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The "Endless Perspective" to University – Industry – Government Relations

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Abstract

Since the emergence of the Triple Helix, expansions to Quadruple, Quintuple, N-tuple helices, and models decomposing higher-order helices into multiple interrelated triple helices, or two-layer triple helices have been proposed. Albeit presenting alternative conceptual frameworks these different Helix models seem unsuited to address internal boundaries to the institutional spheres of the university, industry, and government. Addressing this circumstance, the present article pursues the research purpose of conceptualizing a perspective that opens the possibility of analysis to occur between but also within the boundaries of the institutional spheres. To that effect it advocates the application of different reference frames (scopes) to capture the dynamics that empirically emerge from the system under research. The novelty of this study is that it expands the existing theory by proposing that adding "scopes" (instead of introducing new helices) can increase the analytical potential of the Triple Helix.

Keywords

endless frontier – endless perspective – endless transition – innovation systems – n-tuple helix – triple helix – university – industry – government

1 Introduction

The Triple Helix was introduced in the 1990s by Etzkowitz and Leydesdorff (Etzkowitz, 1993; Etzkowitz and Leydesdorff, 1995) to describe the innovation model based on the dynamic relationships between university – industry – government institutions. It emerged from the observation of the Massachusetts Institute of Technology's actions and their relationships with the high-tech industries clusters surrounding the MIT. By then, the MIT was already working in accordance with the Triple Helix, although using neither the terminology nor the theory behind the Triple Helix (Etzkowitz, 2010). Indeed, elements of this thought may be identified in pioneering works, such as in the Sábato Triangle – in which the government takes on the top position, and the lower vertices are the scientific and technologic infrastructure and the industrial infrastructure (Sábato and Botana, 1968) – and in Lowe's work (1982), which addressed the triangular organization of interests (industry, universities and government) present in biomedical research carried out in the USA.

The model reflects the change from an industrial society, where the relationships established by the industry – government dyad prevailed, into a knowledge-based society, characterized by the university – industry – government triadic relationship, in which institutions develop intersections preserving not only their identities and main roles, but also assuming others institutions' roles as a result of weakened positions or insufficient performance (Etzkowitz, 2003, 2008; Ranga and Etzkowitz, 2013).

One might say that unlike National Innovation Systems (Lundvall, 1988, 1992; Nelson, 1993), that give predominance to companies, and unlike the Sabato Triangle (1968), that focuses on the government sphere, the Triple Helix model emphasizes the roles of universities as essential institutions, a source of entrepreneurship and technology, which introduce a sieve of critical analysis associated with the scientific progress through review mechanisms. Universities are further recognized to have a pivotal role in crossing the functions established between the parties involved in the triad for the creation of new formats and for knowledge production, transfer and application (Etzkowitz, 2008; Ranga and Etzkowitz, 2013).

The Triple Helix model is applied as the scientific basis of research and innovation strategies across nations (Mccann and Ortega-Argilés, 2014). We are thus

facing a model in line with the importance that knowledge, a crucial resource (Bollinger and Smith, 2001; Hanushek and Woessmann, 2015; Lundvall and Johnson, 1994; Moustaghfir and Schiuma, 2013), assumes in advanced economies, which recognizes that it is the basis for the emergence of new industries (Colombelli et al., 2014; Guerzoni et al., 2014; Powell and Snellman, 2004) and it is directly related to countries' economic performance (Foray and Lundvall, 1996; Hulten, 2013; Strulik, 2014).

In academic communities there is a continuous research engagement on the Triple Helix, focusing particularly the future of innovation in society with a constant effort to employ and develop the model combined with criticisms on its limits or limitations (Cai and Amaral, 2021). As accelerated changes occurred in our societies, the Helix models, as analytical instruments aiming to describe the mechanisms of innovation, ought to be reviewed and developed (Amaral and Cai, 2022).

Although established for decades the Triple Helix is a vibrant and thriving academic field with novel and distinct prospects for developing theoretical and practical applications of helical concepts, welcoming contributions linking the Triple Helix with alternative approaches in innovation studies (Amaral and Cai, 2022)

Developing Triple Helix concepts is known to be challenging as is common in interdisciplinary approaches (Cai, 2020). Within the framework of transition from innovation systems to innovation ecosystems Zheng and Cai (2022) expressed that although in innovation systems boundaries are frequently establish spatially or according to their sector, in innovation ecosystems knowledge and innovation take place across boundaries that can encompass multiple geographical locations or a global context.

