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RESEARCH ARTICLE

Effectiveness of National Innovation System of Sri Lanka: examining the roles of universities, S&T institutions and industry

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Abstract: After resolving internal conflicts in 2009, Sri Lanka experienced significant economic growth through infrastructure development and other policy initiatives. However, the pace of growth has since decelerated, and the country now faces numerous challenges related to the sustainability of its progress. Scholars and policymakers have identified a primary issue: the need for a systematic approach to the country's development models. Consequently, this study was conducted to comprehensively examine the policy inputs necessary for optimizing the National Innovation System (NIS) in Sri Lanka, focusing on the three main actors: universities, S&T institutions, and industry. A robust conceptual model was formulated by exploring the existing literature on NIS, their functions, and roles, with particular emphasis on the imperatives of NIS in developing countries. This study aims to understand the roles of these three main actors within NIS, evaluate the effectiveness of their functions, and assess the strength of the networking relationships among them. Based on this conceptual framework, the empirical phase of the study was structured and implemented. This research proposes several policy recommendations based on data analysis to enhance the three primary NIS actors' role effectiveness and strengthen their network relationships, providing a solid foundation for future policy decisions.

Keywords: National Innovation System (NIS), Actors of NIS, Networking Relationships, R&D, Innovation, Sri Lanka.

INTRODUCTION

Innovation is the kickstarter for developing entrepreneurs who contribute to uplifting the social standards and economic development of any country. Accordingly, innovation studies have attracted the attention of many development-oriented researchers while opening a new array of studies on the systems approach of national innovation in the late 1980s. The system approach to studying national-level innovation initiatives has become a mature research domain in the context of developed countries. The theoretical understanding and empirical investigations in the same field of study appeal to more research attention in developing countries. Hence, these underrepresented developing countries must conduct sufficient studies on national-level innovation systems in their contexts and promote entrepreneurial activities based on their research findings (Lindberg *et al*., 2014; Andersson & Billou, 2007).

The composition of elements and their interactions for securing practical national-level innovation is configured as a National Innovation System (NIS), which is the central theme of this study. The authors—Freeman (1988), Lundvall (1992), and Nelson (1993)—have significantly contributed to concretizing the idea of the NIS by emphasizing its importance and figuring out its constituents and functions as a system configuration ensuring effective innovation performance at the national level.

As a result of converging the research focus on NIS in a developing country context, there were several research studies conducted in Asian countries, for example, in China (Boeing & Sandner, 2010; Song, 2013), in

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Thailand (Intarakumnerd *et al*., 2002; Intarakumnerd *et al.,* 2012), in India (Rajan, 2012; Mehta, 2018; Bokachev, 2019), in Pakistan (Naqvi, 2011; Ul Huq *et al*., 2014), in Malaysia (Kanagasundram, 2013), in Philippine (Habaradas, 2008), and in Indonesia (Taufik, 2007; Zu Koecker, 2012). The concept of NIS was also one of the prominent research domains among the researchers in the African region (Toivanen & Ponomariov, 2011; Allard & Williams, 2020), and Latin American region (Lindberg *et al.,* 2014).

It was hard to find such NIS studies in Sri Lanka before 2010 and some postgraduate studies were observed in 2010s. Consequently, studies on different aspects of NIS have been conducted by researchers such as Weerasinghe & Jayawardena (2018), Wickramasinghe & Malik (2018), and Weerasinghe & Dedunu (2021). Against that backdrop, the main objective of this exploratory study is to assess the roles played by universities, S&T institutions, and industry based on empirical findings and to suggest policy changes needed for establishing a more conducive NIS for the economy's growth. The potential impact of our research on policy changes is significant, offering the possibility of establishing a more conducive NIS for rapid economic growth through commercially and socially important innovation.

LITERATURE REVIEW

The concept of NIS

Innovation results from a systematic approach at different levels of society rather than being accidental. Lundvall (1992) has mentioned that NIS includes institutions, interactions, policies, and procedures to promote innovations and use innovations for commercial gains. Edquist & Hommen (2008) extended this idea of NIS by emphasizing its significant determinants that influence the development and diffusion of innovation. Hence, actors have been mentioned as components of innovation systems. The functions that the actors should perform, including the relationships among them, are mentioned as system constituents. The interconnected actors of the NIS make collaborative efforts to create, store, and transfer the knowledge, skills, and resources toward the promotion of innovation at the national level (Metcalfe, 1995).

According to Balzat & Manusch (2004), the NIS research domain tries to understand innovation broadly instead of limiting it to the number of new products. This approach involves a non-linear and multi-disciplinary nature while studying behaviors of interactions and interplays among the system's actors. Increasing the complexity, the idea of NIS was modified with the concept of a 'national innovation ecosystem' presented by Fukuda & Watanabe (2008) to highlight the importance of harmonizing conflicting innovation variables for more sustainable innovation outcomes and practices. Jackson (2011) has enriched the same idea by conducting a critical inquiry to highlight the importance of the national innovation ecosystem and reemphasized the need to address innovation for well-being and sustainability through collaborative attempts.

Accordingly, irrespective of the country's size and economic development level, the concept of NIS becomes more critical to understanding socioeconomic development (Lundvall, 2007). Innovation has become one of the significant concerns among a few in many countries, highlighting the need to study the configuration of the NIS for making fruitful policy imperatives. Edquist & Hommen (2008) have also emphasized that theoretically based empirical research and comparative studies on various NISs are needed to ensure quality inputs for national innovation policies. The importance of formulating an effective innovation policy for persuading the innovation outcome through formal studies is also highlighted by Edler & Nowotny (2015), who suggested two significant functions of innovation policy to cover a wide area of actors and functions of a NIS. Facilitation to develop capabilities and connectivity among actors through a proper regulatory framework was indicated as the first function of a NIS while giving direction for the generation and diffusion of knowledge and innovation was suggested as the second function.

Compositions and functions of NIS

To conduct a complete study, the different compositions of an NIS should be figured out. Three major components of the NIS: constituents, functions, and the boundary are widely recognized. The constituents are of two types: system components or actors and relationships among the actors.

Actors of NIS

North (1994) has introduced many actors directly and indirectly involved in NIS as political bodies, bureaucratic bodies, regulatory bodies, social bodies, educational bodies, knowledge-oriented bodies, non-profit organizations, profit-oriented organizations, and bridging bodies. However, clustering the actors of NIS was one of the main focuses among many researchers in this study area from the inception of the concept of NIS. Concentration on the government, universities, and industry as the main three actors appeared in those studies; meanwhile, it was reemphasized by Etzkowitz & Leydesdroff (2000) with their Triple Helix model (Figure 1). They introduced three stages of triple helixes based

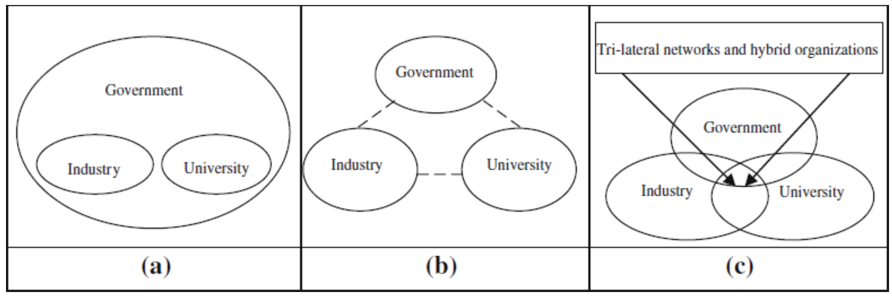

Figure 1: Triple Helix
Source: Etzkowitz & Leydesdroff (2000)

on the centrality and the roles played by the main actors of the NIS. According to the statist model presented in Figure 1(a), the government plays a dominant role, encompasses industry and academia, and directs the relationships between industry and academia. The rigidity embedded in this top-down approach discouraged innovation. Hence, this mode was considered a failed approach to economic development.

