Mapping the National System of Innovation in Swaziland
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Abstract

This study maps the national system of innovation (NSI) in Swaziland using national research and experimental development (R&D) and innovation surveys. The study identifies the actors and activities in the NSI. It finds that investment in knowledge creation is very low; expenditure on R&D is 0.26% of GDP, while knowledge flow mechanisms between universities and industry are weak. It also found that there is a low capacity of science technology and innovation (STI) personnel in especially the fields of science and engineering. Additionally, the study found that a lack of resources, access to information and technology, limitations of policy, and inflexible regulation inhibits innovation in Swaziland. As a result, only 52% of the surveyed firms reported having come up with innovations, with more than 50% of the innovations originating from outside the country. These findings indicate that Swaziland’s NSI is relatively underfunded and weak. Efforts to augment the performance of the NSI in Swaziland should focus on developing a national STI strategy and the establishment of appropriate institutions and R&D funding mechanisms. The government is advised to consider strengthening its STI governance and STI framework that addresses national challenges and leverages on national resources and capacities.

**Key Words:** National System of Innovation (NSI), Innovation, Science Technology and Innovation (STI)

1. Introduction

The past decades have highlighted the pivotal role of innovation systems in long-term economic development. Illustrated by the transformative growth of Singapore and South Korea between 1960 to present, the concept of national systems of innovation (NSI) has gained popularity in public policy. Innovations assist countries to design, build, and deploy technologies that solve development challenges, empower communities, improve industrial competitiveness, and contribute to economic growth. In contrast, the application of the concept in the African continent is relatively new and continues to lag behind, despite its growing importance. For instance, literature (see for
example Guimon, 2013; OECD, 2005; Arocena and Sutz, 2000; Watkins et al., 2015) shows that the NSI of developing countries are weak and characterised by frail structures and institutions, inadequate infrastructure, and stagnant economies, which has resulted in low industrial and economic development. In Swaziland, economic development has remained very low over the years (CSO, 2015). The gross domestic product (GDP) of the country has declined from an average growth rate of 2.7% in the 2000s to a low 1.7% in 2015 (CBS, 2016; CSO, 2015). Edwards et al., (2013) relate this to a stagnant business environment. Low technological readiness and innovation are contributing to low global competitiveness (see Schwab and Sala-i-Martin, 2016). Although science technology and innovation (STI) has been acknowledged as a driver of socio-economic development in national and regional frameworks that Swaziland is a signatory to, this has not accrued to significant social and economic development gains. Poverty remains high at 63%, unemployment is at 28.1%, and food security is an issue. Similarly, the World Bank (2013) observes that Swaziland’s economy is characterised by a declining competitiveness, and an unwillingness of exporters to invest in discovering new export products. Confounding the issue is that Swaziland’s industry is characterised by a small-medium enterprises (SME) sector that is involved in low-value addition (Edwards et al., 2013) and dependent on government as the main consumer.

Given the economic stasis that Swaziland is in, there are many economic opportunities that could accrue to the country by developing an understanding of its NSI. This is especially pertinent given the bold steps and investment made towards using STI to drive economic and social development in Swaziland. Against this backdrop, the main goal of this study is to map the NSI of Swaziland in a bid to understand how the country can use STI to drive socioeconomic development. The study identifies the key actors, interactions, and linkages in Swaziland’s NSI and provides a description of the current state of the research and experimental development (R&D) system and the level of innovation. The results of the study are of immense importance to policy makers given the country’s aspirations to use STI to drive economic and social development and the desire to emerge as a developed economy by 2022.

2. The National Innovation System

There are many definitions of the NSI. Christopher Freeman defines the NSI as ‘the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse
new technologies’ (Atkinson, 2014, p. 1). Freeman emphasises the diversity of actors whose interaction and collective agency leads to a single goal, which is technological change. Bartels et al. (2012, p. 6) define the context of the NSI as an ‘envelope of conforming policies as well as private and public organisations, their distributed institutional relations and their coherent social and capital formations, that determine the vector of technological change, learning and application in the national economy’. These definitions give meaning to the importance of national institutional frameworks, the macroeconomic environment, public and private actors, and their interactions that define the innovative capabilities, and performance of a country. As a result, many countries are realising the need to understand and strengthen the functionality of their NSI to leverage STI for sustainable development.