Triple Helix boundaries in terms of analysis scope have been thoroughly researched as the model is considered effective in understanding the dynamics of innovation at the regional, national, or international level but also designed to address transformations and dynamics within each of the helices providing a conceptual body to frame the nature of university, industry and government (Cai and Amaral, 2021). In this respect, Triple Helix is used to address the transformation: in university as an instrument to study the capitalization of knowledge, in industry to depict the boundary-spanning, and to address the 'innovation state' that implies the government as a regulator but also as an active agent (Cai and Amaral, 2021; Etzkowitz and Zhou, 2017)

The current academic discussion is centered on relations between Triple, Quadruple, Quintuple and N-tuple helices models researching options as sticking to simple Helix models, or adding further helices especially when considering higher-order dynamics, either decomposing higher-order helices into multiple interrelated triple helices (Amaral and Cai, 2022; Park and Stek, 2022).

For Carayannis and Campbell (2022) Triple Helix boundaries should be expanded with environment and civil society to address "modern, sustainable and democratic knowledge economies and societies" but as Cai (2022) develops a neo-Triple Helix model with its triads within triads or two-layer triple helices it present a scope perspective although without unequivocally expressing the concept.

Within the scope perspective, works as neo-Triple Helix model (Cai, 2022), or Triple Helix Twins (Etzkowitz and Zhou, 2006; Zhou and Etzkowitz, 2021) are relevant as they foreseen the application of different reference frames to capture the dynamics that empirically emerge from the system under research although doing so using multiple interrelated Triple Helices.

Addressing this gap, engaging the discussions promoted by Amaral and Cai (2022) on the relations between the different Helix models, the present article questions the opportunity of considering a scope perspective within boundaries of a "simple" Triple Helix framework.

This perspective distinguish itself from its emphasis in developing a conceptual framework within the borders of the university – industry – government as the Triple Helix Twins combines the "traditional" university – industry – government with the university – public – government Triple Helix (Zhou and Etzkowitz, 2021), and the neo-Triple Helix comprises two sets of triads, the "classic" university – industry – government, and the interactions of innovation genes, social structures and the natural environment (Cai, 2022).

2 Research Method

The Triple Helix model has been developed following multidisciplinary approaches. The challenge for developing interdisciplinary approaches is that concepts are eminently either unclearly defined or defined as self-statements (Cai, 2020). Main academic journals recognize the need for conceptual research able to bridge theories, connect concepts across disciplines, provide multidisciplinary approaches, and broaden the scope of knowledge. As powerful methods of theory development conceptual articles are challenging endeavors due to the lack of common recognized development models, as they do not drive from data but require assimilating and combining previously developed concepts. That is the reason because is difficult to write rigorous conceptual articles and they are often circumscribed to a literature review or to compelling but inconsistent ideas (Jaakkola, 2020).

To address these limitations the research under the present article was driven following Jaakkola (2020) methodological considerations as the author

develops a systematic approach to a conceptual article, instructing that one crucial function of the research design is to "explain how and why the theories and concepts on which it is grounded were selected" and how they are linked to clarify the key stages in the argument.

Contemplating the methodological challenges, we follow the Theory Adaptation one of the four potential templates for conceptual articles that Jaakkola (2020) proposes, as addressing the research question requires to enhance the Triple Helix model by introducing and applying the 'scope' perspective as a new or innovative lens by informing it with other theories or perspectives. Such an approach is suitable for our research as theory-based adaptation articles establish contribution by developing existing knowledge by proposing a new perspective from alternative frames of reference (Macinnis, 2011).

Within this methodological framework we proceed (in Section 3) to the characterization of the main systemic models of innovation, applying an inductive reasoning to infer adaptability as a distinctive Triple Helix characteristic due to its versatility and flexibility.

In Section 4 we introduce the perspective that the progress of innovation models from an *endless frontier* (Bush, 1945) to an *endless transition* (Etzkowitz and Leydesdorff, 1998) induced an evolution to relations among the academia, industry, and university proposing that relations will evolve to accommodate new societal changes.

Departing from the Triple Helix adaptability and the perspective that the model will adjust to societal changes (theories and perspectives established in previous sections) in Chapter 5 we engage with the discussions promoted by Amaral and Cai (2022) on the relations between the different Helix models to establish that of a couple of academic publications giving attention to relations within the boundaries of the institutional spheres (Lee and Kim, 2016; Simões, Moreira, and Mendes Dias, 2020) were not adequately addressed in the existing Triple Helix conceptual framework. Identifying this situation as the focal point of departure (Jaakkola, 2020) the conceptual argument develops using a multidisciplinary approach leverage in kinematics, and Triple Helix adaptability, to propose taking advantage of different reference frameworks (scopes) to expand and enhance the Triple Helix model into an *endless perspective*.

3 Triple Helix Adaptability (Versatility and Flexibility)

Towards the end of the 20th century, intellectual resources became a foundation for development theories, with the reasoning of inducing a self-sustainability

dynamic, given the presumable continuously renewable and expandable nature of knowledge (Dzisah and Etzkowitz, 2008).

