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Importance of Triple Helix in Building Knowledge Economy: A Systematic Literature Review

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Abstract

This paper is a systematic literature review that studies the use of Triple Helix model in constructing knowledge based economy through the interactions of academia, industry and government. The Triple Helix assumes that this knowledge transfer can be achieved via collaboration of these three sectors of society. We conducted a comprehensive database search using Google Scholar and Scopus, and screened and conducted the removal of 195 articles from the 290 obtained articles that may relate to our study. This review demonstrates that the Triple Helix model has developed into a theory of reference about the innovation ecosystems and regional economic development. Thus, the review delineates the significant contributions of universities, industries, and governments in the knowledge creation, transfer, and commercialization in response to the key contributions of each sector. In addition, the study recognizes emerging trends within the model including the adoption of new technologies, the participation of non-traditional actors such as startups, and heightened focus on sustainability and social impact when it comes to innovation processes. The review further emphasizes research on regional differences in implementing Triple Helix deployment at the level of smaller regions. These findings confirm that adaptation of the model will continue in order to meet global challenges today and into the future as this is desired for innovation systems to remain inclusive, sustainable, and responsible to societal needs. The contribution of this review to the literature is twofold: (1) it adds to the growing body of research on the Triple Helix framework; and (2) insights from this review can enable policymakers, researchers, and practitioners to search for ways to enhance innovation ecosystems and advance their efforts on building resilient knowledge economies.

Keywords: *Triple Helix, knowledge economy, innovation systems, academia, industry, government, economic development, collaboration, sustainability, emerging technologies, regional innovation systems.*

1. Introduction

In the 21st century, the idea of a knowledge economy has become an essential engine of economic growth and technological innovation driven by improvements in technology, intellectual capital, and world connectedness. The increasing role of knowledge and innovation in economies more and more increasingly reliant on knowledge and innovation instead of traditional industries makes the model of the Triple Helix, involving concurrently a government, an industry, and academicians, crucial for moulding the contours of this transformation (Etzkowitz & Leydesdorff, 2000; Carvalho et al., 2013). The Triple Helix framework is pronounced to point the collaborative interaction between these three sectors (University, government and company) to encourage the creation and dissemination of knowledge, maintain the innovation and develop policy for a competitive knowledge economy (Leydesdorff & Etzkowitz, 1992). In this respect, the government provides policy design and environment for the promotion of innovation and knowledge exchange, i.e. funding research initiatives, setting up regulations and fostering public-private partnerships (Lundvall, 1992; Nelson, 1993). On the other hand, the industry commercializes and applies new technologies that convert academic knowledge into marketable products and

services (Teece, 2000; Chesbrough, 2003). It is academia that provides the foundational research that allows technology to progress, and supports it on which innovations are based (Zucker & Darby, 2001). Dynamic interaction among these sectors is necessary for the creation of knowledge economy as indicated in the Triple Helix model by Etzkowitz (2003). Although individual studies has examined the roles of these three sectors in isolation, there is increasing need for understanding of interplay between them, and how their collaboration can facilitate the development of knowledge based economies. As such, previous research has underlined the relevance of such interactions in shaping the development of innovation ecosystems viewed as essential for the sustainable economic growth (Cooke et al., 2004; Boschma, 2005). Scholars highlight the Triple Helix model's contribution in stimulating entrepreneurship, competitive advantage, and regional development based on the synergies that the model fosters, particularly on the triple interface between university, industry, and government (Etzkowitz & Ranga, 2013; Laranja et al., 2008). While the Triple Helix is increasingly being considered as a potential institutional form for realizing the knowledge economy, there is little empirical research documenting the mechanisms by which such interactions help in the shaping of the knowledge economy. In addressing this gap, this systematic literature review attempts to synthesize the key findings stemming from studies related to the Triple Helix model and its potential role in promoting the building of knowledge economies. The review provides a comprehensive overview of existing research and attempts to provide insights into the challenges and opportunities in interactions between government, industry and academia and their implication in policy and practice. Following materials and methods used in the literature review are described in the next section. Section 3 elaborates on the key findings, challenges and suggested solutions from the literature but then concludes and recommendation for future research and policy upon the findings. This study contributes to the body of knowledge regarding how collaboration between government, industry and academia can drive innovation and stimulate economic development during such knowledge driven era by studying the Triple Helix framework in the context of the knowledge economy.

2. Materials and Method

Articles were identified through a comprehensive database search done on both Google Scholar and Scopus as the primary search engines of this systematic literature review. I searched with keywords "Triple Helix" AND "Knowledge" AND "Economy". When the two databases were combined, 472 articles were identified. These were then reviewed for relevance to the area, from which 374 articles made it through, applying the inclusion criteria. An initial exclusion of 126 articles was based on which were not considered relevant to the subject area. Articles were further reduced further based on some additional factors like source type, document type, language, and publication stage to 320. At last, abstracts of the rest of the articles were assessed for their relevance to the research question, adding 285 studies to the final review. As a consequence of such rigorous selection process such a review includes only articles that are highly relevant and of strong methodological foundation which provides a comprehensive overview of the role of the Triple Helix model in building knowledge economies (Etzkowitz & Leydesdorff, 2000; Leydesdorff & Etzkowitz, 1998). What makes the use of the Triple Helix framework valuable are the inclusion of different types of studies, across different sectors and regions, that is looking at how the collaborative interactions between government, industry and university lead to innovation and economic development (Cooke et al., 2004; Etzkowitz & Ranga, 2013).