Figure 1 (b) presents laissez-faire relationships among three actors suppressing the government's dominant role. However, dispersed spheres with strong borders have created a separation of the actors due to the laissez-faire policy. It prevents solid connections and effective communication required to initiate collective efforts for impactful innovation with commercial viability.

Triple Helix in Figure 1(c) describes the importance of the openness and boundary overlap among the main actors. It encourages more collaborative and hybrid associations by aggressively linking and sharing resources, facilities, capabilities, and information through intermediate steps and interfaces between actors by removing the hard borderlines of the three spheres of the NIS. Creating an innovative environment to encourage university spinoff firms, tri-lateral initiatives, and strategic alliances among firms, government laboratories, and academic research groups was highlighted for an effective NIS.

Although many researchers appreciate the Triple Helix model in NIS studies, Carayannis & Campbell (2009) have introduced 'Mode 3' of NIS, named Quadruple Helix, which extends the Triple Helix by adding 'creative classes,' the fourth helix. The creative class represents the media, creative industries, culture, values, lifestyles, art (which will create public awareness of innovation), and knowledge to create an innovative culture. The Quadruple Helix model emphasizes the importance of these additional elements in fostering innovation. Strengthening the three main actors - the government sector, universities, and the industry- was noticed as relatively weak in the developing countries. Hence, prioritizing triple helix is justifiable in a developing country context as the fourth helix can be merged into a developed triple helix subsequently.

Functions of NIS

Functions performed by the actors in the NIS are essential to promote positive actions and eliminate and deflect hindrances within the system. All actors in the NIS must play multiple roles for their existence while creating an atmosphere for harmonious multiple interrelations and independence. These roles can be categorized into two functions: hard and soft functions. Hard functions are activities related to hard resources and facilities, such as physical laboratories and equipment needed for R&D and innovations. On the other hand, soft functions are linked with behavioral and other soft matters in the organizational settings involved in advising, consulting, networking, and interfacing roles. Soft functions are usually prioritized due to their complexities, although the balance between them is highlighted.

North (1994) discusses four primary functions of the NIS that are to be performed by different actors to ensure the system's effectiveness. Formal constraints linked to patent law, formal criteria for allocating resources for S&T, peer review procedure, technical standards, and norms are included in the first function, and the second function deals with informal constraints – norms, behavioral conventions, and codes of conduct. The third function is the enforcement activities of the first two functions, which include fiscal levies and traditional conventions. The fourth function, the incentive structure, is crucial as it promotes, awards, recognizes, and incentivizes innovative activities. It also introduces tax concessions, which further encourage innovation within the system. Galli & Teubal (1997) suggested some functions that the actors of an NIS should perform.

Accordingly, the role of bridging organizations, the basic market-oriented infrastructure, the availability of soft infrastructures such as information and communication technology, and advisory and consultancy to deal with increased complexity with large numbers of players and various types of networks among players are crucial for effective NIS.

NIS in developing country context

Although NIS studies have emerged from advanced economies since the 1980s, researchers have now turned their attention to NIS studies in developing country contexts. Lundvall (2007) has highlighted the importance of conducting NIS studies in developing country contexts with a focus on the economic development of those countries. With these developments, there has been increased attention to research in NIS and its related areas. For example, Viotti (2002) studied innovation patterns in technological laggards using Brazil and South Korea as two representative cases. A study on NISs in former socialist countries in Central and Eastern Europe was conducted by Freeman (1995) meanwhile, Intarakumnerd *et al.* (2002 and 2012) conducted studies in Thailand representing Asia.

Kayal (2008) identified weak institutional composition, less advancement of S&T activities, and linkages between organizational units, and he suggested that the actors of NISs should play a different role in less developed countries, emphasizing the active role these actors can play in shaping the future of NIS in these contexts. Furthermore, he has attempted to develop a conceptual model for studying NIS in a developing country and tested an empirical model with secondary data available.

Balzat & Hanusch (2004) and Intarakumnerd *et al.* (2012) have revealed that fragmented innovation systems are still present in developing countries and suggested that identifying the lack or weak development of factors affecting poor innovation and finding areas of improvements are needed for upgrading the NISs. Foray (2009) identified two major types of developing countries based on the distinctive features of their NISs. Large and developing middle-income countries are progressing because of their openness to foreign technologies through FDI and international trade, enabling them to improve absorptive capacity. On the other hand, some low-income economies have yet to show much progress in science, technology, and innovation.

The importance of allocating a considerable amount of funds and conducting R&D activities for developing context-based innovation mainly through general-purpose technologies and focusing on local market needs to introduce more inclusive innovation are highlighted by Foray (2009). The World Bank (2008) also emphasized the importance of absorbing knowledge and experiences through FDI and returned migrants for local technology developments and innovation in developing countries. Furthermore, a positive relationship between technology transfer and the reforms of intellectual property rights has been found in middle-income countries as inward FDI and trade are promoted through a more robust patent system (Branstetter *et al*., 2007).

Observing the experiences of newly industrialized Asian countries, Kayal (2008) has emphasized the requirement of inward transferring and exploitation of technologies developed from external sources. Cohen & Levinthal (1990) elaborated on this as absorptive capacity, although it initially focused on firm-level innovation. At the national level, the importance of learning from other countries and acquiring technologies with the capacity of modifying and adapting the knowledge and technologies developed somewhere else to the local contexts is a more practical solution, providing a source of enlightenment and information. Mazzoleni & Nelson (2007) have reemphasized the need for the absorption of knowledge and technologies developed in other countries, highlighting that latecomers perform better than the first inventors of the knowledge as they can learn from first movers and rectify errors and solve the problems with less effort and risk than the first movers.

Galli & Tuebal (1997) have suggested that NIS actors in developing countries work remotely and separately, with weak ties maintained among them. They name the traditional weak ties System 1 (S1) and propose a new, more robustly connected model called System 2 (S2). The transformation of the traditional S1 into the new S2 (Figure 2) is not just a change, but a leap forward. This transformation, with more interactions with subsystems through interface units, a system's functioning that is more central and coupled with techno-economic capabilities, the presence of interfacing units, and a restructured business sector, holds the potential to revolutionize the NIS landscape in developing countries.

The S2 model highlights strong relationships between the industry and university sector, such as collaborative research studies, training programs, and knowledge and technology transfers, by establishing a University Interface Unit (UIU) for mutual benefits. The roles of large firms and capital goods suppliers are also prominent, especially in providing the required facilitation for SMEs through funds and knowledge transfer within the business sector.

Kim & Dahlman (1992) have also highlighted the requirement for policy intervention to develop NIS in developing countries. They have considered the resource-constrained environments in developing countries and suggested that well-formulated policies and strategies

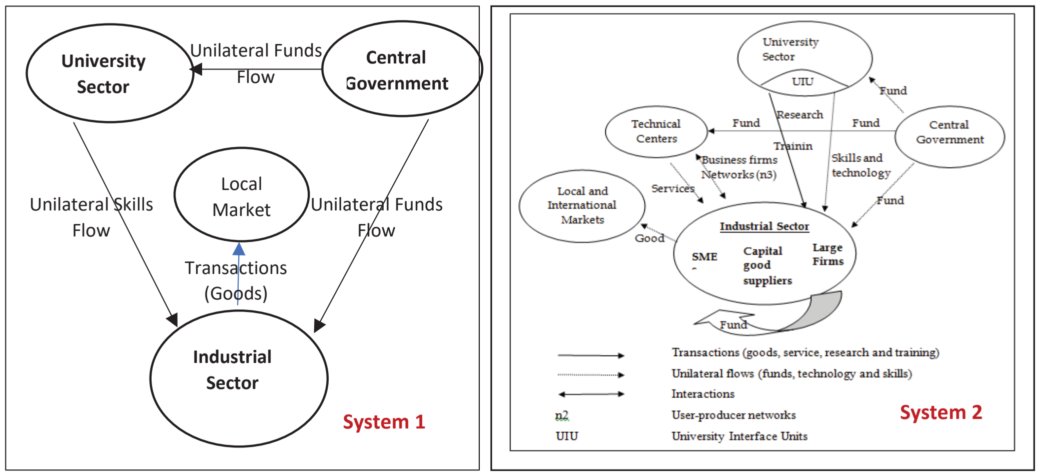

Figure 2: System 1 and System 2 Configurations

Source: Galli & Tuebal (1997)