The concept of innovation systems emerged in the late 1980s in order to study the relevance of innovation and knowledge in economic growth, in which institutions and the learning process play a central role (Freeman, 1987), being used to better understand the interactions and knowledge transfer among organizations (Carlsson, 2006).

This initial concept evolved to give form to the National Innovation Systems, which aggregated actors responsible for innovation, their activities, and interactions from a national perspective, favorable to the dissemination of localized knowledge and to the promotion of relationships based on the geographical and cultural proximity between the institutions (Lundvall, 1988, 1992; Nelson, 1993). However, given the inability of capturing the full interactions among such actors, other innovation systems with different degrees of aggregation have been introduced, such as:

– Regional innovation systems (Asheim and Gertler, 2006; Braczyk et al., 1998; Cooke et al., 1997), in which the regional dimension comprises a more homogenous socioeconomic, cultural, institutional and relational identity that better promotes innovation, especially in medium and large countries (Estevan, 2011);
– Sectoral innovation systems (Breschi and Malerba, 1997; Malerba, 2002), in which an analysis bound to the institutions of a sectoral activity is fostered, regardless of their location and type of technology used (Estevan, 2011);
– Technological innovation systems (Carlsson and Stankiewicz, 1991), which are focused on actors developing relationships based on a certain technology or set of technologies (Ranga and Etzkowitz, 2013).

As presented, these systems are appropriate to analyze phenomena with well-defined boundaries; however, another perspective is required if discontinuous innovation phenomena are under analysis. The relevance of this position holds greater significance considering that innovation increasingly stems from the external borders of an individual company or university (Etzkowitz, 2002).

As an Innovation System gives consideration, to boundaries, whether the system is open or closed the Triple Helix considers what transpires in the boundaries of the institutional spheres, plus their "overlapping" relationship. The Triple Helix focuses on "overlapping" spaces of the boundaries of the institutional spheres, support a more flexible, and productive, innovation model (Etzkowitz and Zhou, 2017).

Etzkowitz and Zhou (2017) present the Triple Helix as an "open" innovation concept that can be replicated as a universal innovation model and employed to examine strengths and weaknesses in Innovation Systems to fill its gaps.

Unlike national, regional, sectoral, or technological innovation systems, the Triple Helix is used for researching different fields of knowledge, enabling analysis of the dynamics that empirically emerge from the relationships between universities, state, and industry. There are situations where, comparing to an imminently geographical analysis, the use of a reference system by sectors and/or technologies may be considered the most appropriate unit of analysis to capture the interactions arising from the innovation systems (Carlsson, 2006; Leydesdorff, 2013).

Within a global reference framework, Choi et al., (2015) use scientific publications as proxy to assess university-government-industry relationships, concluding that developed countries see greater involvement of the industry than developing countries. This study identifies a small percentage of scientific publications with the simultaneous involvement of the three helices.

From a national standpoint, Etzkowitz et al. (2005) study the emergence of incubators, arising from the end of the military regime in Brazil, which privileged the promotion of large technological projects. The authors analyzed Brazil's transition from a top-down innovation system to a Triple Helix model.

The evolution of South Korea's innovation system has been researched using patent data. Yoon (2015) analyzed the transition of the innovation system, which was a State-based Triple Helix in the 1980s, to a model close to the balanced Triple Helix in the first decade of the 21st century.

The Triple Helix has been also used to study relationships between countries, e.g., the comparison between South Korea and the Netherlands (Park et al., 2005), Russia and China (Balzer and Askonas, 2016), and the cooperation between Israel and Turkey (Goktepe, 2003).

There are articles enabling a multilevel analysis by measuring Triple Helix synergies studying how the innovation system of a country varies at a national level and within its different regions. Some examples are given in articles analyzing Germany (Leydesdorff and Fritsch, 2006), Sweden (Leydesdorff and Strand, 2013), China (Leydesdorff and Zhou, 2014) and Russia (Leydesdorff et al., 2015).

At a regional level, Klofsten et al., (1999) use the Triple Helix to examine and describe the different actors that have contributed for Linköping to become one of Europe's most developed regions. Egorov et al., (2019) presented and econometric analysis centered under the Triple Helix concept to assess the innovation development of the Russian Arctic regions. In an inter-regional standpoint Triple Helix was applied to explore the collaboration from four non-contiguous regions belonging to four distinct European countries Romania, Hungary, Spain; and Ireland (Lalrindiki and O'Gorman, 2021).

Triadic relationships are also used to analyze industries and/or technologies at the center of the contemporary debate, as are examples smart cities (Deakin,

2014; Leydesdorff and Deakin, 2011), eco-innovation (Yang et al., 2012), circular economy (Anttonen et al., 2018; Barrie et al., 2017, 2019), sustainable development (Luengo-Valderrey et al., 2020; Scalia et al., 2018), photovoltaic industry (Klitkou and Godoe, 2013), drones (Fu et al., 2021), startups (Pique et al., 2018), nanotechnology (Cheng et al., 2019), and evaluating the Hyperloop potential (Gkoumas and Christou, 2020). Some authors explored the practical value of the Triple Helix applied to a single institution, as in the case of the University of Coimbra (Marques et al., 2006) and Google (Steiber and Alänge, 2013), showing the model's usefulness to represent such realities.