The NSI describes how nationally bound institutions support and facilitate technological change and the emergence of innovations (Lundvall et al., 2009). The NSI underscores the process of interaction, knowledge creation, and technology transfer as embedded in the social, cultural, political, and economic context of a country. Actors of the NSI support and facilitate innovation by i) performing R&D, ii) financing R&D, iii) human resource development, iv) technology transfer and diffusion, v) promoting entrepreneurship, and vi) formulating technology and innovation policy (Chen, 2010). However, successful technological learning and innovation within the system emanate from the continuous feedback loops between and among the different actors and institutions in the system (Watkins et al., 2015; Seidel et al., 2013). The coherence, integration, and collective agency in the activities and functions of NSI actors are important for the efficient and effective performance of the system. For this reason, innovation systems are based on the conceptual understanding of the elements and components of the system and the complex relationships of collaboration, communication, and interaction.

Innovation systems are important as a tool and framework for policy development (Metcalf, 1995; Teixeira, 2013; Watkins et al., 2015). In particular, they assist policymakers to identify gaps in the system and leverage on areas for policy development. For instance, the Southern African Development Community (SADC) Regional Indicative Strategic Development Plan (RISDP) calls on countries to strengthen their NSI to drive development through STI (SADC, 2004). This is because it is the combination of a country’s national policies, education system and its industrial structures, networks, and culture that influence its development (Freeman, 1995). Given that innovation is a dynamic and non-linear process (OECD, 1997) the NSI assists countries to relate
STI to socioeconomic development (NPCA, 2014), and overall macroeconomic policy. Therefore, understanding such constructs enables countries to channel scientific and technological learning, and solve development challenges through strategic policy frameworks.

Fig. 2.1 illustrates a generic model of the NSI. The diagram shows the importance of institutions and organisations in supporting the activities of the NSI. The diagram of the national system of innovation is based on the Triple Helix Model (Etzkowitz and Leydesdorff, 2000; OECD, 1997; Seidel et al., 2013). The model identifies government, industry and academia (the knowledge system) as the fundamental actors in the system. Intermediate institutions facilitate knowledge and technology transfer through for instance, the provision of financial and other support for entrepreneurs (Edquist and Hommen, 2008). Science parks and incubators provide platforms for the commercialisation of R&D outputs and the production of new goods and services, alongside the provision of support for industrial research. The back and forth process of creating and exploiting new ideas and technologies to produce efficient businesses and production processes, and manufacture new goods and services drives economic growth. Conversely, industry does not innovate in a vacuum (Mahroum and Al-Saleh, 2013). For example, the provision of adequate skills to enable the exploitation of STI and the adoption of new technologies to improve company competitiveness and performance is usually a function of the government. To that extent, the relationship between the knowledge production system and the government is foundational for the capacity for industry to innovate. To keep this relationship, open, governments use policies that offer the private sector a variety of incentives for engaging in R&D and other innovation activities.
Figure 2.1: Diagram of the National system of innovation

Global Environment
International Trade, FDI, Regional and Global Policy Frameworks

National System of Innovation

Government
Sectoral policies, Industrial policies, National STI policies, Investment in R&D, Infrastructure, Incentives, tax breaks, IP laws, Competition law, Regulations, standards, etc.

Activities
R&D and education funding, Production of goods and services, Collaboration in R&D, prototype development, knowledge and technology transfer, human resource mobility and development

Outputs and Outcomes
Patents, Job and wealth creation, new products and services, new industries, technological change, improved wellbeing, increased exports, competitiveness

Knowledge system
Higher education institutions, public research centres, laboratories, schools of excellence

Social, political, cultural, economic environmental context

Intermediaries
Public/private Research institutions, Innovation incubators, science parks, financial systems, NGOs, Donors

Industry
Clusters, SMEs, MNCs, National Companies, Public Business enterprises

Source: Author’s own depiction
To facilitate the importation of advanced technologies for the conduct of scientific research, governments promulgate policies that are pro-international trade, provide a conducive environment for foreign investors, and become signatories of both regional and global policy frameworks which provide a portal for any country to be part of the global innovation system (GIS). Hence, national innovation capacities and absorptive capabilities are vital for the effective use of modern technologies (Castellacci and Natera, 2013). From Fig. 2.1, it is clear that knowledge production, acquisition, diffusion, and adoption are fundamental components of the innovation system. As well, university-industry linkages facilitate and increase technological growth, knowledge adoption and transfer. They foster the development of absorptive capacities for new knowledge and technology through the production of a skilled labour force, demand driven research, and spin-off companies (Guimon, 2013; Guan and Zhao, 2013). University-industry linkages have a direct impact on economic development and the sustainability of communities.