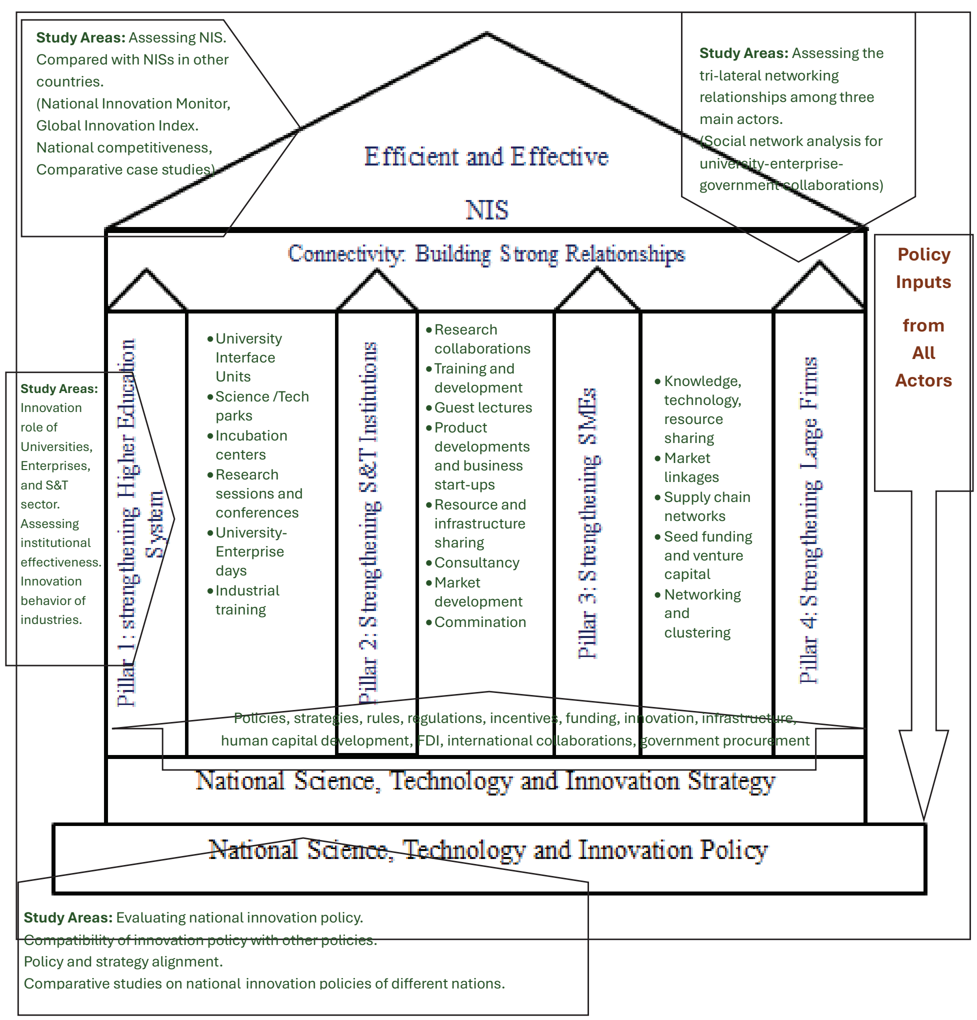

Figure 3: Conceptual model for NIS studies in developing countries
Source: Developed by authors

are essential for managing national-level innovation by configuring well-designed system configurations. Confronting the challenge of making policies in more complex situations and grasping the benefit of unarticulated knowledge and innovation systems is more needed.

Research model

Based on the literature review, the need for concrete conceptualization of NIS in developing countries was recognized. Accordingly, the study model presented in Figure 3 was developed by the authors, who paid attention to multiple dimensions while understanding the need to be practical in conducting this study.

The three main actors and the functions performed by the actors are considered the main body of the framework developed. The government's invention of the NIS was contributed to by several players, such as S&T institutions, the legislation system, the line ministries, and the country's financial sector. However, most innovation-related government actions are implemented through the S&T institution sector of many countries. Previous studies (Nelson, 1993; Kostova, *et al.,* 2008) have also confirmed the role of the S&T sector as the best government representative of the NIS. Aligning with the previous studies and considering the study limitations, the S&T institutions sector was selected as the government representation in this study. Three actors or actor groups should be coherently built upon the foundation created by the innovation policy and strategies. Networking relationships are significant concerns in the NIS concept, and trilateral relationships are highlighted herewith while emphasizing the importance of the iterative process of functioning and re-functioning the process through policy inputs.

METHODOLOGY

As outlined in Figure 3, the three main sectors—the university sector, S&T institutions, and the industry—were assessed by their roles and performance. The networking relationships among the actors were also investigated as a main composition of the NIS. This complexity requires employing both quantitative and qualitative methods to conduct studies. This paper is based on a series of studies conducted by the authors in

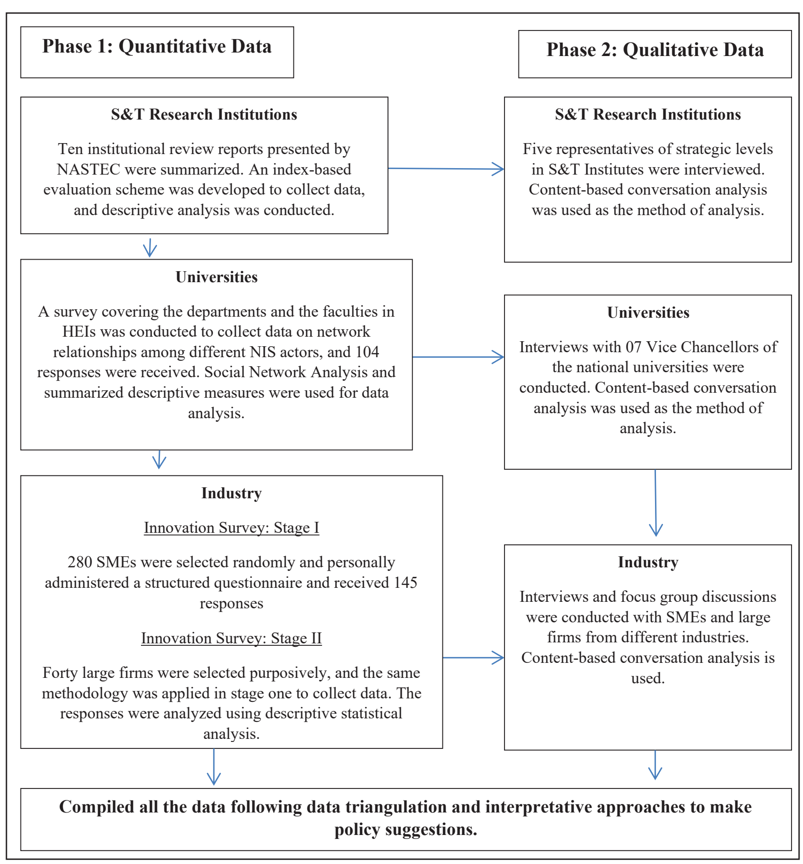

Figure 4: The process of sampling, data collection and data analysis
Source: Developed by authors

collaboration with various stakeholders, using different research methods.