The academic focus to the university – industry – government helices was also evaluated as a systematic literature review that found four Triple Helix main clusters/trends (Galvao et al., 2019): (1) innovation and knowledge policies; (2) entrepreneurial universities; (3) business innovation strategy; and (4) triple helix stakeholders in innovation, knowledge, and regional development.

Following these examples, the Triple Helix may be framed in the context of innovation systems in accordance with Leydesdorff and Zawdie (2010). The authors argue that the knowledge-based economy is developed according to a dynamic system, at a global level, in which the value generated from knowledge must be captured locally. In this sense, national, regional, sectoral, and technological innovation systems may be deemed as system retention mechanisms developed globally. Therefore, as explicit from Table 1, while national, regional, sectoral and technological innovation systems aim at keeping the benefits from knowledge within specific borders, the Triple Helix supports the study of innovation systems at various levels, in terms of institutional and functional categories (Leydesdorff and Zawdie, 2010).

Trough inductive reasoning, by the end of this section, we infer the distinctive Triple Helix adaptability as it demonstrates to have the quality of being able to change or be changed to deal successfully with new situations (Oxford University Press, 2022a); due to its:

– Versatility – defined as the capacity to embrace a variety of subjects, fields or skills (Merriam-Webster, 2022).
– Flexibility – defined as the ability to change to suit new conditions or situations (Oxford University Press, 2022b).

Adaptability, although not a nominally recognized characteristic, it's implicitly integrated in the Triple Helix framework having the potential to leverage new approaches and scopes. Thereby as exposed in the examples described in the present segment the Triple Helix versatility permits to address a wide range of contexts as its flexibility allows research at various levels, in terms of institutional and functional categories.

TABLE 1 Brief characterization of the main systemic models of innovation

	National innovation systems	**Regional innovation systems**	**Sectoral innovation systems**	**Technological innovation systems**	**Triple Helix systems**
Author(s)	Lundvall (1988, 1992); Nelson (1993)	Asheim and Gertler (2006); Braczyk et al. (1998); Cooke et al. (1997)	Breschi and Malerba (1997); Malerba (2002)	B. Carlsson and Stankiewicz (1991)	Etzkowitz (1993); Etzkowitz and Leydesdorff (1995); Leydesdorff and Zawdie (2010); Ranga and Etzkowitz (2013)
Delimitation/ Boundaries	national analysis of innovation according to interactions, interconnections and synergies established between entities and companies.	regional, in which geographic analysis at the subnational level is considered fundamental because of the importance of factors such as proximity and spatial concentration play in the innovation process	sectoral (generally industrial), focus on companies, agents and institutions that relate to the sector regardless of location or technology used.	technological, focus on the network of agents that relate to a specific technology or a set of technologies	without defined boundaries, focus on emerging innovation in the (discontinuous) knowledge society, which takes place in hybrid institutional spheres and knowledge areas, promoting the acquisition, diffusion, and transfer of knowledge.
			Scope		
National	✓				✓
Regional		✓			✓
Sectoral			✓		✓
Technological				✓	✓

4 From "Endless Frontier" to "Endless Transition"

The Second World War significantly changed the United States' innovation model. Until then, the State was virtually absent from it, given the fact that science and engineering academic research was not deemed as a responsibility of the federal government, and almost all financing activities came from private institutions. There were few research areas developed by universities in the scientific frontier in the USA before 1940s (Mowery and Rosenberg, 1993).

With the beginning of the research on the atomic bomb, it became clear that the delay in the production of weapons technologies could be disastrous for the United States. Therefore, the American government embraced the purpose of achieving technological superiority, by broadening scientific networks, considering that what was done solely through industrial competition was deemed insufficient. These developments are at the root of the innovation promotion model referred to as *military – industrial – academic complex*, whose leading proponents were Vannevar Bush and the team of the Office of Scientific Research and Development. This autonomous complex was organized around a Triple Helix composed of the military, governmental laboratories, and defense suppliers (James, 2009). The wartime Triple Helix had a transformative effect making large research projects (an anomaly in the pre-war) common, and confirming the potential of the government participation in attaining military as well as civil objectives (Etzkowitz and Zhou, 2017).

During the Cold War, the scientific policy of the USA, based on the *endless frontier* of science (Bush, 1945), was firmly anchored in unlimited financing for military research and in the legitimization of fundamental research, which was based on the premise that such research would be useful and have military applications. Hence, soon after Second World War, the USA established an independent R&D system in which researchers were linked to the military, but with civil oversight, thereby giving rise to a dual economy – one civil, subject to market rules, and one military, monitored by the government (Etzkowitz, 1996, 2008; Etzkowitz and Leydesdorff, 1998).

