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Development of National Knowledge Systems to Support the Knowledge Economy Development in Low and Middle-Income Countries

A literature review

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Contents

Executive summary

This study reviews the current literature on national innovation system across Low and Middle Income Countries (LMICs) with a focus on sub Saharan Africa. The review primarily considers the application of the Triple Helix as an explanatory model, as well as to which extent do the three actors –university, industry and government - collaborate in supporting knowledge creation and use in these countries. By explicitly defining the core actors and their interdependent relationship in an innovation system, Triple Helix enables researchers to adopt different methods to measure the extent to which the knowledge flows and through which channel knowledge creation is realised. This literature review covers studies of Triple Helix innovation system in LMICs, primarily focusing on the country or regional level Triple Helix model after the year of 2000. In total, it includes: 1) 19 studies on Triple Helix model; 2) 16 studies touched at least one component (or relationship) among university, industry and government in LMICs; and 3) 1 study on National Research System.

- *Theory*: Although the theory of Triple Helix model has been widely acknowledged in development countries, the nonlinear characteristic and dynamic nature of the Triple Helix give rise to several unanswered questions to LMICs. Comparing to developed economies, research on LMICs innovation systems, especially in sub-Sahara Africa, has lagged behind despite this concept has increasingly drawn attention from development researchers and policy makers. Implications and findings drawn from developed countries become questionable when applying onto the LMICs context because of different local conditions, changing internal and external environment and levels of development.
- *Empirical evidence and methodologies*: the current research remains descriptive and mainly focuses on the existing national/regional innovation system. Both scale and scope in the context LMICs are limited. It is necessary to find out whether these factors are applicable to low-income economies. More attention should be placed on the enablers and barriers such as funding, infrastructure and the absorptive capacity of the system.
- *Application of Triple Helix in LMICs*: In all, the application of Triple Helix model in LMICs is limited. It is still vague on the policy level how 'knowledge economy' can be achieved via applying a Triple Helix model in LMICs. Comprehensive evaluations on Triple Helix application in LMICs are to be explored in future studies.

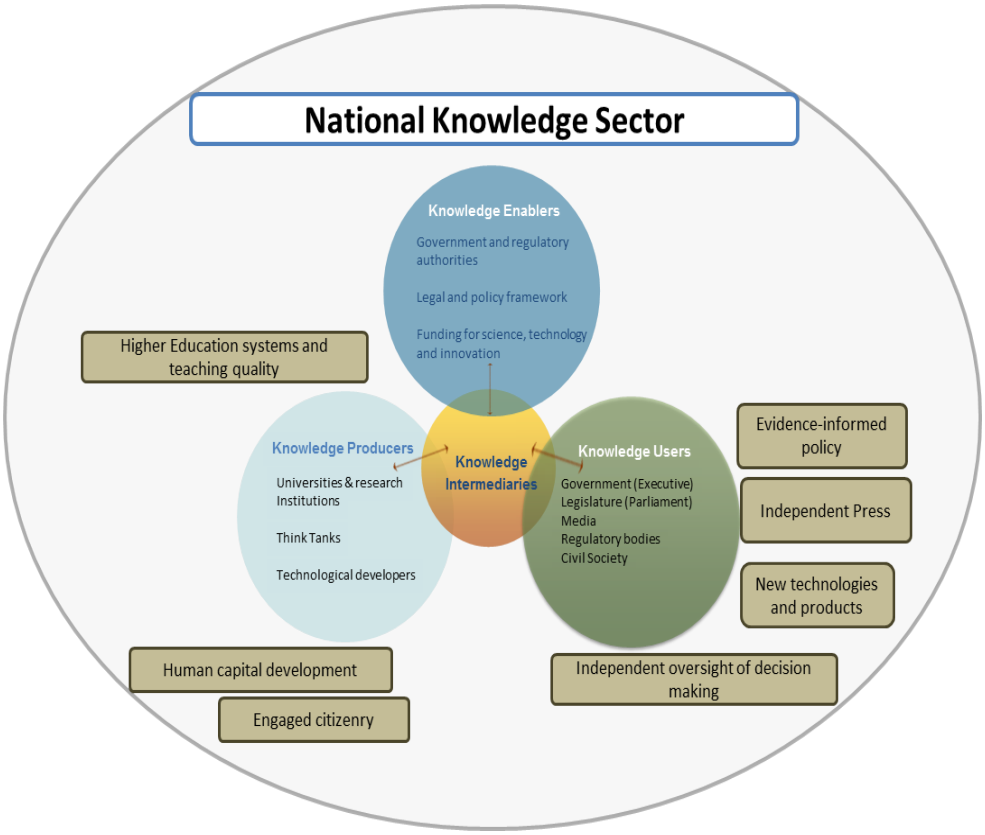
Abbreviations

CEE	Central and Eastern European
GERD	Gross domestic expenditure on Research and Development
GDP	Gross Domestic Product
IP	Intellectual Property
LMICs	Low and Middle Income Countries
NIS	National Innovation System
NRS	National Research System
OECD	the Organisation for Economic Co-operation and Development
R&D	Research and Development
SMEs	Small and Medium Enterprises
S&T	Science and Technology

1 Background

At a national level, a strong academic and research sector underpins evidence based policies, innovation and new technologies, informed debate, and more highly skilled and educated populations. Although there is widespread recognition of the need to invest in science, technology and innovation capability in low and middle-income countries, and strengthening the knowledge economy, there is limited evidence on how this can best be achieved.

National Knowledge Sector diagram



Evidence at national level on the knowledge economy and knowledge system comes largely from the innovation literature. Here the 'National Innovation System (NIS)' framework (Figure above) can help to analyse national knowledge systems. This system is made up of knowledge producers, enablers, intermediaries and users. Knowledge producers include universities and other research institutions, think-tanks, technological developers, national statistics and data agencies. Knowledge enablers include government and regulatory authorities, appropriate legal and policy frameworks, and strong systems to fund research, technology and innovation. Knowledge users include different government departments, legislators, industry and the private sector, the media, regulatory bodies, and civil society. There are also knowledge brokers; institutions and initiatives which work at the interface and promote interactions between of each of these different 'constituencies' of the system. The underlying assumption is that knowledge systems drive human capital development and ultimately economic growth. They do this through the production of high quality higher education; research, innovation and new technologies; and effective evidence based policies. The idea of integrating

innovation into production at the national level has the advantage of providing the analyst with institutionally demarcated system organized equilibrium (Lundvall, 1988, 1992). Instead of the conventional agent-based economic profit maximization, the NIS models consider the interactions between market dynamics and transaction costs as a different micro-economic foundation of theorizing (Lundvall, 1992).

Several concepts emerged to explain the concept of NIS, including Triple Helix (Etzkowitz and Leydesdorff, 1995), Quad Helix and Quintuple Helix models (Leydesdorff and Sun, 2009; Carayannis and Campbell, 2010). This paper reviews the current literature on national innovation system across low – and lower middle- income countries (LMICs). Comparing to other system innovation models, i.e. Quadruple Helix or Quintuple Helix, the Triple Helix places specific emphasis on knowledge production and innovation in supporting the establishment of knowledge economy. It also acknowledges explicitly the critical role of higher education for innovation, as well as highlights the role of governments to steer technological development. By defining the three specific components, Triple Helix model is traceable and measurable. This review primarily considers the application of Triple Helix model, as well as to which extent do the three actors –university, industry and government - collaborate in supporting knowledge creation and use in these countries. It allows the investigation of questions of technological determinism such as 'to what extent do various agents and mechanisms control the on-going developments?'

The concept of 'knowledge economy' is increasingly pervasive in sub-Saharan Africa, where knowledge intensification is recognised as critical to address development challenges. However, there is evidence to suggest that approaches and policies appropriate to advanced high income economies are adopted in an imitative manner, without necessarily understanding the specificities of the very different contexts of low and middle-income countries. Compared to developed economies, research on LMICs innovation systems has lagged behind despite this concept has increasingly drawn attention from development researchers and policy makers (Lall and Pietrobelli, 2005; Giuliani and Bell, 2005; Lundvall et al 2006). Some attempts have been made but consensus has not been reached (Nelson, 1993, Ernst and Lundvall, 1997; Gu, 1999; Cassiolato et al., 2003; Lall and Pietrobelli, 2005). It is suggested that technological and institutional properties in developing countries are generally inadequate to provide strong driving forces to modern growth. To understand these forces NIS should be developed and studied with taking into account local conditions, changing internal and external environment and levels of development (Lall and Pietrobelli, 2005; Pietrobelli and Rabellotti, 2011; Eduardo et al, 2015).

The next section describes the development of national innovation system framework for developing countries. The applications of Triple Helix as an explanatory model in LMICs are elaborated in section 3. Section 4 discusses the potential barriers and enablers within the Triple Helix model, and its extension to NIS more broadly and section 5 briefly introduces the research system and its application in the context of LMICs. The last section summarises the evidence gaps.

2 National Innovation System Framework for developing countries

Following a comprehensive introduction of innovation system framework (Lundvall, 1988), this approach was soon proliferated among studies analysing countries' innovation motives, behaviours, and the institutions that shape these (Freeman, 1987; OECD, 1997, 2001; Lundvall et al., 2002). The innovation system literature was further enriched in several theoretical discussions (Dosi et al., 1988; Lundvall, 1988, 1992; Freeman, 1987, 1995; Nelson, 1988, 1993; Kim, 1997; Edquist, 1997) Its empirical application focuses primarily on national-level industrial policy in countries that were experiencing rapid industrialization during the 1980s such as East Asian countries, Japan and South Korea. Since the 1990s, new analytical dimensions have been added to innovation system concept, including different spatial levels (Saxenian, 1994; Braczyk, Cooke, and Heidenreich, 1998; Fritsch, 2004), different sectoral structures (Breschi and Malerba, 1997; Malerba, 2002; Adeoti and Olubamiwa, 2009 and Malerba and Nelson, 2012), different time periods (Anderson and Teubal, 1999; Andersen, 2000, 2004), and different technology backgrounds (Carlsson and Jacobsson, 1993; Carlsson, 1995, 1997).

Several concepts have emerged following the development of the innovation system framework, including Triple Helix (Etzkowitz and Leydesdorff, 1995), Quad Helix and Quintuple Helix models (Leydesdorff and Sun, 2009; Carayannis and Campbell, 2010). The notion of Triple Helix was formally proposed and defined by Etzkowitz and Leydesdorff (1995) and acknowledged as one of the key framework to support the development of national innovation system (Etzkowitz and Leydesdorff, 1999; Godin and Gingras, 2000). According to Etzkowitz and Leydesdorff (1999), the Triple Helix model is a "*Spiral model of innovation, which is able to capture multiple reciprocal linkages at different stages of the capitalization of knowledge*". By explicitly defining the core actors and their interdependent relationship in an innovation system, Triple Helix enables researchers to adopt different methods to measure the extent to which the knowledge flows and through which channel knowledge creation is realised, for instance, input-output analysis, citation or patent analysis, social network approach (Olmeda-Gomez and Perianes-Rodriguez, 2013; Mêgnigbêto, 2013). The Triple Helix innovation model focuses on the interdependent relationship between university, industry and government while the Quadruple Helix model embeds the Triple Helix by incorporating a fourth helix the 'Media-based and culture-based public' and 'Civil society' (Leydesdorff and Sun, 2009; Carayannis and Campbell, 2010; Kimatu, 2016). The Quintuple Helix model is further broadened by contextualizing the Quadruple Helix by addressing the perspective of the 'Natural environments of society' (Carayannis and Campbell, 2010, Carayannis et. al, 2012).