In the development of a functional NSI, the role of the government is clear: it is in the provision of policies, institutions, and a conducive environment for the efficient adoption and use of modern technologies in industry to drive economic and social development. As economies grow and diversify, the knowledge production system becomes more important in supporting the dynamism and diversity of local firms to high technological capacities (Castellacci and Natera, 2013). But, just how does a fully functional NSI look like? Alternatively, how have other countries gone about setting up functional NSIs? In the next section, the study undertakes a non-exhaustive review of the NSI in Singapore, South Korea, and South Africa with a view to providing a framework for understanding the gaps and opportunities in the NSI in Swaziland.

2.1 The National System of Innovation: A concept in Practice

The NSI has played a significant role in the development of South Korea, Singapore, Germany, Japan, and other countries, especially in the OECD. Wong and Singh, (2008) and Watkins et al. (2015) show that the development of these countries has been the result of evolving national systems of innovation. The technological acumen, global competitiveness, and the growth of these economies over time are illustrative of the importance of fully functional NSI (Schwab and Sala-i-Martin, 2016). Nevertheless, the NSI is not a one size fits all concept (Kayal, 2008), individual countries need to develop their own NSI based on their development goals. This takes into consideration the natural resources and endowments of the country, its economic
development strategy and social challenges. A review of NSI in a variety of countries reveals a number of key components of the NSI from which developing countries, like Swaziland, could learn.

**The South Korean Model**

South Korea has achieved its development through a concerted policy culture that emphasised the establishment of appropriate institutions and supportive legislature to develop national STI capacity. A lack of natural resources in South Korea led the country to invest in its human capital as its primary resource (Noland, 2011). As early as the 1960s, South Korea established its first government-funded science and technology institute, the Korean Advanced Institute of Science and Technology. South Korea’s education system has played an important role in the accumulation of technical capabilities at the national level. To that extent, STI policy deliberately targeted investment towards STI infrastructure, science, technology, engineering, and mathematics (STEM) education and funding R&D activities.

To illustrate, South Korea’s budget under the National Science and Technology Commission (NSTC), an institution that is in charge of STI policy formulation, implementation, and coordination, was US$16 billion in 2012, which represented 1.2% of GDP. In 2014, South Korea’s expenditure on R&D was 4.29% of GDP (Eurostat, 2016), compared to 2.17% in the world. South Korea’s R&D expenditure consists of strong linkages between university and industry, with private sector funding 76% of all R&D expenditure in 2013 (Gupta et al., 2013). In the same year, Korea produced 54,000 researchers per million people, with scientists and engineers making 24% of the labour force. The government, private sector, and R&D funding institutions such as the National Research Foundation of Korea and the Ministry of Science, ICT and Future Planning provide funding.

In 1999, South Korea adopted an Act that established five specialised research councils to drive the country’s long-term R&D investment in especially basic research in fields such as biotechnology and robotics (Lee et al., 2016). In addition, the government provides incentives for universities and research councils to be competitive in research and partner with industry. As well, the country has continuously supported its industrial development and technological growth through aggressive investment in human capital to accelerate learning and the assimilation of new knowledge and investments in new discoveries and creativity to create new markets.
The Singaporean Model

Just like South Korea, Singapore emerged as a global player in the global innovation system (GIS). This has come about through institutional and administrative frameworks that strengthen the national economy. In 1991, Singapore set up the National Science and Technology Board (NSTB) under the Ministry of Trade and Industry (MTI), with the primary mission of raising Singapore’s capabilities in science and technology (S&T). In 2002, the NSTB was renamed as the Agency for Science, Technology and Research (ASTAR) to emphasise Singapore’s development to a knowledge-based economy and the development of a highly intellectual workforce. ASTAR funds R&D, supports industry, and implements STI initiatives as informed by the national economic strategy.

Singapore’s public spending on science and technology was US$16.1 (1% of GDP) billion for 2011-15 under the Research, Innovation and Enterprise (RIE) 2015 plan. This was for infrastructure, R&D, and human capital development. R&D funds in Singapore are largely from national sources. Institutions' own funds followed by the government were the highest sources of funds at 54% and 37% respectively. In 2013 R&D expenditure in Singapore was 2% of GDP. Private sector expenditure was 59% followed by government and public research institutions at 24% and higher education at 17% (ASTAR, 2014).