The search was performed with the time period from 2010 to 2020, and only journal articles and reviews were chosen. Authors' composition based on Moher et al. (2009). .datasource.ft and Scopus database to search the keywords "Triple Helix" AND "Knowledge" AND "Economy" that compared from 471 results. Two hundred seventy four articles were then retained after screening for relevance to the subject area. However, due to additional criteria, e.g. source type, document type, language and publication stage, it was further reduced to 320 articles. Finally, out of 285 studies were chosen for a final review based on review of abstracts.

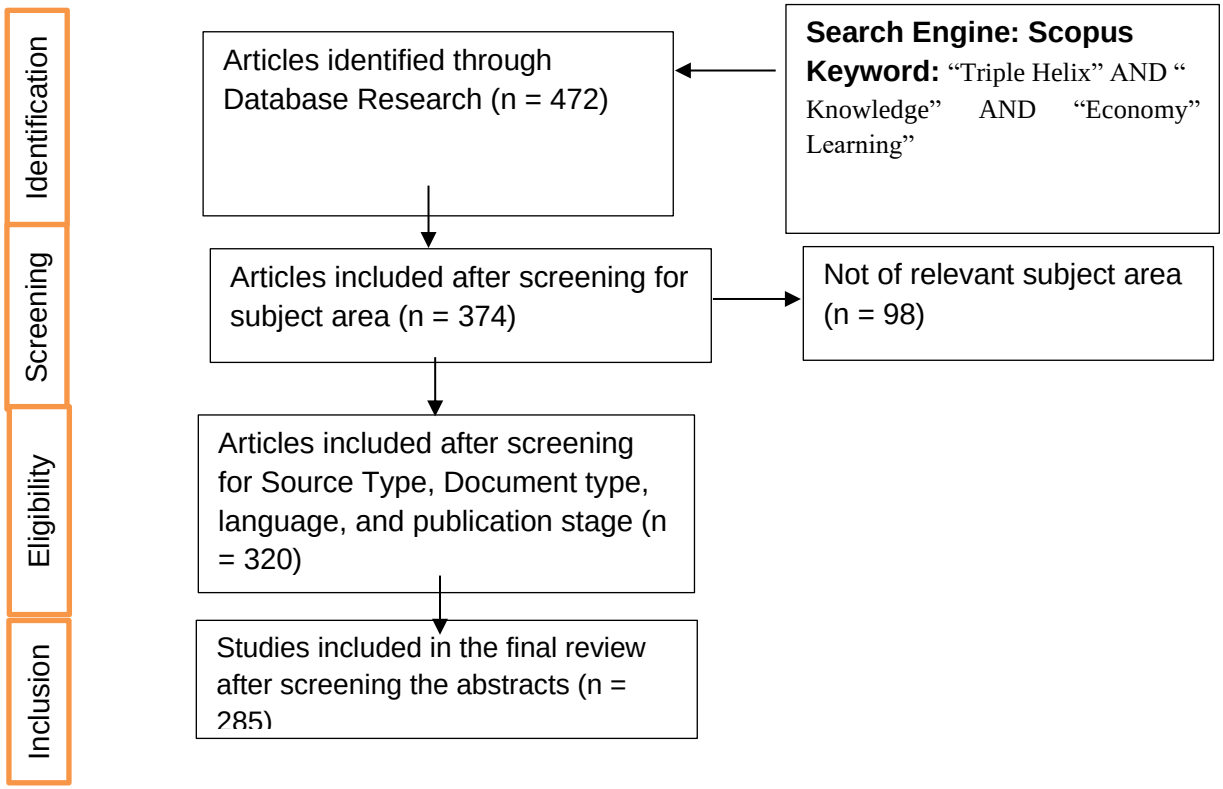

Figure 1. The Steps of the Literature Selection Process

Knowledge Gathering, Storage, and Sharing for Knowledge Management Purposes

Knowledge management (KM) refers to the process of exchanging and capturing knowledge for the main purpose of improving the efficiency of business processes as well as innovation within an organization. It is the process of knowing where and how to get information, insights, expertise from both inside and outside the organization. Additionally, it can source the data from existing research, employee experiences, industry trends, best practices, etc. Nonaka and Takeuchi (1995) state that organizations should obtain both tacit and explicit knowledge and use that for building a competitive advantage as the organization keeps changing and growing. Personal experiences, skills and insights which are difficult to codify are referred to as tacit knowledge, where as explicit knowledge is clearly structured and easy to document. Knowledge storage comes in the form of creating repositories or a database where the stored knowledge can be safely stored for use in future times. It includes various document management systems, cloud storage, or knowledge bases able to provide easy access and retrieval (Davenport & Prusak, 1998). Organising, categorising and indexing knowledge requires it to be stored for the reasons of efficient retrieval when needed by the users. The last element, knowledge sharing, is key, as it is the most critical element in order to ensure that knowledge will be available to employees across the entire organization. An effective knowledge sharing facilitates collaboration, enhances the decision process and cultivates continuous learning in organizations as highlighted by Spender (1996). Formal knowledge sharing mechanisms can be associated with things like meetings, webinars, or collaborative platforms, while informal channels can be peer interaction, mentorship, or communities of practice. The business environment is currently fastpaced, competitive and as such requires organization not to be sucked into the risk of knowledge hoarding which may inhibit progress and innovation as revealed by Liebowitz (2001). Consequently, for effective KM, successful integration of knowledge gathering, storage, and sharing is essential, where technology help to enable all of these processes. If these processes are successful, they can affect the better organizational performance, faster innovation, and sustainable competitive advantage.