The Triple Helix model has three sub-dynamics: the economic dynamics of the market, the political dynamics of control, and the socio-cognitive dynamics in the production of organized knowledge. Whitley (1984), for example, specified organized knowledge production and control systems as disciplinary combinations of the latter two dynamics in a knowledge infrastructure. Schumpeter (1939,1942) specified the combination of knowledge production and market dynamics as creative destruction, which provides the basis for changes in technological trajectories. The relations between political and economic dynamics have been the focus of theorizing about political economies in both Marxist and non-Marxist traditions. When the model allows for interaction among the three sub-dynamics of the system – with one of these sub-dynamics considered as an exogenous variable conditioning the coevolution between the other two – a triple helix model with three way interactions can be hypothesized. The new model (based on a neo-evolutionary interpretation of the Triple Helix in terms of

interacting functions) enables us not only to envisage trajectory changes in the downswing phases of the economy, that is, at the end of cycles, but also the induction of regime changes in the technological environment, giving rise to the development of innovative products and processes of strategic significance, as in the case of renewable energy systems.

It is widely acknowledged that the nature of technological needs and efforts vary across country context, i.e. developed and developing countries (Lall and Pietrobelli, 2005). The specification of the nation as a well-defined system of reference enables evolutionary economist to study at the macro level, for example, the so-called "*differential productivity growth puzzle*" which is generated by the different speeds of development among the various industrial sectors (Nelson and Winter, 1975). The problem of the relative rates of innovation cannot be defined properly without the specification of a system of reference that integrates different sectors of an economy (Nelson, 1982, 1994). The solutions to this puzzle of differentiation can accordingly be expected to differ among nation-states (Lundvall, 1992; Nelson, 1993). Meanwhile, innovation in developing countries is characterised as a learning and adoption process (Lall and Pietrobelli, 2002, 2003; Fu et al., 2016). Rather than achieving radical invention through in-house research and development (R&D), their mission is to tap into the existing knowledge, skills and advanced know-how, relying primarily on external sources for example, technology imports. Although there might be similar elements that affect their ability to access, assimilate and translate external knowledge sources into local use (Freeman, 1995), these elements are also likely to vary across different country contexts. Difference between these elements in innovation system is vital to explaining the persistent disparity in innovation performance between successful industrialising economies and the less-developed economies (Freeman, 1995; Adeoti, 2002; Lall and Pietrobelli, 2005). Hence, the analysis of the innovation system in developing countries has to take an approach that takes into account their less developed markets and supporting institutions, less developed information networks, less stable macroeconomic environment, and developing financial systems.

In sub-Saharan Africa specifically, the scientific, technological and interactive capabilities of universities and firms differ vastly, and the context of human development, poverty and equitable distribution needs to be taken into account. The development of NIS models in LMICs need to build upon the existing conceptual frameworks and, at the same time, take into account global changes in knowledge generation, diffusion and adaptation in relation to the specificities of African contexts. There is growing debate about the application of the innovation system approach, with attempts to refine frameworks in order to inform policy (Cassiolato et al., 2003; Farley et al., 2007; Lundvall et al., 2009). As yet, the role of universities in innovation and the capacity of government in steering the technology development are not well informed at the policy level (Myamila and Diyamett, 2006; Etkowitz and Dzisah, 2007; Mwantimwa, 2008). In general, there has been little systematic research on the conditions of universities, firms and their potential for interaction across a national system of innovation in the countries of sub-Saharan Africa (Muchie et al., 2003; World Bank, 2008).

It is worth noting that the development of technological capability in developing countries is neither automatic nor costless (Adeoti, 2002 Lall and Pietrobelli, 2005; Lundvall et al. 2007). Even countries that purchase or acquire knowledge externally are required to undertake costly and risky effort to assimilate and transfer into local use (Cohen and Levvinthal, 1990). Appropriate systems for developing countries should be designed to neutralise the market and institutional weakness, as well as establish an enabling environment for knowledge learning and creation. Development policy should also be adopted as an effective tool to address the features of technology systems and remove constraints during the course of learning and catching up.

3 Triple Helix explanation of the NIS at country level: evidence from LMICs

Transforming to a knowledge-based economy, the interactions between university, industry and government of the Triple Helix system become the major source of innovation and development (Mueller, 2006; Etzkowitz and Dzisa, 2007; Krauss et al, 2012). A Triple Helix system framework is acknowledged as a basic foundation and requisite of national innovation system for the development of knowledge-based economy. In Triple Helix system, three main actors - university, industry and government – are interdependent and interacting with each other. To obtain a general picture on how Triple Helix has been implemented and adopted in developing country context, this section reviews and summarises researches in relation to this subject. Studies[1] included in our review of Triple Helix innovation system in LMICs primarily focus on the country or regional level Triple Helix model, covering published articles, research working papers, as well as conference proceeding after the year of 2000. In total, 19 studies in LMICs are selected. [2]

Figure 2: **Triple Helix studies in LMICs: by income levels**

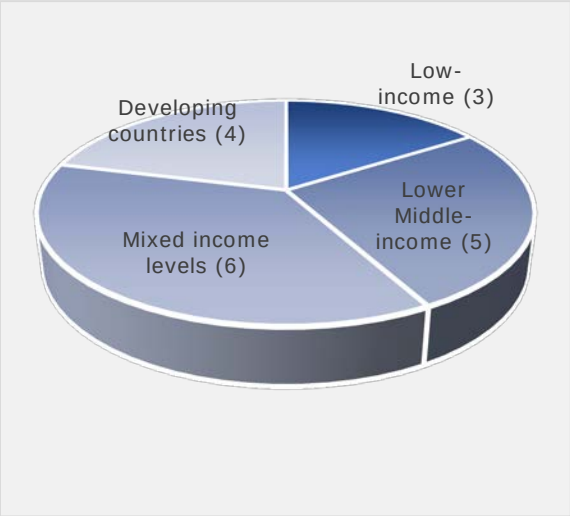


Figure 1: **Triple Helix studies in LMICs: by levels and regions**

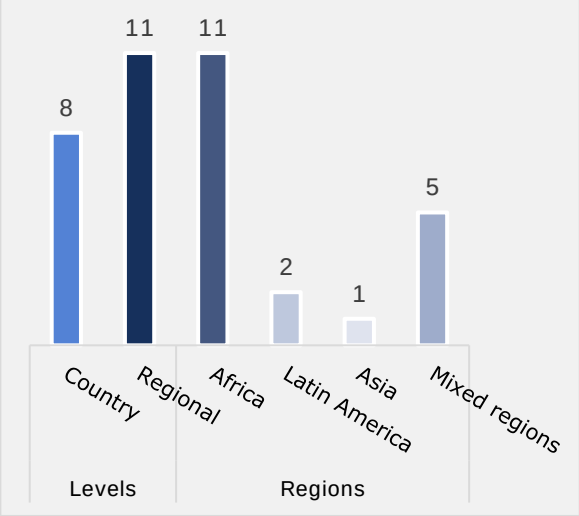


Figure 1 above displays the application of Triple Helix model in LMICs according to countries' income levels, levels of analysis and focusing regions. Of studies that concern the Triple Helix model in LMICs, majority (11 out of 19) focuses on developing countries as a whole without distinguishing its application in low- or lower middle-income countries. For example, Razak and White (2015) examined the Triple Helix institution in developing countries and suggested that the three core sectors - university, industry and government - are non-mutual exclusive and interdependent in the system. De Mello and Etzkowitz (2008) revealed the interactions between academia, industry and policies in Latin American countries and highlighted the central role of university in connecting other core sectors, as well as with local partners.

[1] This literature survey tries to include studies that address Triple Helix model in LMICs. However, the list is certainly not exhaustive.

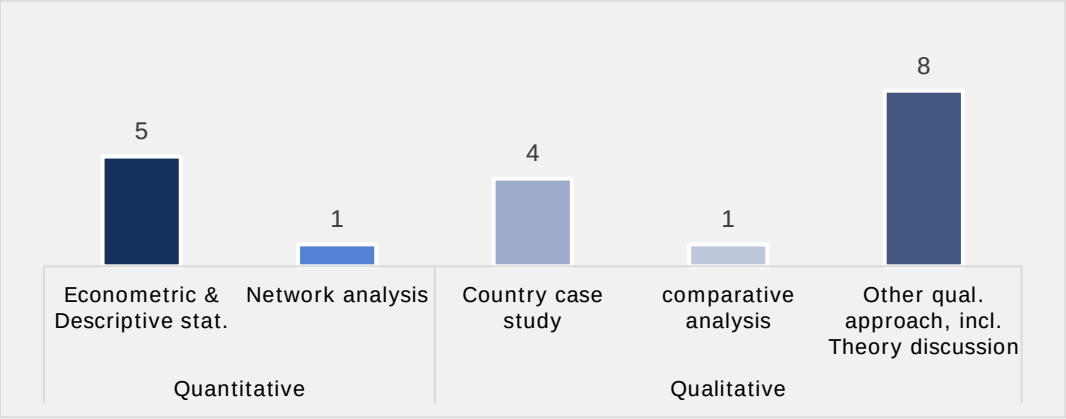
[2] The literature table in appendix A also includes 3 studies in upper middle-income countries. Therefore, in total 22 articles are listed under 'Tripe Helix' section of the literature table.

Although both studies discussed the nature and properties of innovation in developing countries, variations within the group were not addressed.

Clearly, there has been limited applications of Triple Helix innovation system in low-income countries. Only three studies are of this category, two on Ethiopia (Amha and Mekuriaw, 2008; Kitaw, 2008) and one on Tanzania (Mwamila and Temu, 2008). Amha and Mekuriaw (2008) examined the S&T policies in Ethiopia by investigating interactions of various stakeholders in the country's innovation system, including research institutes, small and medium enterprises (SMEs) and policy makers. Kruss et al. (2012) investigates the interactions between universities and industry in three African countries (Nigeria, South Africa and Uganda) and highlights the country specific factors that determined the outcomes of the interactions. Focusing on the same country (Ethiopia), Kitaw (2008) adopted the Triple Helix approach to show the weak coordination between actors in the current innovation system and proposed the establishment of higher education institutions – industry resources integrations centre to solve challenges facing industries. Similar evidence was uncovered in the Tanzania case (Mwamila and Temu, 2008), which highlighted the absent of potential synergic interaction of academia, government and industry. Alternative models have also been developed and applied, mainly focusing on part of the NIS such as the relation between higher education and industry in fostering innovation (Myamila and Diyamett, 2006; Kitaw, 2008; Mouton and Roland; 2009; Kruss et al., 2012). The application of Quadruple Helix and Quintuple Helix has rarely extended to the LMICs context.

Regarding the level of the analysis (Figure 2), 8 analyses are at country level examining the Triple Helix model in Ghana, Indonesia, Ethiopia, Cameroon, Tanzania and Zambia whereas 11 studies carry out at the regional levels including Africa, West Africa, or Latin American. As the least industrialised continent, Africa has drawn a great attention from researchers. Eleven studies in our review are mainly framed in the African context. 5 studies include mixed group of countries across income levels in which Africa elements are also present. Only three articles are addressing the Triple Helix model in non-African countries, including two in Latin America (Sutz, 2000; De Mello and Etzkowitz, 2008) and one in Asia, Indonesia (Irawati, 2010).