Figure 4 illustrates the set of mixed methods followed by the authors for the collection and analysis of data. The mixed-method approach shows how the quantitative and qualitative phases of the research have been linked. Primary and secondary data were collected using document reviews, surveys, and in-depth interviews. Independent reviewers, experts in the field, evaluated S&T institutions to assess their roles and effectiveness. Their review reports, which were based on rigorous evaluation criteria, were used as one of the leading secondary data sources. Their content analysis was conducted to ascertain empirical findings.

The research process was adaptive and resilient, facing challenges such as dealing with the qualitative and quantitative nature of data, the broad scope of the study, busy executive-level respondents, and large samples with a high non-responsive rate. However, every attempt was made to overcome such challenges and avoid any negative impact on the findings. Primary data was collected through three surveys using the structured questionnaire developed for national innovation surveys. Three units of analysis, namely, the manufacturing SMEs, the large manufacturing firms, and the university units were investigated to collect data on innovative activities and related dynamics in these surveys. Furthermore, in-depth interviews were conducted with the Vice Chancellors, representatives of S&T Institutions, and the representatives of entrepreneurs and entrepreneurial managers to facilitate the explorative research design.

An interview was used to collect opinions on the roles played in R&D and other innovative activities, outcomes of R&D and innovation activities, methods used to evaluate the effectiveness, collaboration with industry, collaborations with other universities, collaboration with policy-making and S&T public institutions, collaboration with supportive interface/bridging institutions, strength of the alumni network, planned changes, challenges, and strategies. The role of academics/researcher, human capital, investments and funding for R&D and innovation, R&D outputs, technology transferring, challenges for R&D and strategies to overcome them, innovation and collaborations, and collaborative and networking activities: with universities, government S&T institutions, private sector firms etc. are the main themes used for analyzing qualitative data of the study collected through interviews.

FINDINGS

Data were collected from different sources according to the study design depicted in Figure 4. They were analyzed to meet the main objective of the study, which was to assess the roles played by universities, S&T institutions, and the industry and to propose policy changes for a more conducive NIS. The three sectors' assessment of the roles played are presented in the following sub-sections.

The role of the university system in NIS

The role of the university system of Sri Lanka was studied through in-depth interviews conducted with seven vice-chancellors to derive the following findings. The vice-chancellors were selected based on those leading, established and recently established universities, ensuring a diverse representation of the university system.

The changing role of academics: Summarized data indicated a considerable tendency to transform traditional teaching and learning into research and innovation. One Vice Chancellor highlighted that:

> *"Our academics and students are highly encouraged and engage themselves in research and development activities with funds provided to them for carrying out research projects, publishing research articles both nationally and internationally, as well as conducting research conferences and symposiums for both the academics and the students."- Vice Chancellor A, interview data.*

Most vice-chancellors expressed ideas that were aligned with the above statement. They provided evidence through their corporate plans, research grant schemes, travel grants, and conference proceedings published by the university, ascertaining the increasing trend in total funds allocated for university research and development activities. However, the opinion of another Vice-Chancellor on the same point should be highlighted. He pointed out that:

> *"…there is a big challenge on how to transform the mindset of some academics and students as it gets reinforced over time –since it is just preparing to teach and learn for a paper qualification instead of the full utilization of knowledge and intellectual capacity for contributing to solving social and economic issues of the country." - Vice Chancellor B, interview data.*

Accordingly, most of the R&D activities recorded in the university system are more internally focused. There is an increasing trend to use R&D facilities and funds mainly to publish research papers and conduct research conferences instead of focusing on commercial or social benefits. A few research projects showed the emerging intention for collaborative work with external institutes and industry, though more was needed.

This study identifies positive trends in changing the role of academics, especially in R&D and innovation involvements, and the tendency to generate funds through different sources. The remuneration system, grants for research and publications, awarding, and increased recognition for R&D and Innovation activities have encouraged a new R&D culture, instilling a sense of optimism about the future of R&D and innovation.

Funding for innovation

Although there is a tendency in trying to generate funds through various sources from all the public universities that have highly depended on government funds, interviews revealed that funding still needs to be improved due to the difficulties in developing the required infrastructure. Vice Chancellor' C' revealed that:

> *"We are provided much money for our infrastructure development now. Further, we can allocate the funds we generate for our research and development activities. It is a great strength as we earn the required funds through different sources". - Vice Chancellor C, interview data.*

Challenges to innovation are mainly associated with the need for more funding, as the government must also pay attention to other priorities. If we have more funds, we can do far better than the present work on R&D and Innovation. This challenge emphasizes the urgent need for more financial support for innovation in Sri Lanka.

Most universities, especially established universities, have prioritized generating funds through fee-levying courses such as master's degrees, external degrees, diplomas, and certificate programs, which restrict academics' time for research. Conducting higher-level or postgraduate courses helps improve the university's research capability, although other fund-generating programs have little relevance for R&D activities.

The government and some donor agencies have addressed this issue in the university system and have taken some actions to establish incubators and other R&D facilities in the university sector. One such incubator was established with funding from the National Enterprise Development Authority. As revealed in the study, some private partnerships have been established with the University of Moratuwa, the University of Colombo, and the University of Peradeniya.

Research and innovation outcomes

It is revealed that the present level of research and innovation outcomes needs to be increased. A proper system of recording these statistics must be present in the university system. These research and innovation involvements are more on an individual basis than through organized and proper institutional procedures. This issue has been addressed by universities and the University Grants Commission (UGC). The UGC, as the primary regulatory body for higher education in Sri Lanka, has taken several actions to collect annual data on R&D and innovation activities. However, most monographs and academic papers are the primary outcome of research and development. Incidents about new products, services, and processes developed by students and academics in the university system are rarely recorded, although they are increasing.

Changing the mindset

It is revealed that students' examination-oriented learning approach needs to be changed to include research-led knowledge development and innovation-oriented sophistication techniques. As the key stakeholders, future researchers, and innovators, students must engage in a self-oriented, research-led learning process.

> *"A major challenge for the university education system is the students' current mindset. It is arguable, and we need to determine correctly whether the students demand learning or seek the paper qualification. The educational culture of the country has been guiding them to seek paper qualifications instead of engaging themselves in knowledge creation through research and innovation." - Vice Chancellor D, interview data.*

The academic mindset in the system is also required to be relevantly adapted to friendly circumstances for research and innovation, moving away from the traditional teaching role. Most academics engage in research and innovation to fulfil promotion requirements.

Overall, the efficiency and effectiveness of the innovative activities and commitment of the national university sector should be further improved to meet the expectation of building a strong NIS. This need is reasoned out by several factors, such as internal resource limitations, the traditional culture of the university system, poor external orientation, and the perception of outside parties on the traditional university system, as also confirmed in (Intarakumnerd *et al*., 2012; Dutz & O'Connell, 2013; Weerasinghe & Dedunu, 2021).

The role of S&T institutions for innovation

The findings are summarized below, based on the data collected by interviewing the executive representatives of selected S&T institutions and the evaluation reports published by the National Science and Technology Commission (NASTEC). The evaluations were carried out to assess S&T institutions using nine criteria, a process that was greatly informed by the insights and perspectives of our stakeholders: Institutional response to external and internal environment in planning organizational strategy (MP1), Planning S & T programs and priorities (MP2), Planning S & T projects (MP3), Project management and maintenance of quality (MP4), Human Resource Management (MP5), Management of organizational assets (MP6), Coordinating and integrating the internal functions/ units/activities (MP7), Managing information dissemination and partnerships (MP8), and Monitoring, evaluation and reporting (MP9). A summary of the evaluations with weighted average performance indicators is tabulated in Table 1.

The content analysis of qualitative data, combined with statistical analysis, has yielded specific findings. These findings which are the crux of our research, are as follows:

Managerial performance

Based on the evaluations carried out by NASTEC on the managerial performance of nine S & T institutions (Table 1), five aspects of managerial activities have been described as showing an average or below average performance in all the ten organizations evaluated. These are namely, 1) performance in the project planning, 2) human resource management, 3) coordinating and integrating internal functions, 4) managing partnerships and information, and 5) monitoring, evaluation, and reporting of institutions. Thus, compared to the performance among ten institutions, NSF has recorded satisfactory ratings in these areas according to the evaluation results.