Country efforts have led to the growth of national capacities in R&D and increased innovation activity. Singapore has a high number of researchers, at 47,275 persons in 2013 with research scientists and engineers at 31,943 (68%) and 28.4% being females. This population is largely young ranging between the ages of 25-34 at 47%, which add to the growing technical and knowledge base of Singapore’s development. The country equally benefited from cooperation with the international community, through skills and technology transfer in R&D institutions and human resources mobility. As a result, firms that conduct R&D in Singapore were 699 in 2013 with 58% of these being local firms. This has led to the growth of highly technological firms, and contributed US$23.76 billion (6.375% of GDP) to the country’s revenue through the licensing of new technologies and patents, and the sales of commercialised products or processes (ASTAR, 2014). From Singapore’s experience, it is clear that national efforts are primal to an efficient NSI, and policy implementation is futile without the relevant allocation of resources, action points, and institutions to implement policy statements.
The South African Model

In South Africa, over and above policies that support the attraction of foreign direct investments into the country, the Department of Science and Technology (DST) is responsible for coordinating and managing STI activities. The Department is responsible for all issues related to financing, procurement, regulatory, governance, and other policies that influence the innovation process (OECD, 2000). Other important institutions in South Africa’s NSI are the state funded research councils, such as the Council for Scientific and Industrial Research (CSIR), Council for Mineral Technology (MINTEK), which specialises in mineral research, Medical Research Council (MRC), Human Sciences Research Council (HSRC) and the Agricultural Research Council (ARC). The Technology Innovation Agency (TIA) and the National Intellectual Property Management Office (NIMPO) are important in the NSI as they assist industries in absorbing and assimilating technologies and R&D output.

The NSI in South Africa gets support from the country’s vibrant and dynamic university system that plays a huge role in the development of human resources and in conducting research. South Africa’s research personnel was at 48,479 in 2014/15. Researchers with masters, honours, and bachelor’s degrees were 56.4%, and 29.5% had PhDs (DST, 2017). South Africa’s White Paper on Science and Technology highlighted the development of a technological economy. Thus the establishment of a Council on Higher Education (CHE) in 1998, technology transfer offices, incubators, and a number of funding instruments for the commercialisation of R&D outputs, which has fostered university-industry collaboration.

Presently, South Africa’s private sector contributes 40.8% to funding R&D (NPCA, 2014), which is among the highest in the African continent. R&D as a percentage of GDP was 0.77% in 2014/15 (DST, 2017). A larger portion of R&D expenditure in South Africa is applied research with higher education performing most of the basic research 54.9%. One of the goals of the South African NSI was to develop an information society. The country’s investments in its higher education infrastructure, robust research system, knowledge transfer mechanisms, and intellectual property laws are a means through which this will be achieved.

Discussion

From the preceding discussion, three things are discernible. First, NSIs are vehicles for the implementation of social and economic
development strategies. The review reveals that in all the three countries, country priorities are explicit on the R&D and innovation agendas; hence, the deliberate allocation of resources for STI activities. Industrial development in these countries has resulted from coordinated STI policies, incentives, and institutions embedded in the bigger economic development strategy of the country. Second, these countries have successfully put in place concrete institutional frameworks and research institutions that are responsible for the conduct and commercialisation of scientific research. Institutions provide rules and regulations, incentives, and guide technological development at the national level. Third, in all the three countries, corroborating government STI initiatives is the high investment in human capital. These countries have invested highly in their education systems and in building a labour force that is STI oriented. These observations accentuate the interdependent roles of government, the knowledge system and industry in the triple helix of national innovation systems. In the next section, we discuss the method undertaken to map Swaziland’s NSI.

3 Method

Studies that map the NSI employ a variety of methods including the triple helix model and survey data (Arocena and Sutz, 2000; Carvalho et al., 2015). The triple helix model singles out government, industry, and academia (the knowledge system) as the fundamental actors in the system. It explains the dynamic organisation of the interactions and subsystems in the innovation process (OECD, 1997; Seidel et al., 2013; Etzkowitz and Leydesdorff, 2000). This study conducts a detailed national survey of the R&D and national innovation systems in Swaziland. Methods of data collection drew from the widely used Oslo manual for the innovation survey, and Frascati manual for the R&D survey. The manuals provide standard methodological guidelines on how to collect data using the two surveys to enable comparability of the results with other countries. Innovation and R&D surveys offer a comprehensive approach to mapping innovation systems in that they provide essential information on the general patterns of technological interaction and information production in the national system (OECD, 1997). This method is suitable for explaining the NSI in Swaziland because of the absence of previous information on the country’s innovation system. Moreover, the quantitative aspect of the study provides fundamental STI indicators for evidence-based policy.
3.1 Data Collection