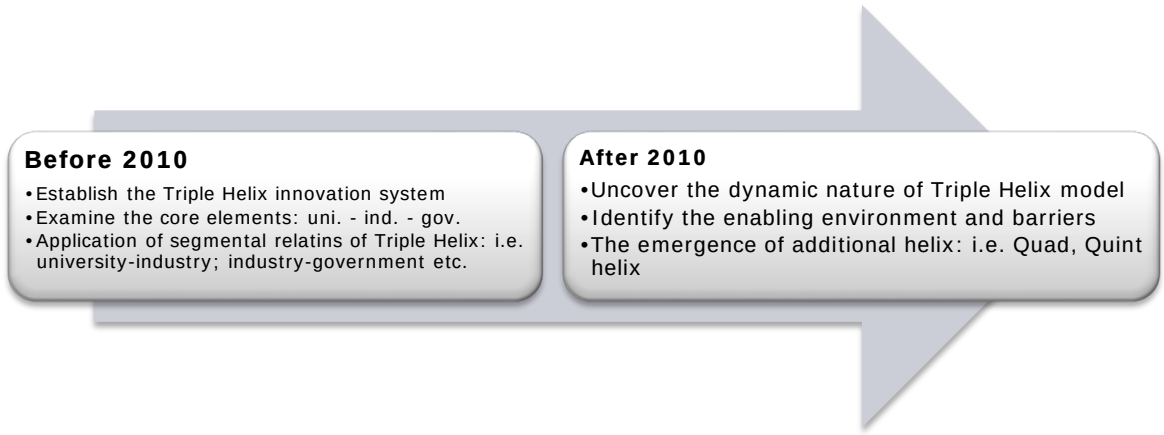
Figure 3: **Triple Helix studies in LMICs: by research methodologies**



Literature on the empirical application of Triple Helix indicators remains thin. The existing applications mainly apply the bibliographic records (Mêgnigbêto, 2013), mutual information approach (Leydesdorff, 2003) in a three or four-dimensional system (Leydesdorff, 2003; Leydesdorff and Sun 2009; Leydesdorff and Ivanova, 2014; Khan and park, 2011; Ye et al., 2013), social network analysis (Khan and Park, 2011). Figure 3 summarises studies on the Triple Helix model in LMICs according to the research methodologies. As the bar graph shows, the current research emphasizing on interrelationship between university, industry and

government is dominated by qualitative approaches. 13 papers employed either country case study or other types of qualitative discussion, while only 5 studies adopt quantitative analyses such as statistical, econometrical or network modelling. One study has used bibliometric data to investigate the relationship between actors in the Triple Helix system in LMICs (Mêgnigbêto, 2013, 2015). Mêgnigbêto (2013) tries to identify the collaboration network between university, industry, and government in West Africa by studying scientific publications and their correlation with on economic development. The author applied the same bibliometric approach to compare the Triple Helix institutions between South Korea and West Africa (Mêgnigbêto, 2015). Findings of both studies suggest that international collaborations are effective ways to promote knowledge sharing between actors in the national innovation system for both South Korea and West Africa, but to a different extent.

Figure 4: **The shift of research focuses on Triple Helix model in LMICs**



Another clear pattern exhibited in the literature of Triple Helix in LMICs is the shift of the research focuses from 'establishing Triple Helix innovation system and examining its core elements' (before 2010) to 'identifying the dynamic nature of triple helix and its enabling environment' (after 2010). In response to this change, policies and interventions drawn from the previous research have also evolved: from emphasizing on strengthening collaborative relationships between university, industry and government (Sutz, 2000; Konde, 2004; Saad et al., 2005; Dzisah and Etzkowitz, 2008; Kitaw, 2008) to maximizing enablers and minimizing barriers (Irawati, 2010; Dzisah, 2010; Razak and White, 2015). The scope of the explanatory model framework has also evolved from segmental to including additional spheres (Quadruple and Quintuple Helix). At the early development stage of Triple Helix, many studies have tried to explore the university – industrial spinoffs (Kitaw, 2008; Mouton and Roland; 2009). The additional spheres, such as the 'Civil society' and 'Natural environments of society', are addressed with the emergence of Quad and Quint Helix models (Carayannis et al., 2012).

Most of the studies in our survey have either explicitly or implicitly address all three core actors – university, industry and government. Two recent research studies carried out by Mêgnigbêto (2013, 2015) have adopted quantitative knowledge output measures, i.e. co-authorships - to identify the presence or strength of linkages between university, industry and government. The author examined the publications from each actor as well as the co-authored outputs among them across west Africa countries. Findings revealed that linkage between government and university was present in Ghana while Triple Helix spheres was found in Nigeria.

4 The main enablers and barriers facing Triple Helix

The Triple Helix model advocates the utilization of synergies between university, industry and government to achieve innovation and economic growth. The potential barriers (or policy enablers) to support the implementation of the system remain underinvestigated, despite the increasing attention in recent research.

Several studies (Sebuwufu et al., 2012; Rivera, 2010; Irawati, 2010; Ranga and Etzkowitz, 2010; Amha and Mekuriaw, 2008) have discussed the enabling environment and potential challenges facing Triple Helix institutions. Among them, 3 studies (Ssebuwufu et al., 2012; Irawati, 2010; Amha and Mekuriaw, 2008) specifically focused on obstacles to the development of Triple Helix model in LMICs. In general, 5 categories of obstacles are identified: relationship, university, policy, finance and institution.

Relationships: relationship obstacles refer to any issues in relation to culture of work between university, industry and government/government agencies, such as 'lack of mutual interactions' and 'weak collaboration agreement'. Policy responses should therefore intend to remove these barriers by produce corresponding enablers such as 'strengthen linkages', 'enhance the leadership of each core actor'. Dzisah (2009) used the Ghana as an example to explain that the lack of mutual interactions between the three core actors have been recognised as the major cause of development programmes[3] failure in LMICs despite of sufficient funding from donors and governments. Analysing the Latin America innovation systems, De Mello and Etzkowitz (2008) identified the vague research interests of the three core actors and the unstable relationship between them as the main explanation for the weak science and technology development in the region. The lack of collaborative arrangements, weak connections with local partners are also highlighted in several studies in developing countries (Ranga and Etzkowitz, 2010; Saad and Zawdie, 2010; Irawati, 2010; Sutz, 2000).

University: university obstacles mainly refer to the weak academic and commercialization capabilities. Majority of university in LMICs are mainly teaching institutions with inadequate research infrastructure and business-orientation. Strengthening the linkages between university and industries should enable them to exploit university entrepreneurial potential and commercialisation skills. Dzisah (2009) pointed out that the slow development of S&T has always been a major barrier of the tertiary education system in Ghana. The limited graduate programs and business cooperative projects have severely limited the development of the entrepreneurial university. Similar findings were revealed in the case of Zambia, (Konde, 2008). The author suggested that an entrepreneurial culture should be integrated throughout the academic institutions. In addition, Ranga and Etzkowitz (2010) pointed out that the low levels of research and commercialisation capabilities across Central and Eastern European (CEE) countries were one of the major obstacles in their national innovation system.

Policy: policy obstacles refer to the right policy solutions to support knowledge integration between actors in the innovation system, the establishment of an environment for commercialisation and knowledge creation mechanisms such as intellectual property (IP) policies. The lack of coordination and coherence in policy development and implementation have also been identified as one of the main reasons to explain the failure to promote innovation (Rivera, 2010). Amha and Mekuriaw (2008) conducted a preliminary review of innovation (incl. S&T) policies in Ethiopia and uncovered a series gaps in the country's national

[3] For example: Ghana Technological plan in 1982; National Development Policy framework: Long-Term Development objectives: Ghana-Vision in in 1995; and National S&T policy document in 2000.

innovation policy, including lack of priority sectors, demand side interventions and social science as an essential components S&T system. Therefore, appropriate emphasis needs to be placed on encouraging government interventions to address these weaknesses. The author also highlights the importance of small and medium-sized enterprises (SMEs) in the national system via policy solutions. In the study on Latin America (Bianco and Viscardi, 2008), the authors suggest that appropriate innovation policies are expected to optimise the allocation of resources and establish enabling environment and institution to support the knowledge economy. Rivera (2010) also argue that the lack of government engagement was the main cause of failure to achieve objectives in Mexico. Policy instrument should be adopted to encourage interactions, coordination and the required structural reforms.

Finance: refers to innovation or technology learning funding sources, financial support for innovation infrastructure, capacity building, skill upgrading etc. Difficulty in securing finance is recognized as one of the most severe internal barriers to innovation. Financial constraints as internal hampering factors to innovation system, in particular to universities and firms, have been dealt with in previous literature. Himmelberg and Petersen (1994) use small firms in the high-tech industries to show a significant positive relationship between internal finance and firms' R&D. Stockdale (2002) reports that financial constraints are the second most important impeding factor for innovation for active firms. Similar results also have been obtained by other studies (e.g. Mulkay, Hall and Mairesse, 2001; Savignac, 2006; Tiwari et al., 2008). With respect to developing countries, Disah (2009) argues that the major deterring factor affecting innovation investment in Ghana is the lack of funding resources. Although a series of funds programmes have been launched by the government to support research activities, the extent has been limited and the implementation hindered by delays in payment (Dzisah, 2009).

Institutions: is understood as the rules, norms and environment that are crucial for the outcome of what innovation actors decide and do in relation to innovation (Lundvall et al., 2006). The potential barriers can may refer to inflexible structures, strict bureaucratic procedure, lack of capabilities, lack of funding and traditional values/philosophy of institutions. The lack of democratic governance and a culture of corruption as people are unwilling to give up power are also cited as important barriers to innovation system in development countries (Dzisah, 2009; Razak and White, 2015). Table 1 summarises the types of barriers and the corresponding enablers in LMICs' Triple Helix system.

Table 1: Summary of barriers and enablers in Triple Helix System

	Barriers	Enablers	Corresponding Practices	Selected literatures*
Relationships	* lack of mutual interaction, * weak collaboration between university, industry and government * low level of knowledge creation in innovation system	* Linkages between actors * Leadership * Resources	* strengthen linkages; * enhance the leadership of each actor; * increasing movement of resources to strengthen interdependencies between actors.	De Mello and Etzkowitz, 2008; Dzisah, 2009; Ranga and Etzkowitz, 2010; Irawati, 2010; Saad and Zawdie, 2010; Razak and White, 2015
University	* Inadequate research infrastructure and missing business-orientation; * low levels of research and commercialisation capability	* Linkages: spinoff * Entrepreneurship * Commercialization of technology	* strengthen linkages between universities and industries * integrated entrepreneurial culture throughout the university * strengthen university's role in technology transfer	De Mello and Etzkowitz, 2008; Ranga and Etzkowitz, 2010; Saad and Zawdie, 2010; Razak and White, 2015

Policy	* lack of coordination and coherence in policy; * lack of government engagement * absence of policy to protect intellectual property	* Prioritize innovation * The role of Government * Complementarity in policies	* appropriate innovation policies; * government's role in encouraging interactions, coordination; * innovation polity to allocate resources, human capital and coordinate regional integration of knowledge generation activities;	Ranga and Etzkowitz, 2010; Irawati, 2010; Bianco and Viscardi, 2008; Rivera, 2010; Saad and Zawdie, 2010
Finance	* difficulty in securing finance; * lack of financial resources; challenges in utilising fund	* Financial source * Public financial support * Private financial support	* diverse research financial sources; * committed finance supports from public and private sectors	De Mello and Etzkowitz, 2008; Dzisah, 2009; Irawati, 2010; Saad and Zawdie, 2010
Institution	* inflexible structure * strict bureaucratic procedure * lack of democratic governance * culture of corruption	* efficient and transparent system	* establish lean and efficient innovation system * reducing procedures for research and development collaboration, funding application and technology transfer procedures	Irawati, 2010; Bianco and Viscardi, 2008; Rivera, 2010; Saad and Zawdie, 2010; Razak and White, 2015

* The selected studies not exhaustive regarding the barriers and obstacles of Triple Helix in LMICs.

In the context of LMICs, several major barriers have been identified in the existing innovation system. Based on these major deterring factors, corresponding strategies or practices are proposed in order to establish an enabling environment for learning, knowledge transfer and innovation. Most of these country case studies have covered all three core actors in the Triple Helix system whereas the five types of obstacles/enablers discussed above have also been fully or partially addressed. Given countries' economic, political and social characteristics, their national innovation systems and policies reflect different priorities. Due to the limited evidence of Triple Helix specifically in LMICs, our review of country cases extends to studies covering national innovation system framework in LMICs. In total, 16 additional studies are added.[4] It is worth noting that these additional studies are added to present the evidence based country-level results under the NIS framework. They were not necessarily referring to Triple Helix model but addressing at least one of the components (or linkages) among university, industry and government. Table 2 is presented on country-basis and include both 19 Triple Helix studies as well as the additional 16 studies to summarize the major barriers, enablers and implementation outcomes of the national innovation system in selected LMICs.[5]

Several common obstacles are identified across all reviewed countries, including weak collaborative research activities, inadequate funding sources, as well as the lack of entrepreneurship components in universities. Different policy solutions are adopted across countries in response to these common barriers. For example, the Ghanaian government has provided several government schemes (i.e. Ghana Education Trust Fund) to support the research activities in universities (Dzisah, 2009) to overcome the financial obstacles whereas Ethiopia has committed to spending 1.5 of the country's GDP in R&D across public and private sectors (Amha and Mekuriaw, 2008). In order to strengthen the research capability of university and industries, some countries choose to invest in research infrastructure

[4] For the detailed list of literature summary, please see the literature table in appendix A.