Institutional framework

Many institutions are established for S&T and innovation research and facilitation for R&D activities, which are operated under the purview of the Ministry of Science and Technology. The NASTEC is the apex body for policy formulation and advisory services on science and technology matters in Sri Lanka. Whenever

Table 1: Summary of evaluations of nine managerial performance indicators

Measurement Criteria	Measurement Criteria	IFS	NERDC	NSF	Arthur C.	Atomic	SL Acc	ITI	NBRO	METEO	Coconut Re
MPI_1		1.89	1.89	2.44	1.78	2.25	2.5	2	1.78	1.56	2
MPI_2		1.9	1.44	2.43	1.7	2	2.2	1.56	2.2	1.4	2.1
MPI_3		2.1	1.5	2.4	1.7	2	1.88	2	1.9	1.33	2.7
MPI_4		2.1	1.9	2.33	2.3	2	2.63	2.5	1.8	1.4	2.1
MPI_5		2	1.25	2	1.63	1.88	2.14	2	1	1.13	1.88
MPI_6		2	2.43	2.2	1.86	2.57	1.5	2.8	2.14	1.33	1.57
MPI_7		1.83	1.67	2.5	1.83	1.83	2	2.2	1.33	1.33	2
MPI_8		2	1.25	2	1.5	1.75	1.33	2	1.75	2	2
MPI_9		2	1.4	2	1.4	1.8	2.2	1	1.2	1	1.8

Source: Author developed based on NASTEC Evaluation Reports (2012) an institutional framework is available, it always emphasizes the necessity of coordinating with other institutions. This fact was also confirmed by the officers interviewed. However, the study findings revealed poor interrelationships and partnerships for information sharing among evaluated institutions. An official from NASTEC who was interviewed in this study stated that,

> *"We are trying to ensure uniformity across the institutions becoming involved in the process of the evaluation of the performance of S&T institutions and publishing the information to the public to convert those institutions as responsible entities to capitalize public funds more effectively and efficiently by contributing 'impactful' S&T and innovation outcomes to the society. However, we feel that most institutions are still isolated, and many duplications and repetitions remain in the institutional system." – Officer from NASTEC, Interview data.*

This reluctance to work collaboratively is present in several institutions, and most interviewees were interested in working independently. Many institutes operate with rather conventional scientists and researchers who need to adapt more readily to changing their old working style. It has created a comfortable zone for those scientists and researchers to maintain a life of comfort and convenience with only a few or no work-related issues.

Funding and other operational limitations

The study revealed several problems encountered by S&T institutions, including funding limitations (from both the public and private sectors), a shortfall in required skills, inflexibility created by rules, regulations, and procedures, and a lack of motivation arising from the prevalent culture for innovative projects. However, the need for consistent strategic direction has been more concerned due to frequent government changes and non-scientific ways of shuffling and re-shuffling Cabinet portfolios, underscoring the urgency and importance of this issue.

Insufficient funds due to solely relying on government funds for research and innovation is the leading cause for the dearth of quality research and innovation outcomes. The interviewed officers expressed their anxieties, concerns, and problems and revealed the stark reality of S&T institutions in the country, highlighting the gravity of the situation.

> *"We are faced with a big threat of recruiting and retaining high calibre scientists and technologists because of dearth or restriction of funds. Most young graduates stay with us to the utmost for less than two years till they find another well-paid job in the private sector or secure a placement for their higher education. We are losing capable people as we do not have enough funds to start attractive research projects or pay them as they expect, making these institutions ineffective." NERDC Official, Interview data.*

However, one officer from NSF mentioned that people are reluctant to apply for positions, and the available funds obtained through different grant schemes for R&D and innovation are rarely used. Thus, all kinds of lengthy formal procedures are in practice, and they are revealed to be the barriers to applying for such grants, as stated by the respondents. They revealed that funds are primarily utilized for higher educational purposes as it is a more convenient way of utilizing funds than engaging in impactful research and innovation projects.

Inward orientation

Many institutes are highly inward-oriented and follow the 'wait and see' course of action. Scientists and technologists mainly work inside the institutions and activate only if funds and inquiries reach their workplace. An officer from NERDC mentioned:

> *"We are eagerly waiting for problems to come to us from the industry as we can solve most of the industrial problems. However, we do not have a system, capacity, or enthusiasm whereby we could go to the sites and see the problems faced at the grass-root level and develop solutions accordingly." NERDC Official, Interview data.*

This point of view is further supported by the statistics collected (Table 1) through NASTEC evaluations on the innovation and research outcomes of the ten S&T institutions. It presents a minimal number of impacted outcomes produced by these institutions during the evaluation period. They mainly focus on services such as testing products, consultancy, and issuing certificates to the industry.

Intellectual property rights

The need for improved communication and trust in the patenting procedure in Sri Lanka is a significant finding.

Delays in the patenting process, often attributed to the unavailability of skilled scientists and technologists for evaluating patent applications, can be discouraging for patent applicants. This particular finding underscores the importance of public awareness and understanding of the patenting process to encourage more patent applications.

The officer-in-charge interviewed by the National Intellectual Property Office (NIPO) accepted these ideas and supported the entrepreneurs' opinions.

> *"We need to understand the problems embedded in our processes due to the limited capability of the IP Office and the problems we face in obtaining the services of experts even though we are a government organization. It takes time to send the applications to suitable evaluators, sometimes externally and following the dilatory procedures. However, we try our utmost to ensure innovation protection, although some inventors and innovators have qualms about information leakages." – Officer from NIPO, Interview data.*

Public-private partnerships

The importance of promoting Public-Private partnerships for R&D and innovation cannot be overstated. Despite this, only two such collaborative organizations have been established. The establishment of more such partnerships, like the successful examples of Sri Lanka Institute of Nanotechnology (Pvt) Limited (SLINTEC) and Polipto Lanka (Pvt) Limited, could significantly boost the S&T sector. It's worth noting that the role of these institutions has remained marginal and has yet to be considered for NASTEC evaluation.

Innovation outputs of S&T institutions

Based on the innovation output data for ten selected S&T institutions summarized in the NASTEC Annual Reports (2013), the recording process of innovation inputs and outputs of those S&T institutions needs to be revised. Measuring the effectiveness of achieving goals and objectives and efficiency in resource utilization of the institution remained utterly impossible due to a lack of data. Maintaining a standard system for collecting innovation input and output data in the government S&T institutions is imperative to ensure their effectiveness.

The above findings on the role of S&T institutions were also confirmed in previous studies by Jackson (2011), Etzkowitz & Leydesdroff (2000), Carayannis & Campbell (2009), and Galli & Teubal (1997) conducted in various country contexts. Policy and strategic intervention are emphasized to make this sector more effective in contributing to NIS in Sri Lanka. More attention must be paid to developing their human resources capacity and other modern facilities to create a creative environment for research and innovation.

Assessing the role of industry for innovation

This section elaborates the research findings of the two surveys conducted on 140 manufacturing SMEs in the Western province of Sri Lanka and 40 private sector large-scale manufacturing firms in the Colombo district. Further, interviews conducted with the firm's representatives are also included in the findings.

Study findings on the role of SMEs

The first survey of this study gathered data from manufacturing SMEs in the Western province of Sri Lanka using a well-tested CIS survey instrument. A sample of one hundred forty-five completed questionnaires was collected with information related to innovation inputs, outputs, and networking relationships. Despite their commitment to enhancing innovative capacity, SMEs must sufficiently acquire external knowledge for improvements. Data from 136 respondents indicate that only 19 organizations acquired new machinery and equipment, whether locally or from abroad; 14 organizations allocated funds for in-house R&D activities; and 12 organizations invested in acquiring external knowledge, such as purchasing patents, designing, and paying for consultancies.