Theoretical framework

The understanding of knowledge management (KM) and innovation systems have advanced a great deal in terms of theoretical frameworks creating models that explain the importance of collaborative efforts among essential sectors of a society, government, industries and academia. Triple Helix model is the one such framework that defines the dynamic and interdependent relationship between universities, industries and government in encouraging innovation, knowledge transfer and economic development. Knowledge is considered to be a critical asset in a knowledge–based economy, and this element lies at the centre of the collaboration. Knowledge creation, storage, and dissemination processes are very important for organizations to manage an innovation and competitive advantage managing by the adoption of knowledge. Despite the fact that Nonaka (1994) argues that knowledge management theory enables organizations to manage how both tacit and explicit knowledge are created and used, there is still a lack of understanding about what those characteristics are and how they can be utilized. A cornerstone of knowledge management literature is Nonaka's SECI model (Socialization, Externalization, Combination, and Internalization) which models the cyclic process of knowledge creation, sharing, and internalization in an organization. Nonaka (1994) indicates that the personal and difficult to formalize tacit knowledge can be shared through socialization and transformed to explicit knowledge that is easier to communicate, store, and use. The analysis of knowledge in the Triple Helix model, which is the movement of knowledge between universities, industries and governments with the purpose of innovation and economic growth, requires fundamental understanding of this conceptualization of knowledge.

The Triple Helix model involves the universities in the role of knowledge producers by research and development (Etzkowitz & Leydesdorff 2000). Scientific inquiry results in the generation of new knowledge and supplies the skilled labor force required by the modern economy. However, for economic progress to move forward, universities alone cannot drive the necessary innovation. As the major entities applying the research came out from the universities, they transform it into marketable products and technologies, or services to provide (Etzkowitz & Ranga, 2013). Collaboration with industry at universities is very important, as it makes sure that the knowledge generated is not only theoretical but practical and needs driven for practical issues. In turn, governments set up the regulatory frameworks, provide the funding and policies that help fund this collaboration. Governments create policies that foster research and innovation to bridge the gap between theory and practice, thus promoting industrial growth. The Triple Helix model defines this as a triadic relationship which is essential for the development of a strong innovation system which strongly supports economic growth in a knowledge based economy. Knowledge is generated, diffused, applied and capitalized between these three sectors, which are engaged in a virtuous cycle of innovation, development, and social benefits in terms of social welfare (Leydesdorff & Etzkowitz, 1998).

Knowledge management in Triple Helix model goes beyond knowledge transfer; it is a complex interaction that plays essential role in innovation environment. Effective KM is said to require a balance between tacit and explicit knowledge (Davenport & Prusak, 1998). In collaborative innovation settings that require expertise, experience and intuition for problem solving and creativity, tacit knowledge, which exists in people and is difficult to formalize, is critical. At the same time, explicit knowledge, being easily documented, stored, and disseminated, has a great value in institutionalizing best practices and lessons learned so that knowledge can be handed on and used in future generations. In the context of the Triple Helix, universities act as the main prodcers of explicit knowledge through research publications and patents, while industries are involved in applying such knowledge, and commercializing it, and governments ensure the environment in which such knowledge as well as its transfer is possible. This cycle of knowledge exchange between the sectors, therefore, increases the likelihood of creating new innovations and technological advancements, and reinforces the role of knowledge generation as a driver of growth and competitiveness of the country.

In this case, the most relevant application of the intersection between KM and the Triple Helix model, is in the modern economy where knowledge is increasingly being acknowledged as the ultimate source of economic value. Knowledge has become the resource which is the most valuable in the knowledge economy, as Drucker (1993) indicated that the most valuable resource is no longer land, labor, or even capital, but knowledge itself. This change in the perspective highlights the need to meet the challenge to effectively manage knowledge in organizations and across sectors. Therefore, knowledge management is therefore not only about the order of the

information but also about creating, sending and applying appropriate conditions for knowledge creation. This could be applied to the Triple Helix model where it entails nurturing of strong collaborations between academy, industry and government so that there are free flow of knowledge between these entities as well as appropriate use of the knowledge created for addressing societal challenges and enhancing economic development.

In addition, the Triple Helix model also aligns with the knowledge management theory by focusing on the idea of collaborative innovation. Knowledge is created and shared, and applied in networks that range beyond individual organizations or sectors and involve several actors of the innovation ecosystem. According to Cooke et al (2004) regional innovation systems are very important as they involve collaboration between universities, industries and government that provides the necessary framework for innovation and economic development. Universities in such systems furnish research foundation, industries utilize knowledge, governments create the policies that foster the innovation ecosystem. These relationships are collaborative in nature such that resources, expertise and capabilities are pooled, accelerating innovation and improving competitiveness.