[5] Results of table 2 are consistent with the findings revealed in Table 1. The difference is that Table 1 is exclusively to address the enablers and barriers in Triple Helix literature. It was based on the 19 studies review in the previous section and focusing on the three main actors in Triple Helix, both empirical and theoretical studies. It is of a general summary of enablers/barriers in response to the development Triple Helix development.

(Ethiopia), some focus on the development of SMEs (Tanzania, Indonesia), others may emphasis on the role of education (Zambia, Ghana).

Turning to the outcomes of Triple Helix application, results vary across countries. The successful implementation of formulated policies or programmes is inhibited by several factors in Ghana (Gzisah, 2009), including delaying payment of committed government funds, lack of democratic government and corruption. Meanwhile, Government of Ethiopia commitment to invest 1.5% of the annual GDP for S&T activities in the country, no mechanism has been developed to allocate core S&T resources annually for programmes and projects approved by the national S&T council (Amha and Mekuriaw, 2008; Kitaw, 2008). The Tanzania national innovation policy may not be well linked to any financing mechanisms and also does not address some critical issues such as research infrastructure and tax burden for SMEs (Mwamila and Temu, 2008). Regarding the Indonesia case, there has been a persistent difficulty in transferring university technology to industries, which has affected the outcome of joint partnership programme between university and industry adopted in the country (Irawati, 2008).

Table 2: The major barriers, enables and implementation outcomes of Triple Helix in selected LMICs.

	Main sphere	Major barrier	Enablers	Results
Ghana (Lall and Pietrobelli, 2005; Dzisah, 2009; UNCTAD, 2011; Voeten, 2016)	*university and government institutions are the main knowledge producers; * weak linkages between industry and other two actors	* low level of science and research presence in tertiary education; * few entrepreneurial university; * inadequate fund * no linkages between SMEs and public sectors	* government funds; * add capitalization of knowledge to university's role; * strengthen S&T institutions and universities * reduce obstacles to innovation in competition and in regulatory and legal frameworks	Several factors have inhibited the implementation of policies. * arrears in payment; inadequate funding volume; * lack of democratic governance and a culture of corruption
Ethiopia (Amha and Mekuriaw, 2008; Kitaw, 2008)	* weak capabilities of university, industry and government in knowledge creation; * collaboration between core actors are absent.	* missing legal foundation for Triple Helix; * weak research infrastructure and insufficient research fund;	* establish legal basis that defines the Triple Helix relationship; * committed R&D spending (1.5 of GDP) from government; * technical, financial and administrative support to young graduates; * establishment of a national intellectual property system; * expanding ICT use across the country.	* no mechanism has been developed to allocate core S&T resources programmes and projects approved by the national S&T council; * the imposition of taxes on imported technology goods have not been well designed.
Zambia (Konde, 2008)	* university leads knowledge creation but capability is low; * university – industry linkage is absent	* weak entrepreneurship culture in university; * narrow funding base;	* integrated entrepreneurial culture throughout the university; * wider funding resource base, * independent, strong and efficient managerial systems	* describe the case of the University of Zambia (UNZA) and there is no evaluation and assessment provided.
Tanzania (Mwamila and Temu, 2008; Mwantimwa, 2008; Voeten, 2016)	* university and industry are two main actors leading knowledge creation, but linkages between them are weak	* low level of technological capabilities in industry; * few industrial firms engaged in collaborative learning; * innovation system is under developed;	* small and medium Enterprise Development Policy in 2003; * national Science and technology Policy of 1995; * the establishment of industrial research institutions;	* policy is not linked to any financing mechanism; * policy did not adequately address issues of the poor infrastructure; * high cost of utilities and communication system;

		* no linkages between SMEs and public sectors.	* emphasis the role of Science and Technology (S&T) * facilitate the articulation and implementation of innovative initiatives;	* taxes burden imposed on SMEs; * the level of industrial R&D is still low because the Government spending on industrial R&D is very limited.
Kenya (Voeten, 2015)	* university and industry are main knowledge producers; * weak collaborative research activities	* the absence of collaborative innovative activities; * no industry-public sector linkages.	* promote import substitution; * reduce obstacles to innovation in competition and in regulatory and legal frameworks;	N.A.
Nigeria (Kruss et al., 2012; Adeoti and Olubamiwa, 2009)	* university - industry linkages * weak internal technological capabilities	* weak capability for adoption, adaptation and assimilation of largely imported technologies; * indirect firm-industry linkages * Policy deficiencies	* form the direct linkages between the priorities and capabilities of manufacturing firms and the university subsystem; * enhance interaction or co-evolution of capabilities in both firm and universities * obtain support from financial sector	N.A.
Uganda (Kruss et al., 2012)	* university - industry linkages * incremental innovation	* innovation activities are incremental, learning within the firm * firms have little R&D * absent of industry-university linkages	* utilize the university as the source of innovation; * use external sources of knowledge to substitute for missing internal capacity; * 'science push' approach and minimal public investment	N.A.
Viet Nam (OECD, 2014)	* university and public institution lead knowledge creation; * weak linkages between industry and other two actors	* weak linkages between public research intuitions and private sectors; * insufficient financial sources	improving public governance of the innovation system; * develop the human resource base for innovation; * foster the innovation linkages between different actors.	N.A.
Cambodia (OECD, 2013)	* weak knowledge capability of three actors; * weak linkages among actors	* absence of strong innovation actors * weak links between indigenous and foreign-based actors	* building up the science base; * encouraging spillovers from FDI; * strengthening innovation linkages between different actors.	N.A.
El Salvador (Szogs et al., 2008)	* university, industry and government are three main knowledge producers.	* weak linkages between actors in innovation system; * missing intermediate organizations in linking actors to each other	* establishing and developing system linkages, and the networking and learning capabilities	N.A.
Indonesia (Irawati, 2008, 2010; OECD, 2013)	* university, industry and government are three main knowledge producers. * weak linkages between industry and government.	* ineffective internal policy, weak funding base, lack ties with private sectors * rare linkages between government research institutions and the small industrial R&D community	* cluster approach which encourages university participating in supporting SMEs; * define priority sectors * encouraging spillovers from FDI; * strengthen innovation linkages between different actors.	Programme in Java Island has helped SMEs in the automotive industry to improve product quality and production efficiency. * in general, the joint partnership between university and industry

		* difficulties for university transfer technology to industries		has mutually benefited all stakeholders. * R&D programmes are not responding to demand from firms and industries;
Sub-Saharan Africa (Lall and Pietrobelli, 2005)	N.A	* modern skills are inadequate for innovators * the physical infrastructure is weak * the inadequacies of the technology system	* allocate substantial resources to support the creation of new links and networks; * it also needs a conducive social, political and economic setting in which enterprises, governments and institutions can plan and implement long-term strategies.	N.A.

5 National Research System in LMICs

Another definition emerged along the development of national innovation system is national research system (NRS). At a workshop held on 6 and 7 April 2006 at UNESCO, the national research system is defined as "*… to learn more about research systems in developing/poor countries, and to help strengthen research and research capacity. Thus, the project supports research on and for development so that developing/poor countries may articulate and have ownership of these systems which are key assets for their development*".

National innovation system framework comprises sectors like government, university and industry and their environment. The framework emphasizes the relationships between the components or sectors, as the 'cause' that explains the performance of innovation systems (OECD, 2013). Similar to national innovation system, national research system is made up of the actors within a country that jointly produce research outcomes. In the conceptual framework developed by OECD (2013), national research systems contain four core elements: components (the operating parts of the system), relationships (interactions), attributes (motivations and goals), and outcomes (the creation of excellent knowledge).

Regarding the difference between NIS and NRS, the research system's ultimate goal is innovation whereas the goal of innovation system is the application of research. One of the prominent advantage of NRS concept is analytically tractable since it adopts various performance and outcome measures, as well as accounts for the nonlinearity and complexity of the system (Carlsson et al., 2002, Lundvall, 2007, Castellacci and Archibugi, 2008, Castellacci and Natera, 2011). The performance and outcomes indicators adopted in the NRS literature normally include: publications, GDP per head and Gross domestic expenditure on R&D (GERD), number of researchers etc. (Mouton and Waast, 2009; OECD, 2013).

Similar to NIS literature, evidence of NRS on LMICs is limited. Both strands of literature emphasis the crucial role of knowledge and research in socioeconomic development, as well as the interaction between key components in the system. However, apart from improving research outcomes NIS also aims to build up an efficient mechanism to stimulate innovation (commercialized research, research entrepreneurship) and ultimately promote productivity growth, increase employment and economic development.

pplying the keywords search approach in the literature survey on national research system in LMICs, only one study is identified to explicitly address National Research System in low-income countries/African countries (Mouton and Waast, 2009).[6] One of the common features of NRS in LMICs is their under-funded research institution and low levels of R&D investment despite commitments always made by ministers of S&T on at least 1 per cent of GDP on R&D annually (Mouton and Waast, 2009). The authors also suggested that it is necessary for government in LMICs to put their commitment in S&T investment into practice, as well as for other policies solutions such as improving research infrastructure, upgrading institutional research capacity, focusing on institution-building and addressing development and economic issues into research and knowledge production.

[6] The keywords used in our search include: 'National research system', 'developing countries', 'low income countries', 'Africa'. Sectoral evidence including agricultural (Nienke, 2004) and health (Mbondji et al., 2014) are not covered by the scope of current research.

6 Summary of literature gaps in Triple Helix innovation system in LMICs

Theory: Triple Helix innovation system emphases on interaction between university, industry and government, as well as their external linkages and collaboration (Saad and Zawdie, 2005). It is different from the conventional innovation model by integrating three complementary but distinct spheres – university, industry and government - and addresses their interdependencies in innovation strategies and policies. Although the theory of Triple Helix model has been widely acknowledged in development countries, the nonlinear characteristic and dynamic nature of the Triple Helix give rise to several unanswered questions to LMICs: what is the pattern across different context such as the levels of the developments and different growth levels? Will the role of university, industry and government alter as the development level remains low? How does the system serve to achieve different development goals across LMICs? Moreover, in most of LMICs, innovation is characterised as a learning behaviour through which various actors identify, assimilate and tab into existing knowledge and techniques and, eventually, translate them into local use. Ignoring this feature would result in failure of the system development and policy solutions.

Empirical evidence and methodologies: the current research Triple Helix in LMICs remains largely descriptive and mainly focuses on the existing national/regional innovation system. Both scale and scope of the evidence in the context LMICs is limited. Empirical evidence of Triple Helix innovation system is mainly drawn from the developed countries. It is necessary to find out whether these factors are homogeneous and can also apply to the low-income economies. For example, do measurements of the system performance need to be changed in LMICs? Are input-output indicators different from that of upper middle-income country context?

Great attention has been placed on the relationship, interaction between three core actors in the Triple Helix model. The external enabler such as funding, infrastructure and the absorptive capacity of the system have not been addressed until recently (Bazak and While, 2015). Empirical evidence is needed to support the theoretical model regarding enablers and barriers. In addition, existing literature mainly apply a qualitative approach (i.e. case study). In order to deliver robust evidence, other research methodologies are needed, such as quantitative analyses; comparison studies across different LMICs, and complementarity approaches (Milgrom and Roberts, 1990).

