concept and argued that, while triple adds substantially to the dyad model by enabling us to study possible conditions of innovation, higher-order helix models can always be decomposed and recombined into interacting triple helices.

As noted, four responses to the article were invited. A rationale for the introduction of further helices was provided by Yuzhuo Cai (2022), who argued that

the surplus of alternative perspectives is that additional-helices models have functions, such as that of contextualisation rather than additional constituencies; e.g., the public conceived as sub-systems rather than primary actors or institutional spheres (Zhou and Eztkowitz, 2021). The basic model has been critiqued for underplaying the roles of different constituencies which may have an interest in a well-functioning Triple Helix model, for example at the regional level (Pugh, 2017).

Cai proposes *a neo-Triple Helix model* that might clarify debates on different helix models. His starting point was the potential synergies between triple, quadruple and quintuple helix models. He elaborated on differences in interpretation (e.g., between Etzkowitz and Leydesdorff) on what constitutes the core of Triple helix interactions – i.e. neo-institutional (Etzkowitz) and neo-evolutionary perspectives (Leydesdorff). He added that these models can complement one another and he illustrated this diagrammatically.

Cai's diagrams illustrate the university-industry-government (UIG) Triple Helix interactions, triple functions, and triple spaces by taking the universities' perspective – and he notes that the same could be done for industry and government. This approach has applications in policy debates, for example, when the focus of analysis is on just one of the three spheres so as to prioritise the positing of one element within an investigation. This raises the question of complementarity. Does analysis have to take sides or should it produce balance by referring to both positions?

Furthermore, Cai (2022) develops a series of propositions which he tests and develops in accordance with Lewontin's (2001) Triple Helix – from the perspective of evolutionary biologists. This brings him a resolution to disputes in relation to what can or cannot be addressed in the various schematizations of TH models. This helps address a dilemma in building synergies between triple and quadruple/quintuple helix models. The objective is to facilitate 1) rethinking and enhancing the theoretical grounds of the TH and the two other models, and 2) clarify the relations between them. Using Occam's razor, the scheme simplifies innovation systems as two kinds of THs or triads.

Cai goes on to develop "a neo-Triple Helix model of innovation ecosystems." The ecosystems comprise two layers of TH interactions (triads in triads); the UIG Triple Helix at the gene level and the TH interactions between innovation genes/dynamics, social structure, and the natural environment at the system level. The objective is to provide a template for integrating other approaches in innovation studies and other relevant social science theories in order to develop a more powerful conceptual framework to guide empirical research and policy design. Unfortunately, this research is not specified otherwise than programmatically.

The approach is potentially useful in developing the spatial element of the model as well as the prioritised natural environment theme developed by Cai. Cai cites Leydesdorff and Ivanova (2021) who argued that spatial interactions are related to the second-order interaction terms in communications. The network relations shape a structure in which both links and nodes have positions and shortest distances (geodesics) among them. Etzkowitz (2008) also introduced a regional dimension in his book but there remains scope for a more developed approach to understanding geographies of innovation from a TH perspective. Cai argues that his neo-model leads to rethinking and enhancement of theoretical grounds of TH and higher models, and the clarification of the relations between them.

In their contribution entitled "From modelling the interactions among institutions to modelling the evolution of an ecosystem: A reflection on the Triple Helix model and beyond," Lan Xue and Yuchen Gao (2022) elaborate on the theme of governance of innovations in higher-order helices models. They argue that a framework based on agile governance can be applied to this model with interactions among multiple triple helices. A set of flexible and adaptive actions or methods can thus be developed in order to make the governance of the higher-order models more agile so that they are able to keep pace with rapid changes in society. The model can remain flexible because – unlike DNA in biological evolution – he codes in the communications remain constructs that should not be reified (Giddens, 1979). These authors emphasize the importance of changing contexts.

In our opinion, the relevant contexts include digital technology advances – and new ways of linking social actors (particularly closer interaction and the greater involvement of civil society), the changing nature of innovation activities (and the reality of global innovation) and how actors can extract excess profits from innovation. The recommendation to government on the basis of these models is to involve more stakeholders, especially civil-society actors, and establish a framework for agile governance. This they argue can be applied to the higher-order helices models with interactions among multiple triple helices.

Mark Deakin's (2022) contribution entitled, "Triple, Quadruple and N-Tuple Helices: the RIS3, EDP and higher-order policy model" focuses on the policy models adopted in Europe – RIS3 of the Entrepreneurial Discovery Process (EDP). His purpose is to examine the respective status of the Triple and Quadruple Helix as the scientific basis of research and innovation strategies related to smart specialisation RIS3. The starting point is the choice of the TH model for European regions such as Westphalia in Germany and the Basque country in Spain. Deakin asks how one would measure the potential synergy

that exists between the Triple and Quadruple Helix in the structure of organised knowledge production.

Like Cai (2022), Deakin pays attention to the eco-system concept highlighting in his words that an ecosystem is "structural and deterministic' in its selection mechanisms. The link to the ecosystem concept is that the TH model is based on social networks and cultural codes of communication interacting in an overlay in the fourth selection mechanism (the "overlay") based on in interactions among the other three.

In his conclusions, Deakin revisits the theme that the TH's social networking and cultural codification is significant, as these elements help overcome the limitations of the Quadruple Helix – which is an interesting way round – that the TH model itself highlights the limitations of the later version – because of its selective ecology (selection also being a feature of evolutionary economics). He also critiques other critiques for mis-reading the original TH model – a cautionary note for other scholars. Particularly, the distinction (in our wordings) between a QH model that simplifies by integrating normatively, and the fourth helix as emerging in a knowledge-based economy, continues to drive the policy orientation of TH models.