The investigation into firms' innovative activities revealed a remarkable level of involvement in product and process development, with 38.6 percent to 52.9 percent of the observed firms actively participating. Notably, 95 percent of these innovative activities were new to the firm, demonstrating their resilience and determination to survive in a competitive market. While these innovations did not always lead to significant financial gains, they played a crucial role in helping the firms meet the demands of their customers and stay competitive.

In addition to the focus areas, the study identified innovations in management, operations, marketing, and daily routines. Many firms need to participate in innovative activities within these non-production areas actively. Instead, most organizations continued to rely on traditional management practices rather than exploring new, cost-effective solutions. A few firms demonstrated strength in management and marketing innovations within the selected industries. However, many firms remained stagnant or experienced downturns due to inadequate marketing and management practices. Additionally, 57 respondents found new markets within Sri Lanka, while only 14 firms accessed foreign markets in the past three years. This finding highlights the solid local market orientation of SMEs in Sri Lanka, which limits their potential by confining them to a small domestic market rather than seeking opportunities in the global arena.

The survey further revealed limited connections between SMEs and the university system. Thirty-five organizations reported a need for more understanding about the potential university support for promoting innovation. Conversely, the 18 organizations that maintained good relationships with universities expressed a keen interest in strengthening these ties to improve their products and processes through innovative solutions. The perceived importance of university support is highlighted in seven key areas.

The survey confirmed the perceived low importance of facilities and support the university system provides for business innovation and development. Most organizations needed to show more appreciation for external information sources used for innovation. Accordingly, organizations relied heavily on internal data sources, with 54.2 percent ranking them highly important. This reliance on internal sources contributed to limited innovative capability and insufficient innovations within the sector.

Approximately 10 percent of the companies had strong relationships with external organizations, such as consultancy firms, research institutes, universities, and government institutions. However, 29.2 percent of respondents had formal relationships with their suppliers, 24.3 percent maintained linkages with clients or customers, and 16 percent connected with competitors and firms in the same industry. This limited networking contributed to their restricted exposure to innovation through knowledge spillovers from sources where new knowledge is generated.

The study also investigated the obstacles hindering the innovative efforts of manufacturing SMEs in the Western Province of Sri Lanka. According to the survey, key barriers included the high cost of innovation, lack of internal and external funding sources, shortage of skilled personnel, insufficient information on technology, and the country's poor economic condition, which limits the purchasing power of the population.

Level of innovation

Based on the findings discussed above, the innovative activities of SMEs are fundamental, low-cost oriented, and low-tech, new to the firm product and process innovation compared to other types of innovation. This sector shows a low level of innovation as in many developing countries, and it can be further improved through different strategies.

R&D investments

Due to funds constraints, investments in R&D and the acquisition of new technology are rarely reported. Hence, most SMEs use low-cost and locally developed reconditioned or foreign-used technologies, such as repairing and using old machines elsewhere. Moreover, SMEs are confronting competitive pressure, as mentioned in a respondent's opinion below.

> *"We are always struggling with local competition in the market to reduce our production costs. Especially how we can easily recover the investment in innovation and new technologies; it is a risky job, as we mostly compete with low-cost products. Customers are not ready to pay an additional price for innovation." Entrepreneur B, Interview data.*

Relationships

The study found that SMEs with other firms, S&T institutions, and universities maintained minimal networking relationships. SMEs were highly inward-oriented and maintained relationships only with their main value chain activities, such as purchasing and selling. They still need to understand how other firms, universities, and S&T technology institutions can help them engage in innovation.

Constraints for innovation

The study found that the constraints of the high cost of innovation, dearth of internal and external funding sources, paucity of skilled personnel, lack of information on technology, and the prevalence of the country's poor economic condition restrict the purchasing power of the people, triggering many significant restraints on innovations.

Absorptive capacity

The SMEs' poor absorptive power was revealed due to their feeble volition regarding R&D investment and acquisition of S&T human capital. Thus, insufficient attention to knowledge creation and accumulation by the private sector in Sri Lanka was reported. Many respondents believe such relationships are mildly essential or unnecessary for their business operations. More evidence of investment in knowledge acquisition is needed.

Operating in foreign markets

Foreign markets prevailed shallowly, and almost all the SMEs were locally oriented. Only seven organizations recorded some foreign collaborations related to ownership or management. A few firms exported mainly agricultural products such as dehydrated vegetables, processed foods, and beverages.

Anderson & Billou (2007), Intarakumnerd *et al.* (2012), Dutz & O'Connell (2013), Intarakumnerd *et al.* (2002), and Cohen & Levinthal (1990) confirm the above findings in their studies of SMEs in developing countries. Overcoming these challenges through the right policies and strategies can significantly benefit SMEs and developing countries' economies.

Study findings on the role of large firms in industry

Following the first survey, a second was conducted to investigate large-scale local enterprises using the same CIS questionnaire. Data were collected from 40 large manufacturing firms in the Colombo district of Sri Lanka. The findings revealed a significant commitment to human capital development in these firms, with five organizations employing more than 80 graduates, demonstrating their dedication to strengthening innovative capabilities. Similarly, there was a considerable increase in diploma holders employed by these firms, indicating a promising future for innovation in Sri Lanka.

The survey data revealed that 37 respondents engaged in R&D activities to some extent. However, eight firms did not have any employees in R&D, while 21 firms reported having 1-10 R&D employees. The remaining eleven firms employed more than ten R&D personnel. Additionally, 27 firms did not report any R&D expenditure for the year, while the other 13 firms made some investments. Only three companies recorded investments ranging from Rs. 300,000 to Rs. 1,000,000. There was minimal expenditure on acquiring R&D from external sources, with just four firms making nominal investments. Expenditure on acquiring external knowledge, introducing new markets, and new design costs remained minimal, while only a few companies recorded costs for training and development and purchasing new machinery.

Respondents were asked whether they had licensing agreements with other parties to assess the connectivity of the selected firms in terms of knowledge creation. Twenty firms reported agreements with principal companies to produce or sell global products in Sri Lanka. Another significant investment in technology acquisition involved purchasing machinery and equipment. Thirty-six firms indicated they had acquired new machinery and equipment during the study period. Of these, 17 firms imported their machinery, 18 purchased both local and imported machinery and only one bought machinery solely from the local market. This result indicates that local firms are exposed to global technologies by acquiring advanced machinery and equipment.

Responses regarding funding support from various organizations revealed the stark reality of limited opportunities for obtaining such facilities. Six firms received financial assistance from local and regional authorities, while only three were supported by the central government. Additionally, only two firms benefited from international or other organizational funding. Most companies reported insufficient R&D funding, training, subsidies, tax rebates and incentives, technical support, and infrastructure facilitation needed to be more robust. However, 17 firms notably praised the availability of government loans and grants for innovation.

Regarding innovative outcomes, the study found that only one patent application was recorded yearly, with a single patent granted. One industrial design was registered. No copyright registrations were recorded during the study period, while four Trademark registrations were included. Many respondents expressed a need for more awareness and confidence in the formal intellectual property protection process, indicating a low interest in safeguarding intellectual property. The survey aimed to assess each firm's involvement in innovation activities. Seventy-five percent of companies rated institutional support from S&T institutions poorly, with about 25 percent indicating that such support needed to be more present. A few organizations reported having strong relationships with universities to bolster innovation.

The responses indicate noticeable innovations, including the introduction of new products, improvements to existing products, and implementing new or enhanced processes. Among these, improving existing products received the highest average ranking. Additionally, respondents reported engagement in quality initiatives, new routines, procedures, and operations, new management and marketing innovations, and in-house innovative programs. However, the focus on domestic and international market development and reverse engineering practices is less intense than other types of innovation. There is moderate involvement in new approaches to building relationships with external parties.