Application of Triple Helix in LMICs: Triple Helix offers an appealing framework which identifies the importance role of knowledge producers as well as emphasises the synergies arising from their interactions. Applying this concept to address innovation challenges in developing countries has become increasingly popular. It is necessary to differentiate approaches according the different contexts and the innovating objectives to be achieved. It is widely acknowledged that external learning and adoption are the main behaviour of innovation when level of development is low and internal technological capabilities are limited. To establish a sustainable innovation ecosystem, simultaneous efforts should also be given to the development internal innovation capability, including R&D investment, funding for research institutes and private research activities. Yet, it is still vague on the policy level how these objectives can be achieved via applying Triple Helix model in LMICs. In addition, the application of Triple Helix model in LMICs should also take into account role of networks since both internal linkages between the three actors and their external linkages to NIS systems are critical in fostering knowledge creation and innovation (e.g. Quad and Quintuple Helix models). In all, empirical evidence on the application of Triple Helix model in LMICs is limited.

The evaluation of Triple Helix application should be explored in future studies. Government should provide a comprehensive development and policy package, including technical upgrading through internal and external sources. This package will also emphasis the interaction and interdependencies between the three core actors in the Triple Helix system, as well as take into account the institutional and contextual factor which may influence the formation and application of the system.

References

Adeoti, John O. (2002). Building technological capability in the less developed countries: the role of a national system of innovation. *Science and Public Policy*, Vol. 29, No.2, pp. 95–104.

Adeoti, J.O. and O. Olubamiwa (2009). Towards an Innovation System in the Traditional Sector: The Case of the Nigerian Cocoa Industry, *Science and Public Policy*, Vol.36, No.1, pp.15-31,

Alcorta, L. & Peres, W. (1998). Innovation systems and technological specialization in Latin America and the Caribbean, *Research Policy* 26, 857-881.

Amha. M and Mekuriaw. A. (2008). Framework of the National System of Innovation. In Ethiopia Triple Helix Conference proceeding "Transforming University-Industry- Government Relations in Ethiopia". http://www.aau.org/sites/default/files/urg/docs/trans_univ_ind_gov_rel_ethiopia.pdf.

Anderson, J., P. Pardey, and J. Roseboom. (1994). Sustaining growth in agriculture: A quantitative review of agricultural research investments. *Agricultural Economics* 10(2): 107–123.

Arocena, R. & Sutz, J. (2000): Looking at National Systems of Innovation from the South, Industry and Innovation, Volume 7, Number 1, 55-75.

Arocena, R. & Sutz, J. (2001): Changing Knowledge Production and Latin American Universities, *Research Policy* (30) 8, 1221-1234.

Bianco, M. and Viscardi, N. (2008). Research organization in the university: the case of a leading Uruguayan group in basic science. *International Journal of Technology Management and Sustainable Development*, 7(3): 237-249.

Braczyk H., P. Cooke, and M. Heidenreich (1998). Regional Innovation Systems: The Role of Governances in the Globalized World. London: University College London.

Clark, B. R. (1998). *Creating Entrepreneurial Universities: Organization Pathways of Transformation*. Guildford, UK: Pergamon.

Cassiolato, J.E.; Lastres, H.M.M. and Maciel, M.L. (eds.) (2003). *Systems of Innovation and Development: Evidence from Brazil*. Cheltenham: Edward Elgar.

Chataway, J. Smith and D.V. Wield (2006). Science and technology partnerships and poverty alleviation in Africa, *International Journal of Technology Management and Sustainable Development*, 5(2), 103-23.

Carayannis EG, Campbell DFJ (2010): Triple Helix, Quadruple Helix and Quintuple Helix and how do knowledge, innovation and the environment relate to each other? A proposed framework for a trans-disciplinary analysis of sustainable development and social ecology. *International Journal of Social Ecology and Sustainable Development,*1*(1):41–69.*

Carayannis EG, Barth DT and Campbell FJ (2012). The quintuple Helix innovation model: global warming as a challenge and driver for innovation. Journal of Innovation and Entrepreneurship. 1(2), 1-12.

Carlsson, B. (1995). *Technological Systems and Economic Performance: The Case of Factory Automation*. Boston: Kluwer Academic.

Carlsson, B. (1997). *Technological Systems and Industrial Dynamics*. Boston: Kluwer Academic.

Carlsson, B., and S. Jacobsson. (1993). Technological systems and economic performance: The diffusion of factory automation in Sweden. In D. Foray and C. Freeman (Eds.), Technology and the Wealth of Nations: The Dynamics of *Constructed Advantage (pp. 77–92). London: Pinter.*

Carlsson, B., Jacobsson, S., Holmén, M. & Rickne, A. (2002). Innovation systems: analytical and methodological issues. *Research Policy*, 31, 233-245.

Castellacci, F. & Archibugi, D. (2008). The technology clubs: The distribution of knowledge across nations. *Research Policy*, 37, 1659-1673.

Castellacci, F. & Natera, J. M. (2011). A new panel dataset for cross-country analyses of national systems, growth and development (CANA). *Innovation and Development*, 1, 205-226.

Cohen, Wesley, M. & Levinthal, Daniel A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation, *Administrative Science Quarterly*. 35, 128-152.

Cozzens, Susan E and R. Kaplinsky (2011) Innovation, Poverty and Inequality in Bengt-Åke Lundvall, K.J. Joseph, Cristina Chaminade, Jan Vang (2011) *Handbook of Innovation Systems and Developing Countries: Building Domestic Capabilities in a Global Setting*. Edward Elgar Publishing.

De Mello, Carvalho and Etzkowitz, H. (2008). New directions in Latin American university-industry- government interactions. *International Journal of Technology Management and Sustainable Development*, 7(3): 193-204

Dosi, G. (1982). Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change. *Research Policy*, 11(3):147-162

Dosi, G., C. Freeman, R. Nelson, G. Silverberg, and L. Soete (Eds.). (1988). *Technical Change and Economic Theory*. London: Pinter.

Godin, B. and Gingras, Y. (2000) The place of universities in the knowledge production'. *Research Policy*, 29 (2): 273-275.

Dzisah, J. (2006). Information and Communications Technologies and Development in Ghana. *Science, Technology and Society* 11(2)379-396.

Dzisah, J. (2009). Mobilizing for Development: Putting the Triple Helix into Action in Ghana, in Saad, M and Zawdie, G (eds.) (2010) *Theory and Practice of Triple Helix Model in Developing Countries*: Issues and Challenges. London: Routledge

Eduardo, Albuquerque, W. Suzigan, G. Kruss and K. Lee (eds.) (2015). *Developing National Systems of Innovation: University–Industry Interactions in the Global South*, Edward Elgar, Cheltenham UK and Northampton, USA/International Development Research Centre, Ottawa, Canada.

Edquist, C. (1997). *Systems of Innovation Approaches: Technologies, Institutions and Organizations*. London: Pinter.

Ernst, D. (2007) Beyond the 'Global Factory' model: innovative capabilities for upgrading China's IT industry, *International Journal of Technology and Globalisation*, 3(4), pp. 437 – 459

Ethiopian Herald. (2006) *ETHA says universities could speed up dev't*, Ethiopian Herald, April 02.

Etzkowitz, H. and Leydesdorff, L. (1995). The Triple Helix: university -industry - government relations. A laboratory for knowledge based economic development. EASST Review. *European Society for the Study of Science and Technology*, 14(1): 18-36.

Etzkowitz, H. and Leydesdorf, L. (1999). The future location of research and technology transfer. *Journal of Technology Transfer*, 24 (2-3): 111-123.

Etzkowitz, H. (2003a). Innovation in innovation: The Triple Helix of university-industry-government relation', *Social Science Information*, 42(3): 293-338.

Etzkowitz, H. (2003b) "Learning from Transition: The Triple Helix as an Innovation System" Paper Presented to the Symposium on "Knowledge Based Society: a challenge for new EU and accession countries, Zagreb, Croatia, October 23.

Etzkowitz, H. and Carvalho de Mello, J. M. (2004). The rise of a triple helix culture: Innovation in Brazilian economic and social development, *International Journal of Technology Management and Sustainable Development*, vols. 2-3, pp. 159-171

Etzkowitz, H. and Klofsten, M. (2005). The innovating region: toward a theory of knowledge-based regional development'. *R&D Management*, 35 (3): 243-255.

Etzkowitz, H. (2006) The new visible hand: an assisted linear model of science and innovation policy. *Science and Public Policy* 33 (5):310-320

Etzkowitz H, Dzisah J. (2007) The triple helix of innovation: Towards a university-led development strategy for Africa. *Afr Technol Dev Forum* J; 4:3-10.

Etzkowitz, H. (2007) The *Triple Helix: University- Industry-Government Interactions for Innovation* London: Routledge

Etzkowitz, H. (2008), *Triple Helix Innovation: Industry, University, and Government in Action*, London and New York: Routledge.

Farley, S., Arnold, E., Bell, M., Ilzuka, M., Kok, E. and Assaf, G. (2007) Innovation systems in practice: the relevance for industry in developing countries. Implications for UNIDO and its development partners, Mimeo, UNIDO, Vienna.

Freeman, C. (1987) *Technology Policy and Economic Performance: Lessons from Japan*, London: Frances Pinter.

Freeman, C. (1995). The national innovation systems in historical perspective. *Cambridge Journal of Economics* 19(1): 5–24.

Fu X., Woo W. and Hou J. (2016) Technological innovation policy in China: the lessons, and the necessary changes ahead. Econ Change Restruct. 49(2):139-157.

Giuliani, E. and Bell, M. (2005): When micro shapes the meso: learning networks in a Chilean wine cluster. *Research Policy* Vol 34, pp47-68.

Godin, B. and Gingras, Y. (2000) The place of universities in the knowledge production. *Research Policy*, 29 (2): 273-275.

Gu, Shulin (1999). Implications of National Innovation Systems for Developing Countries: Managing Change and Complexity in Economic Development. *Discussion Paper* 9903, United Nations University, Institute for New Technologies, Maastricht, The Netherlands.

Himmelberg, C., and B. Petersen (1994). R&D and internal finance: A panel study of small firms in high-tech industries, *Review of Economics and Statistics* 76(1):38-51.

Irawati, D. (2010). Bridging the gaps in the Triple Helix: A demand or a challenge for Indonesian case study? in Saad, M. and Zawdie, G. (eds.) *Theory and Practice of Triple Helix Model in Developing Countries: Issues and Challenges*. London: Routledge

Juma, C. (ed.). (2005) *Going for Growth: Science, Technology and Innovation in Africa*. London, The Smith Institute.

Khan FG, Park HW. Measuring the triple helix on the web: Longitudinal trends in the university-industry-government relationship in Korea. J Am Soc Inf Sci 2011; 62:2443-55.

Kim, Linsu (1997), Imitation to Innovation — The Dynami cs of Korea's Technological Learning (Harvard University Press, Boston MA).

Kimatu N. Josphert (2016). Evolution of strategic interactions from the triple to quad helix innovation models for sustainable development in the era of globalization. *Journal of Innovation and Entrepreneurship*, 5(16): 1-7.

Kitaw Ing. (2008). Higher Education - Industry Resource Integration Center - Towards Solving Existing Industrial Problems. In Ethiopia Triple Helix Conference proceeding "*Transforming University-Industry- Government Relations in Ethiopia*". http://www.aau.org/sites/default/files/urg/docs/trans_univ_ind_gov_rel_ethiopia.pdf.

Konde, V. (2004) Internet development in Zambia: a triple helix of government university-partners. International *Journal of Technology Management* 27:440-451.

Kruss, Glenda, J.O. Adeoti and D. Nabudere (2012). Universities and Knowledge-based Development in sub-Saharan Africa: Comparing University-Firm Interaction in Nigeria, Uganda and South Africa, *Journal of Development Studies*, Vol.48, No.4, pp.516-530.

Lall, S. and Pietrobelli, C. (2002) *Failing to Compete: Technology Development and Technology Systems in Africa*, Cheltenham: Edward Elgar.

Lall, S. and Pietrobelli, C. (2003) Manufacturing in Sub-Saharan Africa and the need of a National Technology Syste', in M. Muchie, B.Å. Lundvall and P. Gammeltoft (Eds.) *The Making of African Innovation Systems*, Aalborg University Press, http://www.globelics.org/index.php? module=htmlpages&func=display&pid=3

Lall, S. and Pietrobelli, C. (2005) National Technology System in Sub-Saharan Africa. *International Journal of Technology and Globalisation*. 1(3/4), 311.