The *endless frontier* led to the accumulation of academic results, without expression in industrial applications, since it did not cover sufficient transfer mechanisms, which at first was not deemed as a drawback (Etzkowitz et al., 2000).

However, the end of the Cold War wobbled the foundations of this system by undermining unlimited financing and reducing the legitimization provided by the military framework. Cumulatively, along with the preceding effect, a deficit was simultaneously identified in international competitiveness of the United States' industrial fabric, which created intense pressure, for reducing

the time frames, to apply research into the economy. A set of initiatives were therefore taken in order to enable achieving such objective, including assigning a strengthened role to academia within the national innovation system (Etzkowitz, 1996; Etzkowitz and Leydesdorff, 1998).

In the scope of this effort, the promotion of convergences between the civil and military sphere was undertaken, and so, to mitigate the inefficiencies arising from a bifurcated (military and civil) R&D system, "dual use" projects using defense R&D resources have been promoted to develop technologies with civil application, provided they meet the premise of simultaneously having military use and the ability to be incorporated into civil use technologies. Moreover, the identification and removal of barriers was also encouraged, thereby giving momentum to the promotion of R&D projects undertaken by consortiums comprising industry, government, and academia. These concepts lie at the foundation of the knowledge-based industrial transfer policy, promoted by the Clinton administration (Etzkowitz, 1996). With the institutional structures alteration, the role of the military declined, and the academia has risen transforming the network of relationships between university, industry, and government (Etzkowitz and Leydesdorff, 2000).

According to Etzkowitz (2003), such changes move away from the *endless frontier* model proposed by Bush (1945), which is characterized by the assumption that developments obtained through research would translate into applications for a mediated innovation era, toward the *endless transition* model, which is characterized by three transitions:

– First transition occurs in the relationship between basic and fundamental research and product development, evolving from different stages to a common development.
– Second transition occurs among technological areas. If previously the developments occurred according to essentially closed fields of knowledge, the new scientific and technological challenges currently require the collaboration and combination of several knowledge areas promoting a knowledge synthesis, which causes the frontiers between the fields to become diffuse;
– Third transition occurs in the relationship between basic and fundamental research, with the transition from the linear innovation model, where results are produced in a non-autonomous manner, to a model where a series of mechanisms promoting technological transfer are established to harvest the benefits of scientific financing.

Rather of being grounded in stable arrangements, knowledge-based economies are exposed to continuous transformation as they are firmly associated to sources of new knowledge, fostering an endless innovation process. The Triple Helix, as a model to sustain and develop the process of innovation becomes associated to an *endless transition* (Etzkowitz and Zhou, 2017).

Bestowing to this perspective, the archetype proposed by Vannevar Bush, the driving force of most scientific advancements made after the Second World War and metaphorically translated into the *endless frontier*, changed into the *endless transition* (Table 2), being the Triple Helix the most appropriate

TABLE 2 From the *endless frontier* to the *endless transition* -> The emergence of Triple Helix systems

Metaphor	**Author(s)**	**Triggering event**	**Objective**	**Context**	**Model of innovation promotion**
endless frontier	Bush (1945)	end of Second World War	"harvest the spoils of war" promoting civilian applications; achieve technological (military) superiority	unlimited funds for military research, legitimation of fundamental research on the premise that eventually will be useful and will have military applications	military-industrial-academic complex (government with a preponderant role); with spontaneous innovation transfer without liaison agents
endless transition	Etzkowitz (1998); Etzkowitz e Leydesdorff (1998)	end of the Cold War	industrial knowledge transfer, in which fundamental research is useful and applied	end of unlimited funding and diminished military legitimacy, increased international competition, "dual-use" applications; knowledge-based society	triple helix, university-industry-government (university with a preponderant role) promotes the reciprocal creation, diffusion, transfer, and application of knowledge

model to capture the knowledge-based dynamics (Etzkowitz, 1998, 2003, 2008; Etzkowitz and Leydesdorff, 1998; Ranga and Etzkowitz, 2013).

The Triple Helix ascension can be linked to the rise of a knowledge-based economic growth established on continuous innovation and advances in science and technology (Cai, 2015) where the interaction between the institutional spheres generates novelty in an *endless transition* (Etzkowitz and Zhou, 2017). Nevertheless, a digital transformation is generating a distinctive economic growth model derived from data.

The combination of an enhanced capability and convergence of technology with the expanding scale and scope of data is transforming the economy marking the transition from a knowledge-based economy to an data-driven economy (Ciuriak, 2018).