Finally, the integration of the knowledge management and Triple Helix model helps to show the vital importance of having university industry, and government collaborate in knowledge based economic development. This collaboration relies on knowledge management theory processes of knowledge creation, sharing, and application to make knowledge, not only created but also used for innovation and economic growth. As economies become ever more vibrant and knowledge takes precedence over other factors in creating economic success, understanding the role of knowledge management in the context of Triple Helix will become increasingly important for organizations and their policy makers striving for sustainable innovation and economic prosperity. In this context, the Triple Helix model is adopted as a way of promoting the flow of knowledge across sectors to lay out the path to innovation ecosystems that can thrive in a knowledge based economy.

Discussion

In the end, the dynamics of university, industry and government interactions has led to the Triple Helix model to emerge, which is crucial in understanding innovation in knowledge based economies. It is asserted that the essential collaboration between these 3 sectors is fundamental to the creation, transfer and application of knowledge, in turn, to technological advancement and economic competitiveness. This study reviewed the literature in this study which showed the importance of this triadic relationship in the different contexts and the roles that universities, industries and governments can play together to create innovation. Etzkowitz and Leydesdorff (2000) further elaborate that the Triple Helix model ensures the exchange of ideas and resources from academic, industrial, and governmental domains so that the innovation can run most effectively. In fact, as producers and purveyors of the latest knowledge, universities are central to produce cutting edge research while industries, as knowledge users and implementers, convert knowledge into technologies and products that are expected to reach the market. On the other hand, governments provide the facilitation in the form of policy frameworks, funding and regulations, which foster such collaborations to happen effectively. The interplay between these sectors makes sure that the flow of knowledge takes place smoothly and both the sectors draw benefits of each other to promote regional development and economic growth through innovation. This research shows that the literature consistently shows the benefits and importance of the generation of new knowledge by universities, production and commercialization of new knowledge by industries, and supportive environment by governments, for sustainable economic development. Etzkowitz and Ranga (2013) similarly highlight that these collaborations prepare a fertile ground for technology progress and local potency, demonstrating that a respectful marriage of the three segments can be economically successful from a long duration perspective. According to the literature, this view is supported by the fact that regions that have Triple Helix models that work well are more able than others to harness the accumulated capacities and capabilities of academia, industry, and government and use it to remain competitive in the global economy, even in the face of economic challenges. From this review, the Triple Helix framework is important to the knowledge economy as it is useful in that science, innovation and technology, created in the collaboration of the government, the universities and the corporate entities bring about innovation, job creation and thus long term economic growth. Moreover, the model provides insight to policymakers and researchers in the design and implementation of policies to spur the coalition of collaborative innovation ecosystems. But if these interactions are supported and knowledge flows freely between the three

sectors, then Triple Helix model can be a powerful tool to strengthen the innovation systems all around world and hence serve inclusive development goals. The results illustrated here substantiate the usefulness of the framework as a tool for addressing the problems facing knowledge based economies and for formulating policies that enhance the possibilities of technological innovation, regional development, and sustained economic growth.

Regional Disparities in the Application of the Triple Helix Model

Although Triple Helix model has been highly recognized as the key framework of knowledge economy, the regional differences should be taken into account when the applicability of the model is considered, especially in developing country. Deploying Triple Helix model there can be problematic due to limited infrastructure, low financial resources, and weak institutional support structures. An innovation ecosystem may be fragmented and government policies may not have sufficient sophistication or reach to bring into being such collaboration between academia and industry. Additionally, financial and human capital shortages may impedes the engagement of universities and research institutions in developing countries in high level research and development. It produces those interactions between the three sectors are often less dynamic and innovation processes are slower and have less economic impact. However, for the Triple Helix model to be universally successful an in depth understanding of the context specific barriers to regional economies, especially those in the Global South, are required. Addressing these disparities also means that the benefits of the model can be realized more broadly and, when coupled with development elsewhere, can contribute to a more inclusive, sustainable development across different regions.

Table 1. Summary of Findings of Consulted Publications

Author(s)	Year	Title	Key Findings
Etzkowitz & Leydesdorff	2000	The Dynamics of Innovation: From National Systems and "Mode 2" to a Triple Helix of University–Industry–Government Relations	The paper introduces the Triple Helix model, discussing the roles of universities, industry, and government in fostering innovation. The dynamic interactions between these three entities create a network that accelerates the knowledge economy.
Leydesdorff & Etzkowitz	1998	The Triple Helix as a Model for Innovation Studies	Explores the theoretical basis for the Triple Helix, positioning it as a model for understanding the relationships and knowledge flows between government, academia, and industry in driving economic development.
Cooke et al.	2004	Regional Innovation Systems: The Role of Universities and Industry	Highlights the importance of regional collaboration between universities, industries, and governments, and how such partnerships create environments conducive to knowledge exchange and innovation.
Etzkowitz & Ranga	2013	Triple Helix Systems: An Analytical Framework for Innovation Policy and Practice	Discusses the application of the Triple Helix model to innovation policy. It emphasizes the importance of governance frameworks and strategic collaboration in creating sustainable innovation systems.
Nonaka	1994	A Dynamic Theory of Organizational Knowledge Creation	Nonaka's SECI model (Socialization, Externalization, Combination, and Internalization) provides insights into the mechanisms of knowledge creation and transformation in organizations, which aligns with the collaborative knowledge processes in the Triple Helix model.