Leydesdorff L, Curran M. (2000) Mapping university-industry-government relations on the Internet: The construction of indicators for a knowledge bases economy. Cybermetrics *Int J Scientometrics Informatetrics Bibliometrics*;4.

Leydesdorff, L. (2003). The Mutual Information of University-Industry-Government Relations: An Indicator of the Triple Helix Dynamics. *Scientometrics,* 58(2), 445-467.

Leydesdorff, L. (2005). The Triple Helix model and the study of knowledge-based innovation systems. International *Journal of Contemporary Sociology*, 42(1): 12-27.

Leydesdorff L, Sun Y. (2009) National and international dimensions of the Triple Helix in Japan: University-industry-government versus international co-Authorship relations. *J Am Soc Inf Sci*; 60:778-88.

Leydesdorff, L and Zawdie, G (2010). The Triple Helix perspective of innovation systems. *Technology Analysis & Strategic Management*. 22 (7): 789–804

Leydesdorff, L (2012), The Triple Helix of University-Industry-Government Relations. University of Amsterdam, Amsterdam School of Communication Research (ASCoR), Kloveniersburgwal 48, 1012 CX Amsterdam, The Netherlands.

Leydesdorff L, Etzkowitz H. (2001) The transformation of university-industry-government relations. Electron J Sociol;5. Available from: http://www.sociology.org/content/vol005.004/ th.html. [Last retrieved on 2013 May 23].

Leydesdorff L, Ivanova IA. (2014) Mutual redundancies in inter-human communication systems: Steps towards a calculus of processing meaning. *J Am Soc Inf Sci*; 65:386-99

Lundvall, B. Å. (1988): "Innovation as an interactive process from user-producer interaction to the national system of innovation". In: Dosi, G. et al. (eds.): *Technical Change and Economic Theory.* Pinter, London.

Lundvall, B. Å. (1992). National Systems of Innovation. London: Pinter.

Lundvall, B., B. Johnson, E. S. Anderson, and B. Dalum. (2002). National systems of production, innovation and competence building. *Research Policy* 31:213–231.

Lundvall, B.-Å.; Intakumnerd, P.; Vang, J. (2006): *Asian Innovation Systems in Transition*. Edward Elgar, Cheltenham.

Lundvall, B. Å. (2007). National innovation systems—analytical concept and development tool. *Industry and innovation,* 14(1), 95-119.

Lundvall, B.-A., Vang, J., Joseph, K.J. and Chaminade, C. (2009) Innovation system research and developing countries, in: B.-A. Lundvall, K.J. Joseph, C. Chaminade and J. Vang (eds) *Innovation Systems and Developing Coutnries*. Building Domestic Capabilities in a Global Setting (London: Edward Elgar Publishing).

Malerba, Franco and R.R. Nelson (eds.) (2012). *Economic Development as a Learning Process: Variation across Sectoral Systems*, Edward Elgar, Cheltenham UK and Northampton, USA

Mbondji, P., Kebede, D., Zielinski, C., Kouvividila, W., Sanou, I. and Lusamba-Dikassa, P (2014). Overview of national health research systems in sub-Saharan Africa: results of a questionnaire-based survey. *Journal of the Royal Society and Medicine.* 107(1S) 46-54.

Mêgnigbêto, E (2013). Triple Helix of University-industry-government relationships in West Africa. *Journal of Scientometric Research.* 2(3): 214-222.

Mêgnigbêto, E (2015). Effect of international collaboration on knowledge flow within an innovation system: A Triple Helix approach. A *Journal of University-Industry-Government Innovation and Entrepreneurship*2015**2**:16

Milgrom, P. and J. Roberts (1990). Rationalizability, learning, and equilibrium in games with strategic complementarities. *Econometrica: journal of the Econometric Society* 1255-1277.

Mohnen, P. and L. Röller (2005). Complementarities in innovation policy. *European Economic Review* 49(6):1431-1450.

Mouton J., and W. Roland. (2009) Comparative study on national research systems: findings and lessons. In: Meek V.L. (ed.), Teichler U. (ed.), Kearney M.L. (ed.) *Higher education, research and innovation: changing dynamics: report on the UNESCO forum on higher education, research and knowledge 2001-2009*. Paris (FRA); Kassel: INCHER ; UNESCO, 2009, p. 147-169.

Mueller P. Exploring the knowledge filter (2006). How entrepreneurship and university–industry relationships drive economic growth. *Research Policy*; 35:1499-508.

Mulkay, B., B. Hall and J. Mairesse (2001). Firm level investment and R&D in France and the United States, in Deutsche Bundesbank (ed.), *Investing Today for the World of Tomorrow,* Springer Verlag, Berlin.

Mwamila. BLM and Temu AK (2008). Academia-Industry-Government Relationship: Experience of the College of Engineering and Technology, University of Dar es Salaam Tanzania. In Ethiopia Triple Helix Conference proceeding "Transforming University-Industry- Government Relations in Ethiopia". http://www.aau.org/sites/default/files/urg/docs/trans_univ_ind_gov_rel_ethiopia.pdf.

Mwantimwa, K. (2008) The relationship of indigenous knowledge and technological innovation to poverty alleviation inTanzania. *Paper at IV Globelics conference*, Mexico City.

Myamila, B. and Diyamett, B.D. (2006) The position of higher education in the national system of innovation: the case of Tanzania. *Presented to 5th International Congress on Higher Education*, Cuba.

Nelson, R. R. (1988). National systems of innovation: Institutions supporting technical change in the United States. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, and L. Soete (Eds.), *Technical Change and Economic Theory* (pp. 309–329). London: Pinter.

Nelson, R. R. (1993). *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.

Nienke M. Beintema and Gert-Jan Stads (2004). Sub-Saharan African agricultural research: Recent investment trends. *Outlook on Agriculture*. 33(4) 239-246.

Nwagwu WE. The Nigerian university and the triple helix model of innovation systems: Adjusting the wellhead. *Technol Anal Strateg Manage* 2008; 20:683-96.

OECD (1997), *National Innovation Systems*, 1997, Paris, France, pp. 1-48.

OECD (2001) Science and Technology Scoreboard: Towards a Knowledge-Based Economy. Paris: OECD.

OECD (2014) *Science, Technology and Innovation in Viet Nam*. OECD, Paris.

OECD (2013) *Reviews of Innovation Policy Innovation in Southeast Asia.* OECD, Paris.

Olmeda-Gomez, C and Perianes-Rodriguez, A (2013). Antonia Ovalle-Perandones MA. Comparative analysis of university government enterprise coauthorship networks in three scientific domains in the region of Madrid. *Inf Res* 2008;13. Available from: http://www.informationr.net/ir/133/paper352. html. [Last retrieved on 2013 June 18].

Pietrobelli, C., & Rabellotti, R. (2011). Global value chains meet innovation systems: are there learning opportunities for developing countries? *World Development,* 39(7), 1261- 1269.

Razak, A. A. and White, G. (2015) The Triple Helix model for innovation: A holistic exploration of barriers and enablers. *International Journal of Business Performance and Supply Chain Modelling,* 7 (3). pp. 278-291.

Ranga, M. and H. Etzkowitz (2010), 'Creative Reconstruction: A Triple Helix-based Innovation Strategy in Central and Eastern Europe Countries', in Saad, M. and Zawdie, G. (eds.) *Theory and Practice of Triple Helix Model in Developing Countries: Issues and Challenges*. London: Routledge

Rivera, M. (2010). Innovation systems interactions and technology transfer and assimilation for industrial development: The cases of South Korea and Mexico, in Saad, M. and Zawdie, G. (eds.) *Theory and Practice of Triple Helix Model in Developing Countries: Issues and Challenges*. London: Routledge.

UNCTAD (2011) Science, Technology & Innovation Policy Review: Ghana. United Nations Conference on Trade and Development.

Saxenian, A., (1994). *Regional Advantage: Culture and Competition in Silicon Valley and Route 128.* Cambridge, MA: Harvard University Press.

Saad, M. (2004). Issues and challenges arising from the application of innovation strategies based on the Triple Helix culture: Experience of the incubation system in Algeria. *International Journal of Technology Management and Sustainable Development*, 3(1): 17-35

Saad, M., Zawdie, A. and Lee, R. (2005) Issues and challenges arising from a greater role of the university in promoting innovation in developing countries: A comparative study of experiences in Malaysia, Algeria and Ethiopia. In Triple Helix 5: The capitalization of knowledge, cognitive, Economic Social and Cultural aspects. Turin, Italy, 18-21 May.

Saad, M. and Zawdie, G. (2005) From Technology Transfer to the Emergence of a Triple Helix Culture: The Experience of Algeria in Innovation and Technological Capability Development. Te*chnology Analysis & Strategic Management* 17 (1):89–103.

Savignac, F. (2008). Impact of financial constraints on innovation: What can be learned from a direct measure? *Economics of Innovation and New Technology* 17(6):553-569.

Sebuwufu, J., Ludwick, T. and Béland, M. (2012) Strengthening University-Industry Linkages in Africa: A Study of Institutional Capacities and Gaps: A Study on Institutional Capacities and Gaps, pp. 1-61, Association of African Universities (AAU), Accra-North Ghana, Last accessed 18 October 2013, from http://www.aucc.ca/wp-content/uploads/2011/07/aau-case-study-university-industry linkages-africa.pdf.

Shinn, T. (1999). Change or mutation? Reflections on the foundations of contemporary science. *Social Science Information,* 38(1), 149-176.

Ssebuwufu J, Ludwick T, Béland M. Strenghening University-Industry Linkages in Africa: A Study on Institutional Capacities and Gaps. Accra: Association of African Universities-Association of universities and Colleges of Canada; 2012. Available from: http://www.aucc.ca/wp-content/uploads/2011/07/ aau-case-study-university-industry-linkages-africa.pdf. [Last retrieved on 2013 Mar 05].

Stockdale, B. (2002). UK Innovation Survey 2001, *Economic Trends* 580:36-42.

Sutz, J. (2000) The University-industry-government relations in Latin America. *Research Policy*, 29 (2): 279-290. Taylor S. Knowledge circulation: The 'triple helix' concept applied in South Africa. Ind Higher Educ 2004; 18:329-34.

Tiwari, A., P. Mohnen, F. Palm and S. van der Loeff (2008). Financial constraints and R&D investment; Evidence from CIS, forthcoming in Kleinknecht, A., Ott, R., van Beers, C., and R. Verburg, eds., *Determinants of Innovative Behaviour: A Firm's Internal Practices and its External Environments*, Palgrave Publishers, London.

Toivanen H, Ponomariov B. African regional innovations systems: Bibliometric analysis of research collaboration patterns 2005-2009. *Scientometrics* 2011; 88:471-93.

Voeten, J. (2016). Enabling Innovation and Productivity Growth in Manufacturing Small and Medium Sized Enterprises in Low Income Countries: Qualitative Exploration of Policy and Research Issues in Ghana. Tilburg: Tilburg University.

Voeten, J. (2016). Enabling Innovation and Productivity Growth in Manufacturing Small and Medium Sized Enterprises in Low Income Countries: Qualitative Exploration of Policy and Research Issues in Tanzania. Tilburg: Tilburg University.

Voeten, J. (2015). Enabling Innovation and Productivity Growth in Manufacturing Small and Medium Sized Enterprises in Low Income Countries: Qualitative Exploration of Policy and Research Issues in Kenya. Tilburg: Tilburg University.

Watkins A. Papaioannou T. Mugwagwa J. and Kale D. (2015) National innovation systems and the intermediary role of industry associations in building institutional capacities for innovation in developing countries: A critical review of the literature. *Research Policy*. 44(8). 1407-1418.

Ye YF, Yu SS, Leydesdorff L. (2013) The Triple Helix of university-industry-government relations at the country level, and its dynamic evolution under the pressures of globalization. *Journal of the Association for Information Science and Technology.* 64:2317-25.