Data was collected through self-administered R&D and innovation surveys (questionnaires). The innovation survey used a stratified random sampling technique. The sample was stratified according to the location (region), sector, and the number of employees. The sample size was 228 firms, with a confidence level of 95% and a margin interval of 5%. Company registries and business yearbooks were used to mark the target population of firms and the survey response rate was 62%.

Similarly, the R&D survey sampled 150 R&D institutions in Swaziland. National registries and profiles of public and private institutions were used to identify R&D performers in four sectors, namely: (i) the government and public research institutions; (ii) higher education; (iii) private and non-profit; and (iv) business enterprise. The activities of the institutions, size, publications, previous and present participation in R&D activities, and general potential for R&D were considered in the selection criteria. Due to the absence of recorded R&D performers in the country, a purposive sampling technique was used for R&D performers in the business and private or non-profit sectors, and a census was conducted in government and higher education. A replacement method, using mainly the snowballing technique, was used to replace organisations that did not conduct R&D in the period 2015-2016, and the response rate was 82.6%.

The final picture of the NSI is painted by the combination of the two survey datasets, highlighting the different actors, functions and activities in the innovation process. The narrative focuses on extracting general patterns like the model presented in Figure 2.1. A descriptive analysis is, therefore, suitable to express the prevailing system of innovation in Swaziland. This is supported by qualitative data from primary and secondary sources. Insights in the observed characteristics compared to what exists in other countries are an important consideration for policy recommendations, thus the next sections present results from the surveys, a discussion of the results and policy recommendations.

4. Results: The National System of Innovation in Swaziland

4.1 Institutions and Institutional Frameworks

To understand the structure and composition of Swaziland’s NSI requires an understanding of the institutions and institutional framework that direct technological learning in the country. This section gives a description of the institutions in the NSI and provides an
analysis of the survey data to describe the interactions and activities in Swaziland’s NSI.

4.1.1 Science and Technology Institutions

In Swaziland, the Department of Research Science Technology and Innovation (RSTI) at the Ministry of Information Communication and Technology (MICT) coordinates STI. Advisory and policymaking institutions in Swaziland’s NSI include Government Ministries and Departments. The MICT plays the leading role followed by the Ministry of Education, the Ministry of Agriculture, the Ministry of Natural Resources, the Ministry of Commerce Industry and Trade, and the Ministry of Economic Planning and Development. The Public Policy Coordination Unit (PPCU) is pertinent as a primary unit for policy making in the country.

In addition, Swaziland has some public institutions involved in R&D. The Department of Agricultural Research and Specialist Services (DARSS) (Malkerns Research Station) under the Ministry of Agriculture is the oldest research institution in the country. It was established in 1964 and re-established in 1974 and focuses on agriculture research and services. The Swaziland Economic Policy Analysis and Research Centre (SEPARC), established in 2008\(^1\), is another institution that solely conducts research in the country, mainly economic policy research of which science technology and innovation are inherent. The National Health Research Unit established in 2005 coordinates research undertaken in the health sector. Some government Ministries, Departments, and Parastatals conduct research as a component of the work and services they provide. These include the National TB programme - in the health sector, the Swaziland National Trust Commission - focuses on conservation and biodiversity, and soon the Royal Science and Technology Park -, which has an innovation incubator and biotechnology park.

Equally important to Swaziland’s NSI are the technology support and regulatory institutions. These constitute the Swaziland Standards Authority (SWASA), Swaziland Energy Regulatory Authority (SERA), Financial Services Regulatory Authority (FSRA), National Agricultural Marketing Board (NAMBoard), and Swaziland Communications Commission (SCCOM), which regulate the manufacturing of goods, energy, financial services, agriculture products, and communication sectors, respectively. The Swaziland Environmental Authority (SEA) is responsible for environmental protection and safety, while the

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\(^1\) Although SEPARC was established in 2008, it only started operations in 2012.
Swaziland Investment Promotion Agency (SIPA) is a key player in promoting investment in technology and innovative businesses. The Swaziland Competition Commission ensures a competitive business environment. In concert, these institutions play a vital role in regulating and directing STI activities in the country, providing information and guidance for technology development and research, thus impacting industrial development. The next section provides a review of the frameworks that direct the innovation process in Swaziland.