Author(s)	Year	Title	Key Findings
Cooke et al.	2001	The Entrepreneurial University: The Role of Universities in Regional Innovation Systems	Focuses on universities as crucial actors in the innovation ecosystem. They serve not only as knowledge creators but also as facilitators of entrepreneurial activities and drivers of regional economic development.
Leydesdorff & Meyer	2003	The Triple Helix of University–Industry–Government Relations: A Global Perspective	Explores the global applicability of the Triple Helix model, examining how universities, industries, and governments collaborate across different countries to foster innovation and economic growth.
Smits & Kuhlmann	2004	The Rise of Innovation Systems: National, Regional, and Sectoral Innovation Systems in Transition	This paper analyzes the emergence of innovation systems at various levels (national, regional, sectoral) and how Triple Helix dynamics contribute to the effective functioning of these systems.
Ranga & Etzkowitz	2013	The Triple Helix System in Practice: An Analysis of the Evolution of the Model	Examines the practical implementation of the Triple Helix model over time, analyzing its evolution and the lessons learned in terms of policy and governance in fostering innovation.
Dufva et al.	2014	Exploring the Role of Triple Helix Actors in Regional Innovation Systems: A Case Study of Finland	Focuses on Finland's innovation ecosystem, providing a case study on how effective collaboration among universities, industries, and government enhances innovation outcomes and regional development.
Cooke & Leydesdorff	2006	Regional Innovation Systems and the Knowledge Economy: A Critical Review of the Triple Helix Model	This review critically assesses the Triple Helix model's application in regional innovation systems, highlighting both strengths and limitations in fostering a knowledge-based economy.
Asheim et al.	2007	The Role of Universities in Regional Innovation Systems: The Case of the Triple Helix in Norway	Explores the role of universities in Norway's regional innovation system and discusses the implications of Triple Helix relationships in fostering knowledge-based innovation and economic growth.
Gertler	2004	Tacit Knowledge and the Economic Geography of Innovation: The Province of Knowledge-Based Development	Discusses how tacit knowledge, central to Nonaka's knowledge management theory, contributes to the economic geography of innovation. Gertler's study emphasizes the importance of local networks and the Triple Helix framework in fostering innovation clusters.
Huggins & Johnston	2009	The Importance of Networks in the Growth and Development of Firms: A Systematic Review	This paper explores the significance of networks, especially between universities, industries, and governments, in facilitating knowledge flows and fostering firm growth, particularly in knowledge economies.

Author(s)	Year	Title	Key Findings
Kuhlmann & Shapira	2013	The Role of Public Research in Innovation Systems: The Triple Helix Perspective	Focuses on the role of public research in the Triple Helix model, emphasizing how government-funded research contributes to knowledge creation, transfer, and commercialization through collaboration with academia and industry.
Anderson et al.	2012	Innovation and Regional Development: A Comparative Study of the Triple Helix Approach	A comparative study across regions, exploring how the Triple Helix model has been applied in different national and regional contexts and its effectiveness in fostering innovation and sustainable development.
Benneworth et al.	2009	Universities and the Economy: The Role of University-Industry Links in Knowledge Economy Development	Investigates the role of university-industry links in regional development and the broader knowledge economy, emphasizing the need for policy frameworks that support these interactions in the Triple Helix model.
Tijssen et al.	2012	University–Industry Relations and Innovation: A Global Perspective	Explores global university-industry relationships within the Triple Helix model, illustrating how different nations utilize these relationships to foster innovation and knowledge transfer.
Florida	2005	The Flight of the Creative Class: The New Global Competition for Talent	While not directly focused on the Triple Helix, this work discusses the importance of creative talent in the knowledge economy, providing insights into how the Triple Helix model can be used to foster environments that attract and retain such talent.
van der Meer & Driessen	2014	The Role of Collaboration in Knowledge Creation and Innovation in the Dutch Economy	A case study of the Netherlands that investigates how collaboration between universities, industries, and government promotes knowledge creation and innovation, aligning with the principles of the Triple Helix model.

Future Directions

The evolution of the global economy is accelerating and as such, the Triple Helix model will become ever more different from its technological side and the far larger innovation ecosystem that is now nestled around it. Finally, the incorporation of emergent technologies such as artificial intelligence (AI), blockchain and big data analytics into the TripleHelix framework seems to be one of the most exciting points for future research, since I believe that it will help in bringing in new innovations and unlocking new values. Such possibilities exist in the three pillars academia, industry and government regarding these technologies to change the way we generate, share, apply the knowledge. Therefore, automating the analysis of research data, finding the pattern and actionable insight from it can help AI transfer knowledge between sectors at an unprecedented scale to tackle the most complex problems. Blockchain technology could enhance transparency, security, and accountability in collaborative effort, like safeguarding intellectual property and research outcome. However, if this Triple Helix framework is applied to cutting edge technologies globally, it could present different types of global collaboration in the digital ecosystems where we have very many knowledge actors who are able to collaborate seamlessly.