Appendix A: Summary of literature: Triple Helix, National Innovation System and National research system in Low- or Lower-Middle income countries

Study	Research objectives	Country	Methodology	U-I-G*	Main Findings	Policy implications and interventions
Triple Helix						
Razak and White, 2015	Examined the overall barriers and enablers in implementing the Triple Helix model	No specific country focus	Qualitative review	U-I-G	University, Industry and Government are non-mutual exclusive and overlap in the Triple Helix institution. Three issues are identified in relations to the Triple Helix enablers and barriers: Relationship, University and Policies.	Policy implication: maximising enablers and minimising barriers, as well as coordinating the relationships between actors.
Eustache Mêgnigbêto, 2015	Studied the Triple Helix in relation to international co-authorship considered international collaboration as the fourth element of the system.	West Africa, South Korea	Bibliometric	U-I-G	At the domestic level, the South Korean innovation system is more integrated, whereas the West African one is less integrated than that of their partners. Also, international collaboration has strengthened knowledge sharing at the domestic level for both South Korea and West Africa, but to a different extent.	Policy instrument should promote the international collaboration which eventually facilitate knowledge flow.
Eustache Mêgnigbêto, 2013	Investigate the collaboration network between university, industry, and government in West Africa	West Africa	Bibliometric	U-I-G	University is the core player in knowledge creation. Industry exhibits relations with government or university in Nigeria and Ghana only. Three Triple Helix spheres occurred only in Nigeria.	N.A.
Ssebuwufu, Ludwick and Béland, 2012	Investigate what structures, policies, positions, incentives, and funding avenues are currently in place for university-industry linkages in Africa, and what interventions are needed.	Africa region	Quantitative	U-I	African universities start taking initial steps to stimulate and deepen linkages with industry and the productive sector. The importance of leadership, both in terms of policy and personnel, was identified as an important enabling factor for promoting university-	Apply a more encompassing definition of industry - one that includes all aspects of the productive sector, including agriculture and the informal sector - when developing strategies and interventions to strengthen university-industry linkages.

					industry linkages. Meanwhile, various capacity gaps in terms of requisite skills, research infrastructure, and funding represent significant challenges for high education institutions in Africa.	Proposed intervention should focus on funding, capacity building in relevant skills and policy development.
Dzisah, 2019	Investigates the nature of the relationships between the three institutional spheres of the triple helix structure—university-industry-government by drawing on the experiences from Ghana.	Ghana	Country Case study, Qualitative	U-I-G	There are signs of the mobilization of the trip helix for development in Ghana. However, there is the need to strengthen S&T institutions and universities to take on the challenge of knowledge-based development. A continuous flow of science to the economy does not need to be achieved slowly through traditional stages of development-based models but can occur more rapidly by expanding and reorienting universities.	Ghana needs to mobilize its triple helix actors, especially its universities, for development. This demands that policies take on post-partisan modes and universities be made to take their critical core developmental mantle.
Irawati, 2010	Discuss the essential stages required to establish a robust synergy between three different actors: the university, the industry and the government by focusing on the role of SMEs in the Indonesia innovation system.	Indonesia	Country Case study	U-I-G	The triple helix system places the role of the academic sphere in relation to small and medium-sized enterprises to engage in joint networking with other supporting institutions. The Triple Helix concept developed in developed country context may not be applicable for developing countries such as Indonesia. Promoting the triple helix approach in developing countries such as Indonesia, must take into account the value for all actors involved.	It is necessary to construct a vigorous science and technology infrastructure linked to the productive structure of the society. Indonesian universities should involve actively in bridging the gaps between government and other international supporting development agencies for developing SMEs.
Ranga and Etzkowitz, 2010	Identify the key factors which drive the Triple Helix – based 'creative reconstruction' process in Central and Eastern European Countries. Examine changes in university, industry and government associated with	Central and Eastern European Countries	Qualitative	U-I-G	The FDI flows placed a significant impact on the industry helix. National and regional R&D and innovation policies and funding also have strong impact on the government and university, and to a lesser extent, the industry helix.	Consolidate the entrepreneurial potential of Universities by strengthening their Research capabilities, commercialization Skills and infrastructure. Foster innovative firm formation and the absorptive capacity of local firms. Increase the availability of and access to venture capital.

	each of the stages of the triple helix -based innovation strategy.					
Adeoti and Olubamiwa, 2009	examines the impact of the Nigerian cocoa rebirth initiative and makes suggestions that are critical for strengthening the innovation system in the cocoa industry	Nigeria, cocoa industry	Descriptive, country case	U-I-G	Heavily depend on external knowledge sourcing in the cocoa industry. The linkages and interactions between four critical actors (individual cocoa farmers, cocoa processing firms, government and research institute) in the cocoa re-birth programme should be strengthened. Financial sector should also support the innovation activities in the sector.	Policy emphasis should aim to organize the cocoa rebirth initiative as an innovation-focused programme that enables interactive learning among the actors in cocoa research, production and industrial processing
Etzkowitz and Dzisah, 2008	Use the level of knowledge flow in the Triple Helix system to explain the level of development. Use the Triple Helix model as an academic reform strategy in the developing world, whereby higher education is refocused on issues of development, entrepreneurship and innovation.	Africa	Qualitative	U-I-G	The university is the biggest information producer, followed by government. The information sharing and knowledge between university, industry, and government is weak, illustrating the low level of knowledge flow between innovation actors in Africa. Collaboration between the three Triple Helix spheres occurred only in Nigeria.	A triple helix of university-industry-government interactions is crucial to developing organizational innovations in response to Africa's quest for innovation and development. Innovation policy can no longer be conceived only as a "top-down" initiative of national government but should also be seen as the cumulative result of interaction among governments at various levels, business persons, academics, and NGOs comprising membership from all of these spheres.
Amha and Mekuriaw, 2008 (Conference proceeding)	Examine the national S&T policies using the national system of innovation	Ethiopia	Country Case study		Although the National S&T policy has some weaknesses, it has provided the basis to consider S&T activities in a national system. The most important issue in the Ethiopian S&T development is the lack of systematic efforts to implement the Government policy. The existing policy could be upgraded focusing on coordinating, supporting and enhancing interactions of the various stakeholders of the	Appropriate attention needs to be paid to encouraging and supporting SMEs, demand- side interventions, including the use of the government purchasing power. Policy instruments including legal, organizational, operational and financial should be adopted.

					national system of innovation including universities, industry and the government.	
Kitaw, 2008 (Conference proceeding)	The research uses the concept of triple helix and proposes the establishment of Higher Education Institutions-Industry Resource Integration Centre as a way foreword to solving the problems that the Ethiopian industries are facing. Missing linkages between higher institutions and industries are also discussed.	Ethiopia	Country Case study		The past Ethiopian University-Industry linkage experiences were primarily anchored on administrative decision rather than being on needs and demand. The current and future scenario would be complex: public-public, public-private and private-private: where the players would be both public and private higher education institutions and industries owned by the government and private sector. The Centre would be established on true demand and assured sustainability.	Attempts should be made to maximise the existing under-utilized industries, reform the weak regional co-operation, make the industrial ambient attractive to investors and strengthening the link between University, Industry and Government. All actors should make a coordinated effort to establish and strengthen a nationwide Higher Education - Industry Resource Integration Centre.
Affa'a and Dalkir, 2008 (Conference proceeding)	The study intends to analyse the organizational mechanism that transfers knowledge and technologies produced by the research to the targeted users in information and agricultural sectors.	Cameroon	Country Case study	U-I, Information sectors	Knowledge produced is published but the technologies and procedures developed are not transferred to potential end users. It is not due to a lack of a model of good practices. The problem is the organizational mechanisms required to transfer knowledge and to transfer developed technologies to the targeted user population.	University researchers need to start assuming the role of contributing to the economic development of Cameroon – more specifically, to contribute to the strategy of poverty reduction. Research initiatives should take into account informal economic actors in general.
Goktepe and Keskin, 2008 (Conference proceeding)	The research focuses on the Israeli Magnet Program for pre-competitive generic technology production within the consortia of university, government and industry (UGI). Findings are expected to abstract the lessons and implications for a developing country such as Ethiopia.	Israel	Country Case study, Network analysis	U-I-G	A network-based innovation system, which provides the communication linkages and basis among the actors of innovation, leads to the achievement of the synergy among these actors of innovation. Such production system is believed to bring about much more economic and industrial development than the sum of these participants individually.	Ethiopia needs to put efforts towards building up a network-based innovation system.

Dzisah and Etzkowitz, 2008 (Conference proceeding)	This study pointed out that stage models may no longer be relevant to an increasingly knowledge-based society. It proposed a triple helix development model that moves away from staged to a spiral model of education because a continuous flow of science to the economy can occur more effectively under a triple helix of university-industry-government relations.	Africa region	Qualitative	U-I-G	The Triple Helix model provides a flexible framework for the transition of the African university from educating postcolonial elite to playing a more direct role in development, pointing the way for least developed countries to make the transition to a knowledge-based society. Rather than development and redevelopment being the sole responsibility of central governments, a meta-innovation system is emerging from bottom up, top down and lateral initiatives in which science, technology and innovation policy is the outcome of the interaction among university, industry and government.	The potential for regional development in Africa, and elsewhere, resides in entrepreneurial universities taking the lead in infusing knowledge, innovation, technology and enterprise into the entire society.
Konde, 2008 (Conference proceeding)	This paper uses the case of the University of Zambia (UNZA) to highlight possible ways of mobilizing university resources - manpower, national and international links, and close cooperation with partners - to create and support businesses, through specialized units.	Zambia	Country Case study	U-I-G	Despite UNZA cannot be described as an entrepreneurial university by the standards of advanced economies, it exhibits entrepreneurship traits that could help deliver services to industry and the community at large. It plays an important role in mobilizing intellectual capital and social capital to create and support businesses, as well as contribute to development even with limited resources.	Specific practical policy suggestion on strengthening the university entrepreneurship: a forum or an entrepreneurship clinic that bring business experts, government units (e.g. tax and business registration authorities) and business consultants in a non-credit earning session that could be run once or twice a week.
Mwamila and Temu, 2008 (Conference proceeding)	The study highlighted the synergic interaction of academia, government and industry by looking at the basic objectives of College of Engineering and Technology (CoET) at the University of Dar es Salaam.	Tanzania	Quantitative analysis	U-I-G	The CoET has continuously strived to have a functional linkage with industry in Tanzania. Despite some failures experienced in the past, the goal now is to have a link that will serve all levels of industry. Whereas academia-industry relationship looks reasonably strong, the government-industry or government-academia relationship has not been equally strong.	Innovative Industrial Research and Development is a core function which must be done to facilitate the development and dissemination of industrial technologies and innovations. Developing countries, like Tanzania, need to put emphasis and devote adequate resources to IR&D activities if they seriously need fast and sustainable rate of industrial growth.

De Mello and Etzkowitz, 2008	The study analyses the new directions in university–industry–government interactions are taking place in Latin American countries, as well as highlights that university should play an economic role.	Latin America	Qualitative	U-I-G	Findings reveal the lack of collaborative arrangements between Triple Helix core actors, as well as with local Partners, which can be due to the lack of demand for local research to develop new technology.	N.A.
Saad et al., 2005 (Conference paper)	This paper explores the contextual basis of the triple helix model of innovation with reference to the circumstances of developing countries, in general, and invokes the experiences of three countries at different stages of development for Malaysia, Algeria, and Ethiopia to show the prospects and challenges associated with the "triple helix" strategy for promoting innovation and learning societies in these countries.	Malaysia, Algeria and Ethiopia	Comparison study	U-I-G	The universities play the central role in creating, disseminating and sharing knowledge. The 'triple helix' system of relationships between university, industry and government would enhance the relevance of universities to developing countries as active agents of innovation, industrialization and sustainable development.	Prerequisites for the successful implementation of the Triple Helix model include: conditions for the development of learning societies needs to be created; more power needs to be devolved to the main actors; stable, lasting and trusting relationships between the main actors and institutional spheres (universities, government and industry) would need to be developed.
Saad and Zawdie, 2005	Based on the post-independence industrialization experience of Algeria, this paper highlights the business incubation system as an aspect of the triple helix model of innovation in which universities, industry, government and non-government organizations feature as principal actors in the national innovation system.	Algeria	Country Case study	U-I-G	The business incubation system is an important aspect of the triple helix model of innovation in which universities, industry, government and non-government organizations feature as principal actors in the national innovation system. There is need for both technology transfer and the development of the triple helix culture in developing countries.	A major policy initiative is needed in developing countries to put the national system of innovation in place and remove the constraints on the development of the triple helix culture. Policy instrument should target on the culture of bureaucracy and institutional fragmentation which has been a major factor militating against initiatives for technological capability development.
Konde, 2004	This paper uses the development of the internet in Zambia, through commercialisation of a university based academic e-mail system into the country's first Internet	Zambia	Country Case study	U-I-G	The ability of nations to generate and use advanced knowledge for industrial competitiveness is partly determined by the relationship between government, industry and research institutions as well as policies and regulations that	A Triple Helix relation of Universities-Government-Partners may be important in transferring, adapting and mastering knowledge based technologies in Africa.