The study also examined relationships with government, S&T research institutes, universities, and other firms across different industries to explore their impact on firm innovation. However, it found limited linkages among firms in different industries, a concerning trend that hampers collaborative innovation. Instead, firms primarily connect with suppliers, clients, dealers, and other firms within the same value chain to maintain efficient daily operations. There were no significant alliances among firms within the same industry or with competitors to create new knowledge and engage in collaborative innovation, highlighting a key area for improvement in the Sri Lankan innovation landscape.

Level of innovation

According to the findings, there is a more positive indication than what was revealed in SMEs. The introduction of new products, improvements of existing products, introducing new processes, and improvement of existing processes are discernible in these responses. In addition, it was confirmed that there was considerable engagement in innovation activities such as quality initiation, new routines, procedures and operations, new management and marketing innovation, and the introduction of in-house innovative programs.

Human capital

The large firms in the sample have employed many knowledgeable workers with university degrees and diploma qualifications. Compared with SMEs, large firms are good at employing trained people, diploma holders, and graduates in their firms, enabling them to engage in in-house innovation in different areas. However, due to several other factors, private organizations are restricted in employing competent experts such as PhD holders, restraining their journey for innovation. The tendency for skill migration is considered a critical constraint.

Technology transfers and absorptive capacity

The study found several licensing agreements with different principal companies facilitating the production or sale of commodities as global products in Sri Lanka. Similarly, the purchase of new machinery and equipment as a method of technology borrowing is used by 36 firms during the period. Large firms are more capable of investing funds for innovation and the correct calibre of employees who hold diplomas and degrees and are competent enough to absorb new knowledge.

Networking relationships

The study revealed that almost all sources of innovation are considered necessary by the respondents and that firms' orientation for joint innovation activities supports the idea that there is a moderate level of involvement in new approaches to relationship building with external parties. Large firms have also used information within the firm to find new ideas for innovation, such as those of SMEs. Learning through competitive actions was also stressed by many firms, and it supported the idea of staying competitive through innovation. Connections with competitors, government institutions, and private research institutions must still be higher.

Funding for R&D and innovation

Responses to the questionnaire substantiated the idea that most firms need help with the inability to bear high costs related to innovation and a dearth of expedient funding sources. Allocation of R&D funds is recorded as inadequate among many firms. As confirmed by previous studies, only a few firms have received some financial assistance from the local and regional authorities, the central government, and international and other organizations.

Intellectual properties

Similar to the IP recorded in SMEs, only one patent per year was recorded during the study period. Many respondents were unaware of patents and expressed self-assurance that the formal process of safeguarding intellectual properties prevails at a low ebb. However, almost all respondents identified the importance of innovation for improving organizational performance to different degrees.

Support rendered by the government and S&T institutions

According to the responses, the government's support for innovation through R&D funding, training for R&D, subsidies, tax rebates and incentives, technical support, and infrastructure facilitation is very low. The institutional support provided by the S&T institutions is also ranked at a low level. Moreover, the unavailability of the requisite information and unfavorable domestic market conditions contributed to the weakening of innovation in the firms.

The above findings related to industry firms have also been confirmed or tested in previous studies conducted by Galli & Teubal (1997), Cohen & Levinthal (1990), Dutz & O'Connell (2013), and Intarakumnerd *et al.* (2012).

Strength of the networking relationships among key actors of NIS

Data collected from the departments and faculties were used to assess networking relationships among universities, S&T institutions, and industry. There were 104 responses, resulting in an 18 percent response rate. These relationships were evaluated based on five dimensions: 1) the frequency of joint research activities; 2) the frequency of inviting personnel for guest lectures;

3) the extent of mutual joint research conferences; 4) the frequency of workshops, meetings, training, and consultancies for skill and knowledge sharing; and 5) the frequency of shared research and development infrastructure. Social Network Analysis (SNA) was employed to analyze the data and measure the strength of relationships among the selected actors, using summary statistics and standard drawings in NodeXL application software.

The findings, as summarized in Table 2, underscore the need for stronger collaboration for innovation and competitiveness. The highest number of connections (269) were recorded among academic units, followed by S&T institutions with 104 connections. However, no significant relationships were found between the university sector and industry. This highlights the urgent need for stronger collaboration to foster innovation and competitiveness. Only five private sector firms maintained ten networking relationships, confirming the limited networking relationships between the university sector and industry firms.

Figure 5 presents the graphical outputs for these three partnerships, clearly showing that the industry is more isolated than the other two sectors. This isolation could potentially hinder the flow of knowledge and resources, which are crucial for innovation and competitiveness.

Networking relationships among university units

The most vital networking relationship found among all the network relationships tested in this study is the one among university units. The overall strength of the relationships showed that most connected universities are well-established. The University of Colombo maintains a leading relationship in building the university's capabilities, according to statistics. The most frequent type of relationship is related to exchanging academics for visiting lecturing purposes. The second highest number of relationships is maintained for conducting workshops and training. A moderate level of relationship is maintained in conducting joint research and joint-research conferences, while a minimum relationship is maintained in sharing R&D facilities within the university system. Hence, the commitment to engage in collaborative activities for S&T-led innovation is recorded as a minimum.

Networking relationships between the universities and the S&T institutions

The survey results presented the overall relationships maintained by the university sector with the S&T institutions. NSF is the most connected institution with the university sector, and it gains 22 direct relationships with the departments and faculties of many universities. These relationships are more scholarly-oriented collaborative work than technologically-oriented relationships, instilling confidence in academic collaboration.

Networking relationships between the universities and the industry

As per the data gathered, relationships among these two sectors were marginal. Out of the 104 responses from the university Departments and Faculties, the recorded relationships between the university sector and the industry are 65 (Joint-research-12; Visiting/guest lecturing -15; Joint Conferences – 13; Conducting workshops and training-15; and Sharing R&D infrastructure – 10). The findings of this study prove the existing weak relationships between the university system and the industry sector.

Networking relationships between the S&T institutions and the industry

Surveys covering both SMEs and Large firms revealed minimal connections between SMEs and S&T Institutions, while a few relationships were recorded with large firms studied. This study has underscored the urgent need for science and technology inputs to be increasingly multi-disciplinary and multi-institutional with multi-sectoral approaches.

In summary, all those networking ties are weaker

Table 2: Networking relationships among actors

Graph Dimensions	Uni-Uni	Uni-S&T	Uni-Ind
Vertices	95	49	15
Unique Edges	265	104	10
Edges With Duplicates	4	0	0
Total Edges	269	104	10
Applied NodeXL Version 1.0.1.350			