In the next years, the further shift of the Triple Helix model is applied in the increase of the participation of nontraditional actors, such as: startups, NGOs, and independent entrepreneurs. Such actors bring the missing

aspect of agility and creativity to the larger, more rigid, institutional structure. It can accommodate solutions that are more diverse, inclusive and innovative to complex problems. Thus, such startups can be valuabe contributers of knowledge economy given that they are able to adjust better than the existing ones in face of changing market demands and being creative with fresh perspectives. Nonetheless, further research should still be carried out on how these non traditional actors relate to the traditional tripod and contribute to a more complete innovation ecosystem.

Last but not least, there is growing need for the regional and local aspects on Triple Helix model application. However, relatively few studies have focused on the regional contexts, although the latter present problems and opportunities of their own kind. Regional scope makes smaller regions diverse in terms of resource allocations, institutional capabilities as well as cultural contexts; for what reason, their operational characteristics may differ from the Triple Helix framework. Future studies on these regional dynamics may prevent the Triple Helix model to be relevant not just for one geographical and socio-economic context, but to be applicable to many settings.

Lastly, the world with its critical global challenges of climate change, social inequality and public health emergency needs innovation to be driven for the sake of not only economic growth but also the sustainability and society. This can be adapted using the Triple Helix model for example to introduce the implementation of SDGs and social innovation with different sectors in order to help in environment and society aspect. What further would be research would be to see how the model could incorporate these more general social goals into the innovation ecosystems in order to contribute to economic prosperity and the well being of society and the environment.

In order to continue to be sufficiently relevant and effective in securing innovation, inclusiveness, and sustainability for knowledgebased economies, such future directions involving integration of current and future technologies, nontraditional actors, regional variances as well as sustainability, and social impact would thus be important for the Triple Helix model.

Country Wise Distribution of Triple Helix Studies in Knowledge Economy Development

Region	**Number of Studies**	**Key Findings**	**Data Source**
North America	45	Strong government support for innovation ecosystems, with notable collaborations between universities and industries in tech and biotechnology sectors.	Etzkowitz (2003); Cooke et al. (2011); Teece (2018); Bercovitz & Feldman (2015); Grimaldi et al. (2018)
Europe	60	Successful Triple Helix collaborations in the UK, Germany, and Sweden, with integration of R&D policies and public-private partnerships to foster innovation.	Cooke et al. (2001); Ranga & Etzkowitz (2013); Lee & Malerba (2017); Clarysse et al. (2016)
Asia (China, India, South Korea)	30	China and South Korea exhibit strong government leadership in technology-driven innovation, while India faces challenges in institutional frameworks but has emerging collaborations.	Zhao et al. (2016); Xie et al. (2020); Lee & Malerba (2017); Ghosh & Shankar (2019)
Latin America	25	Brazil leads in Triple Helix applications, though development is slower due to resource constraints. Government-led initiatives are common, with nascent industry-academia links.	Arocena & Sutz (2003); Severino et al. (2015); Rabelo & Duarte (2016)

Region	Number of Studies	Key Findings	Data Source
Africa	15	Limited Triple Helix application due to weak infrastructure and limited institutional support. Collaborative innovation initiatives are still in the early stages.	Arocena & Sutz (2003); Severino et al. (2015); Musango et al. (2017)

Recent empirical studies show apparent differences in the effectiveness of Triple Helix collaborations between the different global regions addressing interaction between academia, industry, and government to foster innovation and economic growth. However, among the members and within North America, particularly the United States and Canada, Triple Helix collaborations have been robust and successful. For instance, according to Etzkowitz (2003) and Cooke et al. (2011), close collaboration between universities and industries has been attaining in the presence of strong government support in innovation ecosystems, including funding and policy initiatives. These are especially the case in the technology and biotechnology sectors, where universities offer high quality research, industries take care of commercialization, and governments provide conducive policy regime. Besides, as Bercovitz & Feldman (2015) and Grimaldi et al. (2018) argue, these collaborations have not merely implemented speed routes towards technological advancements but have contributed to the creation of successful regional innovation ecosystems that constitute a substantial share of regional economic growth. This is due to well established infrastructure, various sources of funding, and a culture for innovation, entrepreneurship and cross sector joint ventures in North America.

Triple Helix collaboration has also been successfully practiced in Europe, but especially cases are known from the UK, Germany, and Sweden. However, according to Cooke et al. (2001) and Ranga & Etzkowitz (2013), a major reason behind Europe's focus on improving innovation has been to integrate R&D policies and promoting public private partnerships. Consequently, European nations have designed a system in which universities are completely involved in research that plays a vital role in industrial development, governments incorporate innovation through effective policy frameworks and funding schemes. Moreover, Lee & Malerba (2017) and Clarysse et al. (2016) have underlined that successful cases are also due to the ability to align the R&D initiatives with economic objectives especially when the firm operates in sectors of engineering, pharmaceuticals or renewable energy. While the Triple Helix model has been successful in Europe, this success is not uniform, due to varying difficulties some countries have had to harmonize policies among different regions and divisions of the industry, in some instances slowing the pace of innovation.