Han Woo Park and Peter Stek's (2022) article is entitled "Measuring Helix Interactions in the Context of Economic Development and Public Policies: From Triple to Quadruple and N-Tuple Helix vs. N-Tuple and Quadruple Helix to Triads". It highlights some of the major challenges involved in researching multiple helices as they relate to knowledge innovation and suggests other lines of research. The starting point is that attention to quadruple collaborations has risen rapidly in place of the traditional TH model and therefore there is an increasing complexity of new and developing issues in 3+ helices. The authors also observe that the quadruple model of cooperation has supplanted the original TH model, and that the incorporation of widespread policy viewpoints is a key feature of the approach.

Furthermore, the authors suggest that the concept of social networks, which underpins the original TH model, must be revised in order more accurately to measure a number of new institutional actors involved in multilateral helix innovation across countries and regions. The authors take to task the original TH model for, while being a useful descriptive approach, not explaining the transition from one technological regime to another, which limits the value of the classical TH model. It is argued that it is relatively simple to visualise a quadruple helix: their Figure 1 provides that visualisation. However, the visual lacks a strong scientific foundation. In summary, the task of finding a "proof of concept" remains to be completed (Leydesdorff and Ivanova, 2014, 2021).

Elias Carayannis and David Campbell's (2022) focus is on the Quintuple helix framework which they suggest represents the most comprehensive,

meaningful and valuable construct, and on modality. This is because it encompasses the five core dimensions of modern, sustainable and democratic knowledge economies and societies. Civic society, as well as the three Triple Helix spheres – universities, governments, and industry – are relevant selection environments. This model develops a political perspective as the authors argue that, given current events in Europe, there is a need to advance the development of an Emerging Unified Theory of Helix Architectures (EUTOHA). The purpose is to be able to design solutions for the digital transformations of modern economies. The authors furthermore claim that this construction represents an eco-systemic approach, which builds on and completes the TH and the neo-TH approaches. They argue that the TH framework does not contribute conceptually to understanding democracy and ecology – hence the need for EUTOHA. Neither is attention given to the "significance and differentiation of the Quadruple and Quintuple Innovation Helix Frameworks in comparison with the Triple Helix construct" (page 8). The authors speculate that if Leydesdorff and Eztkowitz in 2003 had decided to add a fourth helix then the history of ideas about innovation would have been very different. Instead, the authors want to revise their interpretation of the work and derivations through using the EUTOHA framework.

3 Points Arising

Although it is difficult to find a common thread among these contributions, the commentaries reveal the multi-dimensionality of the Triple Helix model to understanding of innovation-led economic development. The first is that of a basic understanding of innovation processes through academic discourse and debate – the more abstract approach to innovation dynamics. The second is making the abstract understanding relevant to broader society. A common theme in the responses is how to explain societal, economic, environmental change. The third is that of validation through reliable operationalization and measurement.

From the first perspective issues raised included interpretation of the original TH model. Points that emerged include a sense of hierarchy, for example higher-order and second-order levels of analysis? There is more to say on this topic. Another approach has been the inclusion of other, arguably related, concepts which then build on the first one to either elucidate the original TH model or lay the ground for extra helices.

On the second, a policy agenda can be formulated: for example the role of the TH in practice in governance and government policy design, and whether the idea of multiple triple helices will provide policy makers with additional

tools. The TH has been particularly valuable as an evolutionary tool to help with understanding of historical processes and industrial paths chosen. It has long been used by policy-makers. It is argued in the responding articles that additional helix models are also valuable policy as well as analytical tools. Further research will reveal how useful these different constructs, e.g. EUTOHA, are in political debates and research practices. The shaping of research agenda in terms of operationalizations and measurement brings the TH as a mission home in the university.

4   Priority for Empirical Research

The ensuing questions are empirical. Park and Sterk (2022), for example, formulated: "a (dis-) advantage of empirical studies is the nuancing and differentiation of theoretical questions". Empirical answers no longer have the structure of "yes" or "no." For example, one can ask to what extent a national system of innovations is more innovative than the sum of the country's regional innovation systems? However, can one meaningfully ask for percentage contributions of quintuple or quadruple helices to innovation? or to employment perhaps? or to sustainability? What might the answer be otherwise than programmatic statements; for example, that one would need many (>20) more helices for a complete description of the complexity in modern societies?

In sum, the Triple Helix can be related as a theme to theoretically and methodologically interesting questions and has become a meeting place for scholars from different disciplinary backgrounds with the aim of contributing to the improvement of innovation systems. The call for quadruple, quintuple, and next-order configurations has remained one that can be combined with other metaphors such as "responsible innovation" in "smart regions" which legitimate funding decisions, but have hitherto not yet to offer substantive newness and research perspectives.

In the first section of this contribution, we asked, among other things, for specification of and potential differences in the status of the TH and higher-order helix models. We argue above that higher-order helices have hitherto remained of political discourse, whereas TH asks additionally for the specification of a research agenda. The mission of universities is not only to provide a source of new ideas – as in a kind of linear model – but to exploit the articulation of demand for innovation and further theoretical and/or methodological advancements. It remains unclear to us in what ways quadruple and quintuple models have contributed to this objective.

5   Declaration of Conflicting Interest

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