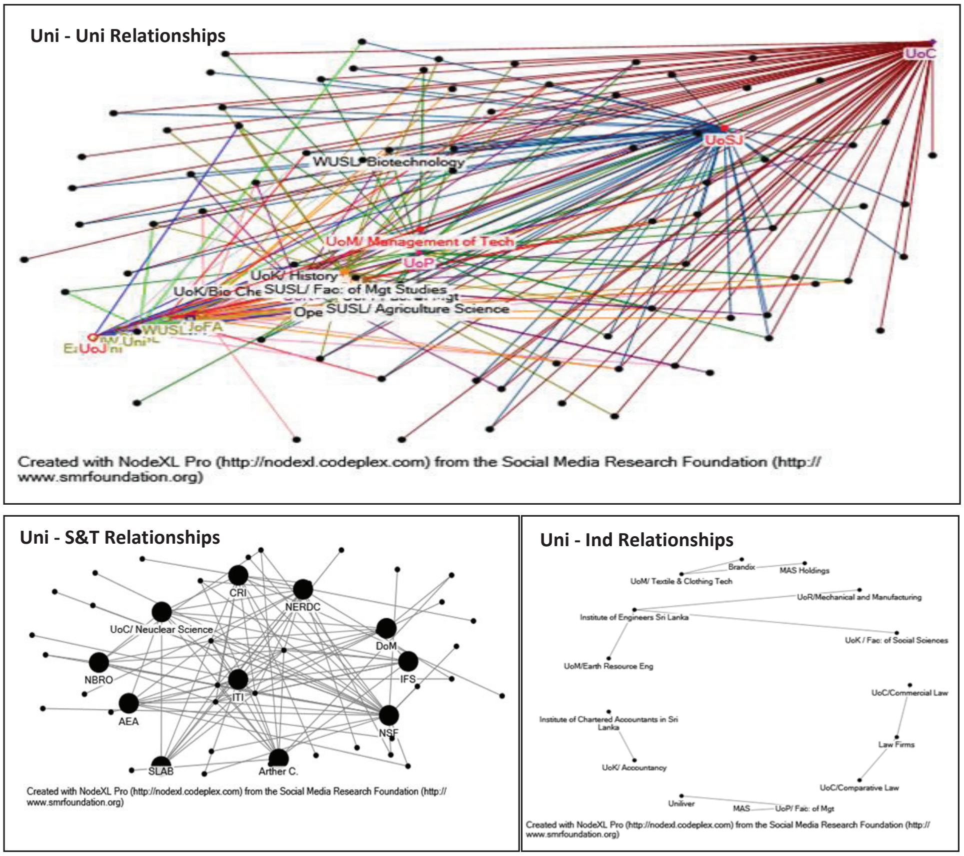

Figure 5: Three types of networking relationships
Source: Survey data

than the requisite level for a nation to become innovative and competitive and achieve better NIS. This is a similar situation described by ‘laissez-faire’ mode in the Triple Helix II (Etzkowitz & Leydesdroff, 2000) and confirmed with ideas of Kayal (2008) and Intarakumnerd *et al.* (2012) regarding NIS of developing countries characterized by isolated individual actions for innovation with fragmentation and separations among the key actors of the system.

Recommendations for policy changes and practitioners

The recommendations provided in the study underscore the necessity of a multifaceted approach to strengthening the NIS of Sri Lanka through enhanced connectivity and robust institutional frameworks. The analysis identifies four primary pillars—higher education systems, S&T institutions, SMEs, and large firms—as critical components for fostering innovation. Each pillar’s unique challenges and proposed strategic interventions are designed to create a synergistic environment conducive to innovation and development.

Firstly, the higher education sector is pivotal in cultivating a culture of innovation. The study recommends a transformative approach to the role of academics, emphasizing the alignment of promotion and rewarding schemes with the triad missions of universities: teaching, research, and community engagement. This role complexity entails redefining academic workloads to incorporate rigorous R&D activities and community engagements. Additionally, the introduction of education reforms aims to nurture graduates with modern skills such as creativity and problem-solving, moving away from examination-oriented teaching. Establishing research centers and tech transfer offices is also crucial to bridging the gap between academia and industry, fostering an environment that supports innovation and practical research outcomes.

Secondly, strengthening S&T institutions requires a robust coordination mechanism and continuous monitoring. The study advises against creating new institutions and advocates for enhancing existing frameworks like the National Science and Technology Commission (NASTEC). NASTEC, as the primary body responsible for coordinating and promoting scientific and technological research in Sri Lanka, can play a crucial role in this enhancement. Key recommendations include bolstering these institutions with the necessary human capital, funding, and infrastructure and fostering a motivational environment to attract and retain skilled researchers. Furthermore, bridging the gap between S&T institutions and industry through establishing techno-parks and incubators can facilitate practical research applications, thereby enhancing public-private partnerships and intellectual property rights management.

The third pillar focuses on SMEs, often the backbone of economic innovation. However, they need help in R&D investments and innovation capacity. The recommendations highlight the need for intermediaries like technology centers, which provide SMEs with access to advanced technologies and technical expertise, and business incubators, which offer a supportive environment for the growth and development of SMEs, to support SMEs. Enhancing communication about existing funding schemes, introducing new financial incentives, and fostering linkages with government institutions and universities are crucial. Additionally, building a research and innovation infrastructure accessible to SMEs can mitigate the uncertainties associated with innovation efforts, promoting a more vibrant and competitive SME sector.

Lastly, large firms are essential drivers of innovation within the NIS. The study suggests enhancing client-based advisory services, which are consultancy services provided to large firms by experts in their respective fields, innovation infrastructure, and funding opportunities to motivate large firms to expand their innovation activities. Policies should focus on developing human capital tailored to industrial needs through collaborations between education institutions and industries. Encouraging technology transfers via collaborative research projects and promoting network relationships through incentives like tax concessions and joint research projects can significantly improve the absorptive capacity and innovation output of large firms.

The policy and strategic recommendations of the study are aimed at creating a cohesive and well-connected NIS that leverages the strengths of its primary actors—higher education institutions, S&T institutions, SMEs, and large firms. The recommendations provide a comprehensive roadmap for fostering a dynamic and effective innovation ecosystem by addressing each pillar's specific challenges and enhancing their interconnectivity. Implementing these recommendations is essential for achieving sustainable economic growth and technological advancement.

CONCLUSION

This study delved into the roles of universities, S&T institutions, and industry within the NIS of Sri Lanka, highlighting their interplay and effectiveness in fostering economic growth and innovation. The research findings underscore a crucial point: while there have been significant strides in infrastructure development and economic growth post-2009, there is an urgent need for a systematic approach to enhance the effectiveness of the NIS. This is a recommendation and a call to action to ensure sustainable progress.

The conceptual framework employed in this study underscore the importance of robust interactions and relationships among the three primary actors: universities, S&T institutions, and industry. The empirical phase of the research revealed a stark reality: the existing networking relationships among these actors should be more cohesive and developed. This fragmentation not only hampers the potential for collaborative innovation but also severely limits the ability of the NIS to contribute to the country's economic and social development.

Universities in Sri Lanka play a crucial role in knowledge creation and dissemination. However, their contributions to applied research and commercialization of innovations are limited by inadequate funding, lack of infrastructure, and insufficient collaboration with industry. Enhancing university-industry linkages through collaborative research projects, internships, and knowledge transfer programs is essential to bridge this gap. University Interface Units, which serve as intermediaries between universities and industry, could facilitate stronger partnerships and mutual benefits by coordinating joint projects and facilitating technology transfer.

S&T institutions are pivotal in advancing technological capabilities and providing the necessary support for innovation. However, the study identified a need to integrate these institutions within the NIS framework more effectively. Policy interventions to strengthen the infrastructure and operational capabilities of S&T institutions, coupled with incentives for collaborative ventures with universities and industry, such as joint research funding and tax benefits for joint projects, are necessary to boost their contributions to national innovation.

While demonstrating innovation potential, the industrial sector is constrained by regulatory challenges, limited access to advanced technologies, and a need for a more skilled workforce. Policies fostering a conducive environment for R&D within the industry are imperative to address these issues. Tax incentives, grants, and subsidies for R&D activities can stimulate industrial innovation. Moreover, fostering a culture of continuous learning and skill development through industry-academia partnerships can enhance the innovation capacity of the workforce.

Based on the findings, this study proposes several policy recommendations to enhance the effectiveness of the NIS in Sri Lanka. First, the government should implement policies that encourage more vital collaboration among universities, S&T institutions, and industry. Second, increasing investment in R&D and innovation infrastructure is crucial. Third, establishing formal mechanisms for knowledge transfer and commercialization of research outputs, such as technology transfer offices and industry liaison offices, to bridge the gap between academia and industry. Finally, creating an enabling environment through regulatory reforms and incentives to attract investments in innovation and technology.

The study highlights the importance of a cohesive and well-integrated NIS for Sri Lanka's sustainable economic development. By addressing the identified gaps and implementing the proposed policy recommendations, Sri Lanka can harness the full potential of its universities, S&T institutions, and industry to drive innovation and economic growth. The findings of this research contribute to the broader discourse on NIS in developing countries, providing valuable insights for policymakers and stakeholders aiming to optimize their national innovation ecosystems.

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