	Service Provider (ISP), to identify the relationship between government-university- (development) partners and to outline some important policy lessons where African universities could play a role as technology transfer agents.				govern the generation, transfer and commercialisation of new knowledge. African innovation systems do not seem to fit such a relation.	
Saad, 2004	This research discusses the incubation system as an aspect of the 'triple helix' model of innovation in which universities feature as organizational actors interfacing the public-private/voluntary sector nexus in the process of economic growth and development.	Algeria	Country Case study	U-I-G	The introduction of the incubation system in Algeria shows the difficulties involved in implementing innovation strategies based on the 'triple helix' model in developing countries in general. The triple helix model itself is vulnerable especially when one of the key actors does not possess the capability and power to play its role effectively.	Policy in developing countries like Algeria should seek to promote learning and innovation through an effective system of interactions between and within the main components of the triple helix model, namely government, university and industry.
Sutz, 2000	The research analyses the university–industry–government relations in Latin America from two points of view: a "bottom up" one that starts from concrete experiences of knowledge user–producer relations, and a "top-down" one that considers the outcomes of the institutionalisation efforts recently developed in the region.	Latin America	Qualitative	U-I-G	Findings revealed that the historical low involvement of industry in knowledge and innovation activities across Latin America has not substantially improved. The weakness of the main actors, the vague status of their research interest and the inactive relations between institutions are the main reasons for the lack of effort of science and technology research into socio-economic development in Latin America.	Policies should be designed to improve the university-industry-government linkages, as well as develop the right strategies to integrate the knowledge activities and bring in commercialisation or intellectual property practices.
National Innovation System						
Voeten, 2016	Identify relevant policy and research issues concerning innovation in manufacturing SMEs within contemporary realities in Ghana.	Ghana	Country case study	U-I	Ghanaian SME innovations are mostly in-house activities. The motivation, contacts and international exposure of the owner were key factors in the engagement in innovative	It is desirable to develop innovation within manufacturing SMEs; the development process in LICs could be supported by tapping existing knowledge and know-how; The government can

					activities. There are no links between the interviewed SMEs and public sector actors, such as universities, governments, or NGOs, as presented in the 'Innovation Systems' analytical model.	reduce obstacles to innovation in competition and in regulatory and legal frameworks. Government-sponsored research and development structures can respond to the needs and demands of surrounding communities; not to focus on governmental policy makers only, but on direct advice
Voeten, 2016	Identify relevant policy and research issues concerning innovation in manufacturing SMEs within contemporary realities in Tanzania	Tanzania	Quantitative, micro econometric	U-I	the incremental SME innovations in Tanzania are mostly in-house activities; contacts and international exposure of the owner are key factors in engagement in innovative activities; There are no cases of collaborative innovative activities; There are virtually no links between the interviewed SMEs and public sector actors.	It is desirable to develop innovation within manufacturing SMEs; the development process in LICs could be supported by tapping existing knowledge and know-how; an efficient innovation policy by governments will address the overall innovation climate, which goes beyond traditional science and technology policy; government action should facilitate the articulation and implementation of innovative initiatives, since innovators need basic technical, financial and other support; not to focus on governmental policy makers only, but on direct advice to SMEs on how to improve their business.
Voeten, 2015	Identify relevant policy and research issues concerning innovation in manufacturing SMEs within contemporary realities in Kenya	Kenya	Country case study	U-I	There is a positive impact of innovative manufacturing SMEs on employment generation. Although most owners and managers indicate that the employees are eager to learn and motivated to work, their limited exposure to sources of information (internet) and limited creativity is considered an obstacle at the firm level. The absence of collaborative innovative activities and the industry-public sector linkages.	Promoting innovation among manufacturing SMEs in Kenya could focus on better products at reasonable prices, as import substitution; the development process in LICs could be supported by tapping existing knowledge and know-how; The government can reduce obstacles to innovation in competition and in regulatory and legal frameworks; not to focus on governmental policy makers only, but on direct advice to SMEs on how to improve their business.

Watkins et al., 2015	Review the NIS literature in developing countries and discuss the important role of both institutions, particularly governments, and the process of institutional capacity building. It also highlights the intermediary role of industry associations.	Developing countries, incl. Africa countries	Qualitative, literature review	U-G	Institutional capacity building might be directed, particularly in the context of developing countries where governance capacities are often lacking, contributing to less effective innovation systems, stagnant economies, and unequal development.	N.A.
OECD, 2014	Review and evaluate the current innovation policies in Viet Nam	Viet Nam	Qualitative, descriptive statistics	U-I-G	Good framework conditions and a healthy business environment are essential for Viet Nam's innovation performance.	Policy instruments should target on improving public governance of the innovation system; developing the human resource base for innovation; strengthening innovation in the business sector and the contribution of public research; fostering the innovation linkages between different actors.
OECD, 2013	Review and evaluate the current innovation policies in Cambodia and Indonesia	Cambodia and Indonesia	Qualitative, descriptive statistics	U-I-G	Research linkages between government research institutions and the small industrial R&D community have been rare in Indonesia. In Cambodia, the nature of its industrial structure and the relative absence of strong innovation actors or strong links between indigenous and foreign-based actors indicate that low efficiency of the innovation system.	Policies should be designed to support building up the science base; encouraging spill overs from FDI; strengthening innovation linkages between different actors.
Kruss et al., 2012	Research on the changing role of universities in firms learning, innovation and national economic development to Nigeria, Uganda and South Africa.	Nigeria, Uganda and South Africa.	Empirical, Cross country comparison	U-I	Nigerian or Ugandan or South African universities adopt models of firm interaction, of technology transfer, incubators or science parks uncritically and uninformed by systematic analysis of sectors and firms in their own contexts, the result suggests they may not succeed in achieving their goals due to the dynamic phases of knowledge-based economic growth.	Firms in services sectors may also turn to universities to complement their internal capabilities; a focus solely on science and technology modes of innovation is likely to lead to erroneous conclusions about university interaction in sub-Saharan Africa.

Cozzens and Kaplinsky, 2011	Understand how systems of innovation and competence building might affect inequality in developing countries	Developing countries, incl. Africa countries	Qualitative, theory development		Investments in building capability to increase absorptive capacity are crucial, not just for growth but for distribution as well.	Investments should be provided for building competitive businesses, improving high equality education, upgrading the capacity of households to use available technologies, as well as encouraging capacity building in local firms especially for small firms.
UNCTAD, 2011	Review Ghana's STI capacities and assess how these capacities are being translated into innovations that help meet the country's socioeconomic development objectives, including supporting economic growth and poverty reduction as well as structural transformation of the economy.	Ghana	Country case study, descriptive statistics	U-I-G	Policy action to promote STI development is required if Ghana is to achieve faster, more sustainable growth and development.	Improving leadership, coordination, and management of STI: 1) Creating incentives and appropriate public support mechanisms for private-sector innovation, technology absorption, and industry-driven research; 2) Growing the science, engineering and technical workforce; 3) Aligning the research and development (R&D) system to socio-economic needs
Pietrobelli and Rabellotti, 2010	Discuss how innovation systems and global value chain (GVC) interact, and how this interaction is likely to affect enterprise learning.	Developing countries, incl. Africa countries	Theory discussion	I-G	Learning mechanisms can vary widely within the various forms of governance of GVC; The relationship between GVCs and innovation system is nonlinear and endogenous; The internal governance of GVC is a dynamic phenomenon that is subject to continuous adjustments and changes, and the nature of the innovation system affects this co-evolution.	Use of "communities of practice," can effectively compensate for lack of geographical proximity.
Mwantimwa, 2008	The relationship of indigenous knowledge and technological innovation to poverty alleviation in Tanzania.	Tanzania	Case study	G-I	Indigenous knowledge creation will be impossible if government of Tanzania will only depend on the knowledge from developed countries without making efforts internally. Technological innovation benefits small farmers and entrepreneurs.	Strategy must be put in place to ensure proper adaptation and use of indigenous knowledge and innovation for higher socio-economic growth and sustainable Development.

Szogs, Cummings and Chaminade, 2008	Discuss the role of intermediate organizations in supporting different forms of interactive learning and capability building in small scale business initiatives in emerging innovation systems in developing countries	Tanzania and El Salvador	Case study	U-I	Intermediate organizations are key in linking actors to each other, strengthening interactive learning and networking capabilities. Their main role is to transfer information from the users to the producers and help them meeting that demand.	Policy and development initiatives should support upgrading and innovation in SMEs in developing countries, explicitly recognizing their capabilities in establishing and developing system linkages, and the networking and learning capabilities that are key determinants of innovation system performance.
Lundvall, 2007	Identify knowledge and learning as the basis for innovation and discuss how different modes of innovation complement each other.	All countries, incl. African countries.	Theory discussion		It is necessary to develop an alternative terminology for less developed countries. The separation and lack of interaction between the knowledge infrastructure and the firms is the most important element slowing down processes of learning and competence building with relevance for economic development.	N.A.
Lall and Pietrobelli, 2005	Develop a concept of National Technology System. Present microeconomic evidence on S&T infrastructure	SSA	Quantitative, descriptive statistics	U-I-G	The study revealed that supply of modern skills is inadequate in SSA countries and the physical infrastructure is weak and often deteriorating. In addition, the inadequacies of the technology system undermine the industrial competence and dynamism.	strengthening the national technology system is necessarily a long-term process and policy supports are needed. Government should allocate substantial resources over a lengthy period to support the creation of new links and networks. It also needs a conducive social, political and economic setting in which enterprises, governments and institutions can plan and implement long-term strategies.
Arocena and Sutz, 2001	This study attempted to compare the National system of innovation between South (Latin America) with North. It identified the characteristics of NSI from a Southern persective and describe a few of the main contextual differences between Latin America and the developed nations in	Latin American countries	Qualitative	U-I	The NSI is existing in the region but in general is weak. As the Uruguayan case shows, there is not a unanimous “social subject” that speaks for the whole society: common people, technicians, elites, government officers, have different perceptions on the matter.	Effectively innovation policies need to be used as a tool in the shaping of NSI; Government should also take into account an actor’s perspective when designing interventions.

	terms of NSI conceptualisation.					
National Research System						
Mouton and Waast, 2009	By using evidence-based approach to compare the national research system, this study describes and evaluates the research institution in African countries.	Africa	Descriptive analyses	University and research institution	Findings suggest that the small scientific communities in African countries are very sensitive to the ups and downs of politics, policies and funding (local or international). Many institutions in developing countries is under-funded. Research in low income countries is often driven by the individual scientist's priorities and interests, and it ultimately aimed at advancing personal (academic) career	Commitment to increased investment in R&D by government in low income countries needs to be put into practice. Government and public need to understand the role of research and knowledge production as an effective way to address development and economic issues such as poverty, infectious diseases, food security etc. Improve research infrastructure such as research and library resources.

*U-I-G: University-Industry-Government; **SSA: Sub-Saharan Africa