In a data-driven society the challenge of transforming information (data) into knowledge, although implying profound transformations to the institutional spheres, still holds relations between the university, industry, and government central, broadly fitting the growth models developed in the knowledge-based economy (Cavanillas et al., 2016; Ciolacu et al., 2017; Ciuriak, 2018).

As documented in this section (for previous transitions) is plausible that the university, industry, and government boundaries will also adapt to accommodate these new societal changes. The intense transformation in institutional spheres, expanding scale and scope of data signals value of exploring Triple Helix adaptability (versatility and flexibility) to extend the potential of transforming information into knowledge.

5 The "Endless Perspective"

As addressed, the Triple Helix has evolved from a metaphor into a model and from a theory into a practice. It has also shifted from an *endless frontier* into an *endless transition*, being a widely employed framework used in the economic literature, as a result of its versatility and flexibility support in the study of innovation systems at various levels, in terms of institutional and functional categories, also supporting the analysis of the dynamics that empirically emerge from the relationships between universities, state, and industry.

Despite the explanatory potential of the model, some scholars consider it insufficient to capture the dynamics of their research fields. To address this perceived limitation the prevailing approach has been expanding the Triple Helix outward adding additional spheres. A Quadruple Helix (Carayannis and Campbell, 2009), comprising the public, and a Quintuple Helix (Carayannis and Campbell, 2010), adding the environment, are firmly grounded in the literature (Carayannis and Campbell, 2022).

While the Triple Helix innovation model underscores the relations between the university, industry, and government the Quadruple Helix adds analytical potential to the model with the civil society as a fourth helix, as the society is crucial to the innovation systems as it sets the context for the promotion of a knowledge-based economy. By incorporating the environment, the Quintuple Helix is even more extensive as it is ecologically responsive, asserting the socio-ecological development of societies and economies in the twenty-first century (Carayannis et al., 2012).

Beyond society and the environment, it is possible to identify other expansionary dynamics emerging from the relationships between universities, state, and industry. As example, localization (local-global) is proposed to be essential to address the knowledge-based economy (Leydesdorff and Park, 2014). Following that framework, in order to explore the implications of localization dynamics, there are works that present an expand the Triple Helix design, to include internationalization, with international co-authorships as a fourth category, using scientific publications as indicators in the study of science, and patents to analyze innovation (Hossain et al., 2012; Kwon et al., 2012; Leydesdorff and Sun, 2009). This outlook is corroborated by Lew and Park (2021) who identify that the N-tuple helices models develop around stakeholders, internationalization, specialization, and ecological conservation.

A significant objection to additional helices is that the Triple Helix model represents three specialized functional spheres, and any additional dimensions should therefore represent an appropriate institutional sphere (Ivanova, 2014; Leydesdorff and Etzkowitz, 2003); furthermore, a helix extension might deprive the model of its creative dynamic (Etzkowitz and Zhou, 2006). Additionally it is possible to identify concern of an inadequate quadruple helix conceptual framework (arguing a feeble theoretical explanatory power and analytical complexity) and the risk of adding helices without adequate empirical evidence admitting nevertheless the existence of quadruple helix dynamics, particularly when considering higher order dynamics (Cai and Lattu, 2021; Park and Stek, 2022).

Although acknowledging that it is admissible to conceptualize N-tuple helices to extend the model in consonance to the required explanatory capacity, several authors advised caution in generalizing beyond the Triple Helix to the extent of not being capable to operationalize and demonstrate development in the comparatively simple case of three dimensions (Leydesdorff, 2012), as the pivotal theoretical and practical advantage of the model is that the Triple Helix reduces the complexity that is present in the innovation systems of the knowledge economy (P. Zheng, 2010), favoring key dynamics to be distinctly perceived (Cai and Etzkowitz, 2020), helping making the analysis more accurate and practical at the operational stage (Park and Stek, 2022).

Despite the expanded attention regarding society and environment, with increased research in the specialized literature, based on quadruple and quintuple helix models, the 'basic' Triple Helix, covering the original three helices of university – industry – government, remains the most applied framework (Cai and Lattu, 2021; Galvao et al., 2019).

The combined effect of university – industry – government being the dominant helix model and the reasoned concerns present above confer a sizeable contingent argument to confer additional academic attention to a less common perspective, which contemplates these objections, allowing nevertheless the expansion of the model to address further dynamics within the Triple Helix. Furthermore it's proposed that N-Tuple helices limitations are overcome by the Triple Helix model as it relays where the novelty production, wealth generation and normative control lying between them rest (Deakin, 2022).

In this context alternatives can be identified in the Triple Helix Twins (Etzkowitz and Zhou, 2006; Zhou and Etzkowitz, 2021), as higher-order helices can be decomposed and recombined into multiple interrelated Triple Helices (Leydesdorff and Smith, 2022; Xue and Gao, 2022); or in the neo-Triple Helix model with its triads within triads or two-layer triple helices: the "classical" university – industry – government, and the interactions of innovation genes, social structures and the natural environment (Cai, 2022). Although the triadic configuration conforms with parsimony criteria of Occam's Razor (Zhou and Etzkowitz, 2021), the Triple Helix Twins and neo-Triple Helix model add complexity with the inclusion of multiple triads, and spheres beyond the university – industry – government.