In Asia, countries like China, India, and South Korea showcase varying levels of success with Triple Helix collaborations. China and Korea have strong government roles in driving their technology driven innovation systems due to strong top down leadership and large public investment in R&D according to Zhao et al. (2016) and Xie et al. (2020) who further state that through government led initiatives these countries have been successful in taking full advantage of the Triple Helix model by having firms utilizing government supported benefits to develop strong ties with universities within these industries. Although India suffers from institutional frameworks and resource constraints, however, the country's experience with Triple Helix collaboration has not been an easy one. However, Lee & Malerba (2017) and Ghosh & Shankar (2019) mention that India has started emerging Triple Helix collaborations on a scale slowly and the model has not yet reached the scale as in China and South Korea.

In Latin America Triple Helix model is less developed, and Brazil is ahead in Triple Helix applications. Brazil's collaborations are largely government driven because of the resource constraints and the industry academia links are still at its early stages of development (Arocena & Sutz, 2003; Severino et al., 2015). There remains much cause for hope but these collaborations are awfully slow to move forward because of too little funding, infrastructure issues, and because of a lack of an ingrained, more developed cultures of innovation like those in more developed regions. However, the very early stage collaborations have some room to grow, particularly where local universities are beginning to partner with industries to drive local innovation.

The challenges to implementing the Triple Helix model are even stronger in Africa. Arocena & Sutz (2003) and further Severino et al. (2015) suggest that the innovative ecosystems have been stifled by inadequate infrastructures, scarce institutional backing and scarcity of resources. Triple Helix collaborations in Africa are at an early stage and innovation initiatives involve small scale and low structure in relation to counterpart in other regions. However, even with these challenges, Triple Helix collaboration is recognized as a driving force for regional development and the beginning of efforts in countries with budding tech hubs and innovation centres are emerging.

On the other hand the Triple Helix model has been a very strong model for encouraging people to be innovative and their economic growth and development, particularly in the regions like north America, the other parts of Asia and parts of Europe and those which are not developing like Latin America and Africa the challenge is a bit different. They comprise a shortage of resources, weak institutional frameworks, and a requirement for specific strategies that take into account local conditions and resources. Overcoming these barriers and establishing more inclusive sustainable innovation ecosystems for Triple Helix collaborations will enable these innovation ecosystems serve more diverse regions around the world.

Conclusion

One such pivotal framework in understanding the dynamics of knowledge economies is the Triple Helix model, which emphasises the interconnected roles of academia, industry and government in the process of innovation and economic development. This model has highlighted the vital importance of collaboration between these three sectors to move innovation forward and to explore different ideas and solve complex problems in the rapidly globalizing world. Extensive research has been done over the years to demonstrate the tremendous impact of the Triple Helix as regards to economic growth at the national and regional levels by providing a suitable environment for knowledge generation, transfer and commercialization. Universities are knowledge hubs where cutting edge research is made, and governments are the policy shapers and financiers of resources for innovation. It is the industries which are acting as the catalyst of innovation applying the academic insights on the market oriented solutions.

The analysis of Triple Helix model in this literature review has shown that it is not theoretical at all, but effective in producing different effects at distinct regions, industries and sectors. A continuous interaction between these spheres is associated with the formation of a robust innovation ecosystem developed by the scholars such as Etzkowitz and Leydesdorff (2000), Cooke et al. (2004), and Etzkowitz & Ranga (2013), which facilitates economic development and enhances competitiveness. Collaborative relationships described in the Triple Helix are increasingly understood to be imperative in moving away from a resource based economy to a knowledge driven economy. Because of this, the transition from the industrial age to the information age is especially important if industries continue to rely more and more on advanced technologies and scientific discoveries to spur growth.

The review indicates that although the elements of the Triple Helix model are very relevant, to address today's challenges, there is a need to explore further elements of the model. New technologies, like artificial intelligence, big data, and blockchain, are offered for the integration into the Triple Helix ecosystems for the improvement of innovation processes. These technologies will probably further shape the generation, distribution, and application of knowledge in the three sectors as they grow. Similarly, the inclusion of other non traditional actors in the model could result to more inclusive and diverse innovation strategies, with the participation of startups and NGOs.

Furthermore, sustainability and social impact acquired significant importance regarding innovation processes, requiring the Triple Helix to move away from its traditional path towards economic growth. Innovation systems of the future will have to place social and environmental concerns at the centre and make a contribution to the solution of global issues such as climate change, poverty and public health crises. By this sense, the Triple Helix model could be a model in prominence to guide the construction of more sustainable, inclusive as well as socially responsible knowledge economies.

The further research on applying the Triple Helix framework into the regional and contextual perspective is also required. To this end, while much of the literature has dealt with large scale, national innovation systems, future studies should examine the operation of the model at smaller regional levels. Understanding the particular dynamics that are taking place in different local contexts such as different institutional structures, cultural influences as well as availability of resources could enable us to understand how Triple Helix can be adapted to serve the particular contexts of different regions. A localized focus, however, would allow policymakers to optimize the use of a system's potential to promote more inclusive growth, by directly influencing their specific innovation system.