Pursuing the challenge of developing a synergetic and flexible conceptual framework, that allows incorporating different, and emerging elements in innovation ecosystems with the Occam's razor principle and its focus on the three fundamental helices (Cai and Lattu, 2021), its aligned with alternatives that explore expansions within the university – industry – government.

Using data regarding South Korea industrial programs, Lee and Kim (2016) expanded the university – industry – government model to analyze interaction in R&D networks, subdividing the traditional Triple Helix institutional actor industry into venture firms, large, small, and medium enterprises because of their different R&D network characteristics, as prior studies overlooked these specificities, since different types of firms, were categorized as one institutional actor, industry.

Simões et al., (2020) widen this inward perspective. Instead of adding, internationalization and dual-use, as additional spheres, the authors applied them as "scopes" to explore the relationships within the defense industry to ascertain how university – industry – government relationships behave in this specific industry. For that effect, for each helix, the total number of projects of

international defense, national defense, international dual-use, and national dual-use projects were determined allowing the enhancement of the explanatory capacity incorporating an international and defense perspective within the model instead of adding additional helices.

The novelty of these works is that they corroborate that the Triple Helix framework presents the possibility to address research questions within the three institutional spheres to quell perspectives as far apart as industry dimension, internationalization, and dual use.

Although, shedding light to the current argument, the progress on conceptual frameworks of different Helix models fostered by leading scholars (Amaral and Cai, 2022), seems unsuited to ground theoretically a model with internal boundaries to the institutional spheres of the university, industry, and government. To that effect it differs from the expansionary propositions on Quadruple and Quintuple Helix models (Carayannis and Campbell, 2022) or models that propose decomposing higher-order helices into multiple interrelated triple helices or two-layer triple helices (Cai, 2022; Leydesdorff and Smith, 2022; Xue and Gao, 2022). A model that contemplates boundaries within the institutional spheres also diverges form the archetype where innovation generates in an *endless transition* by the interaction between relatively independent institutional spheres "taking the role of the other".

Understanding the limitations of the Triple Helix model in terms of its analytical scope and explanatory power, compels awareness into its relations with the Quadruple and Quintuple Helix models bringing into evidence differences but also ability for interaction (Cai, 2022). While the Triple Helix model applies helices as actors or institutional speres Quadruple and Quintuple Helix models address them as political, economic, educational, natural, and public sub-systems (Zhou and Etzkowitz, 2021). Acknowledging the relevance of these dimensions the Triple Helix twins adds the university – public – government Triple Helix representing sustainability; and the university – industry – government Triple Helix representing innovation (Etzkowitz and Zhou, 2006; Zhou and Etzkowitz, 2021). Instead, the neo-Triple Helix model is conceptualized synthesizing insights from Triple, Quadruple and Quintuple Helix innovation models proposing two kinds of triple helices or triads: the university – industry – government for insight of innovation dynamics; and a triad at the system level factoring civil society and natural environment (Cai, 2022). These are relevant points as it indicates that based on the theoretical Triple Helix core principles of: a) Simmel's triadic interactions as the basic unit for exploring the dynamics of innovation processes; b) and holding to the Occam's razor principle on the other, is possible to expand the model boundaries dealing, to a large extent, with a scope perspective though not explicitly using the concept.

In this line the scope perspective can be summed up as a model to enhance boundaries within the university – industry – government yet adhering with the Triple Helix principles of Simmel's social geometry of triadic interactions as an Occam's razor principle of complexity reduction.

To address these considerations and reconciling the necessity to address the dynamics that empirically emerge from the relationships between universities, state, and industry with the challenge of solely considering institutional helices, the distinctiveness identified in articles by Lee and Kim (2016) and Simões et al. (2020) offer the possibility of exploring an inward model expansion, taking advantage of Triple Helix adaptability.

The versatility to embrace a variety of subjects as interaction in R&D networks (Lee and Kim, 2016) or the relationships within the defense industry (Simões et al., 2020) isn't 'per se' distinct from the *endless transition*. The differentiation arises from the capacity to address an array of subjects not between but also within spheres subdividing the institutional actor industry into venture firms, large, small, and medium enterprises (Lee and Kim, 2016) or the helix outlook by projects of international defense, national defense, international dual-use, and national dual-use projects to feature an international and defense perspective (Simões et al., 2020). These examples give evidence to the extended flexibility demonstrated in the ability to change to suit new conditions or situations allowing the possibility to address not only the relations among but also within institutional spheres.