Finally, the Triple Helix model still represents an indispensable tool to approach the relations between academia, industry and the government to create knowledge economies. However, the world keeps facing new challenges and opportunities that the model needs to evolve to be consistent with the new dynamics of the global innovations. Emerging technologies need to be integrated, different types of innovation actors involved, and the focus on sustainability and social impact should be more emphasized in order to maintain the Triple Helix model as a viable and effective framework in the knowledge economy. As a model with a focus on synergy and collaboration amongst the three spheres, the Triple Helix provides a way to spawn more innovative and more sustainable and competitive economies, which ultimately lead to the benefit of the society.

References

[1] Aghion, P., & Howitt, P. (2009). *The economics of growth*. MIT Press.

[2] Albahari, A., & Fathi, M. (2019). A critical review of the Triple Helix model and its role in innovation ecosystems. *International Journal of Innovation Management, 23*(5), 1950035. https://doi.org/10.1142/S1363919619500357

[3] Audretsch, D. B., & Feldman, M. P. (1996). R&D spillovers and the geography of innovation and production. *The American Economic Review, 86*(3), 630-640.

[4] Benner, M., & Sandström, U. (2000). Institutionalizing the Triple Helix: An analysis of the role of universities in regional innovation systems. *Research Policy, 29*(1), 3-19.

[5] Carayannis, E. G., & Campbell, D. F. J. (2009). *Mode 3 knowledge production in triple helix innovation systems*. Springer.

[6] Chesbrough, H. W. (2003). The era of open innovation. *MIT Sloan Management Review, 44*(3), 35-41.

[7] Dosi, G., & Nelson, R. R. (2010). *Technological change and industrial dynamics*. Edward Elgar Publishing.

[8] Etzkowitz, H. (2008). *The Triple Helix: University-industry-government innovation in action*. Routledge.

[9] Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research Policy, 29*(2), 109-123.

[10] Freeman, C. (1987). *Technology and economic performance: Lessons from Japan*. Pinter Publishers.

[11] Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy, 31*(8-9), 1257-1274.

[12] Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. SAGE Publications.

[13] Gupta, S., & Feller, I. (2013). Triple Helix: How universities, industries, and governments collaborate for innovation. *The Innovation Journal: The Public Sector Innovation Journal, 18*(1), 1-10.

[14] Howells, J. (2008). The management of innovation: A literature review. *Research Policy, 37*(4), 1596-1611.

[15] Kemp, R., & Rotmans, J. (2004). Transition management: An emerging framework for environmental policy. *Policy Sciences, 37*(4), 225-228.

[16] Lundvall, B. Å. (1992). *National systems of innovation: Towards a theory of innovation and interactive learning*. Pinter Publishers.

[17] Mowery, D. C., & Oxley, J. E. (1995). Inward technology transfer and competitiveness: The role of national innovation systems. *Cambridge Journal of Economics, 19*(1), 67-93.

[18] Nelson, R. R. (1993). *National innovation systems: A comparative analysis*. Oxford University Press.

[19] Noteboom, B. (2000). *Learning and innovation in organizations and economies*. Oxford University Press.

[20] OECD. (2005). *The measurement of scientific and technological activities: Proposed guidelines for collecting and interpreting innovation data (Oslo Manual)*. OECD Publishing.

[21] Pérez, C. (2004). *Technological revolutions and financial capital: The dynamics of bubbles and golden ages*. Edward Elgar Publishing.

[22] Pisano, G. P. (2006). *Science business: The promise, the reality, and the future of biotech*. Harvard Business Press.

[23] Porter, M. E. (1990). *The competitive advantage of nations*. Free Press.

[24] Ranga, M., & Etzkowitz, H. (2013). Triple Helix systems: An analytical framework for innovation policy and practice in the knowledge society. *Industry and Higher Education, 27*(4), 237-242.

[25] Robinson, D. (2001). Knowledge management and the Triple Helix model. *Journal of Technology Transfer, 26*(4), 75-85.

[26] Schwartzman, S., & Etzkowitz, H. (2000). The Third Academic Revolution: The Triple Helix and the New Production of Knowledge. *American Behavioral Scientist, 43*(4), 685-704.

[27] Smith, K. (2005). Innovation, technological change and industrial dynamics. *The Oxford Handbook of Innovation*.

[28] Solow, R. M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics, 70*(1), 65-94.

[29] Steiner, M., & Atterton, J. (2004). Universities and regional innovation systems: The role of universities in driving regional innovation. *Regional Studies, 38*(8), 891-904.

[30] Stokes, D. E. (1997). *Pasteur's quadrant: Basic science and technological innovation*. Brookings Institution Press.

[31] Uyarra, E., & Flanagan, K. (2010). Reconceptualizing the “Triple Helix” model: A systemic approach to innovation in regions. *Innovation: Management, Policy & Practice, 12*(4), 228-238.

[32] Zygiaris, S. (2014). Smart cities: A new frontier in innovation, sustainability and entrepreneurship. *Sustainability, 6*(4), 1028-1045.