Encouraged by the possibility to trace the disciplinary inspiration for the Triple Helix from chemistry and the existence of multidisciplinary approaches inspired in physics (Cai, 2020; Etzkowitz and Zhou, 2017) we follow this classic influence. As in kinematics, a subfield of physics, we take advantage of different viewpoints (reference frames) to apply algebraic geometry to the study of a mechanical system or mechanism, we can enhance our knowledge of an innovation system according to the applied reference framework.

The application of different reference frames as are examples: a) types of firms (Lee and Kim, 2016); and b) international defense, national defense, international dual-use, and national dual-use projects (Simões et al., 2020); opens the possibility of analysis to occur between and within the boundaries of the institutional spheres. To these different viewpoints Simões et al., (2020) attribute the designation of scopes.

To that effect instead of introducing new helices we can add the necessary "scopes" into an *endless perspective* to encapsulate additional frameworks within the Triple Helix model to capture the dynamics that empirically emerge from the system under research. This is in line with the Occam's razor principle, which proposes adding complex constructs only if necessary (Braithwaite, 2007).

Following Lee and Kim (2016) and Simões et al., (2020) two different approaches: the first subdividing only industry into large enterprises, small and medium enterprises, and venture firm; the second analyzing all the Triple Helix institutional spheres (university, industry, and government) under different reference frames, is possible to foreseen that the scope concept can be assumed in endless different ways contingent to the researchers resourcefulness in using the Triple Helix adaptability to attain the suitable framework to comprehend the system under analysis.

The *endless perspective*, far from moving away, builds on Etzkowitz (2003) *endless transition* expanding the explanatory potential of the model 'ad infinitum' within the frontier of the university – industry – government being characterized by:

- Conceptualizing 'scopes' instead of N-tuple helices to extend the model in consonance to the required explanatory capacity.
- Enhancing the creative dynamic of the Triple Helix as its resilience is conditional to the research resourcefulness in attaining an appropriate framework to grasp the intended perspective of the innovation system.

The *endless perspective* conceptual framework proposing different scopes (reference frames) leverage in the adaptability of the triadic relations of the university – industry – government adheres to the Triple Helix pillars as the Triple Helix conceptual model core (Cai, 2022; Cai and Etzkowitz, 2020) is rooted in the Simmel's triadic interactions (Simmel, 1902) as an Occam's razor principle supporting introducing complexities or constructs only if essential (Braithwaite, 2007). For that reason this new approach is expected to preserve Triple Helix core assumptions as for example the ability to be used to address issues in micro, meso and macro levels (Zhou and Etzkowitz, 2021) adding nevertheless the possibility to focus on subsets of the system under scrutiny.

6 Conclusion

In a digitalized world generating an economic growth model derived from data, where knowledge frontiers are less constrained by space or time, it is relevant to capture the endless dynamics that empirically emerge from the relationships between universities, government, and industry, taking advantage of multiple frameworks to grasp the *endless transition* into an *endless perspective*.

To the effect the discussion evolves from the research of national; regional, sectoral, technological innovation systems to the assumption that the Triple Helix framework adaptability enables it to procced with research wherever dynamics analytically emerge from the relationships between universities,

state, and industry as the Triple Helix supports the study of innovation systems at several levels (micro, meso and macro), in terms of institutional and functional categories.

Building on this, we follow through with the perspective that, in line with the *endless transition*, the Triple Helix is used to capture the knowledge-based economy dynamics as the archetype of the *endless frontier* with its insufficient transfer mechanisms leads to the accumulation of academic breakthroughs, without industrial applications, admitting however that as the knowledge-based economy is transitioning to a data-driven economy, the Triple Helix is expected to evolve to accommodate the new societal changes.

Appling the Theory Adaptation as a template, combining concepts established in this article within the existing Triple Helix conceptual framework the present article tries to bridge the gaps proposing an alternative development to the model the *endless perspective* that, building on the characteristics of the *endless transition* (1. the common development of product development, basic and fundamental research; 2. the promotion of knowledge synthesis with the combination of several knowledge areas; and 3. the formation of transfer mechanisms) adds the necessary "scopes" to capture further contexts within the Triple Helix to apprehend the dynamics that empirically rise from the system researched.

This framework promotes depth to the Triple Helix model adding, to its versatility and flexibility, the capacity to incorporate the inclusion of emerging factors into the analytical fold and the possibility to focus on subsets of the system under scrutiny, allowing a more refined and granular analysis, and doing so, expanding the possibilities of transforming information into knowledge contributing to an enhanced awareness of innovation systems.

Advancing an alternative option to optimize research strategies, enhancing theoretical grounds and practical applications this article fills an existing gap in the literature fulfilling the dilemma of incorporating emerging factors into the model framework while adhering to Occam's razor principle of complexity reduction expanding the analytical potential of the Triple Helix within the three "classical" institutional spheres: university – industry – government.

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