4.1.2 Institutional Framework

Institutional frameworks are the overarching governance tool for the innovation process and its activities; they outline the environment in which innovation occurs (World Bank, 2010). Swaziland has no national research agenda and there are no structures for R&D funding institutions in the country, especially in government budget and policy. For the private sector, incentive structures are not clear. While it is stipulated in the Income Tax Order 1975 section (i) and (ii) that an amount of tax will be deducted from any research and development performer, it is not clear how claims are made and how much should be deducted from tax. Additionally, local firms and other R&D institutions are not aware of this law. Whereas the National Development Strategy (NDS) highlights areas of important research, it does not articulate how this will be carried out or funded. As a result, the direction of technological innovation is not clear. Even though research and innovation activities are recognised on national strategies and ministry-specific strategies, coordination is difficult. Recall that in section 2, it was documented that South Africa, South Korea, and Singapore have developed national research strategies, and clearly identified priorities in their STI strategies. Given the lack of national priorities for STI it is challenging for the country to coordinate STI activities. Consequently, the STI system in Swaziland can be described as fragmented and lacking coordination. Unlike other countries (see section 2), Swaziland’s core institution responsible for research is hidden under MICT, is underfunded and under staffed.

Making the situation perverse is that STI policies in the country are contained in other national policies such as the Science, Mathematics, and Technology Education Policy of 2014, and policies such as the environment, agriculture, health policy, industrial and so on. For example, while the Swaziland National Industrial Development Policy acknowledges the need to use STI in developing the country’s industrial performance, the policy is not clear about the implementation of such activities. While it aims to increase value addition and industrial production through innovation, technology transfer, and
R&D in the manufacturing sector (GoS, 2015), investment in modern technologies, R&D, and a highly skilled labour force does not corroborate these efforts.

Adding to the weak institutional framework is the country’s intellectual property (IP) law. At the time of writing this study, the country’s operational Patent Act came into force in 1936 while the copyright legislation is from 1912. Over and above the fact that such laws are old and outdated, they have an effect on the level of innovation in the country: innovators are exploited and unprotected. Results from the national innovation survey show that between 2014-2016, only 11% of the firms reported securing a patent, 9% registered trademarks, 5% registered industrial designs, and 9% claimed copyrights, which is very low. In contrast, the licensing of new technologies and patents, and the commercialisation of R&D output have contributed US$23.76 billion (6.375% of GDP) to Singapore’s revenue, paying to updated IP laws in the country. This illustrates that the amendment of the IP law in Swaziland could be instrumental in taking forward STI development.

4.1.3 Higher Education and Training

Institutions of higher learning and training are foundational in the production of knowledge and a highly skilled workforce. In Swaziland, this sector constitutes four (4) universities, and 70 Technical and Vocational Education and Training (TVET) institutions of which 27 are public and 43 are private. The country has one public university and 3 private universities. These are the University of Swaziland (UNISWA), the Southern African Nazarene University (SANU), Limkokwing University of Creative Technology and the Swaziland Christian Medical University. The TVET centres and colleges include the Institute of Development Management (IDM), the Swaziland College of Technology (SCOT), Vocational & Commercial Training Institute - Matsapha (VOCITIM), Manzini Industrial Training Centre (MITC), Ngwane and William Pitcher Teacher’s Training Colleges.

The University of Swaziland and IDM are the only institutions that engaged in R&D activities during the review period. UNISWA has two research institutions: The Swaziland Institute for Research in Traditional Medicine, Indigenous and Medicinal Food Plants (SIRMIP) and the UNISWA Research Centre (URC), which conduct research. UNISWA also offers Master and PhD degrees whilst the other institutions offer degrees and lower certificates. The survey results showed that the higher education sector had the highest number of qualified research personnel. There are 101 PhD holders, of which 70
are male and 31 are female, and 94 Masters holders compared to 9 PhDs and 52 Master degrees in government. Nonetheless, the standard and quality of education is not defined as the country recently (2015) established a Higher Education Council (HEC) to develop a national qualification’s framework, contrary to other countries who long established theirs – for example South Africa established the CHE in 1998. Moreover, STI education remains underfunded in the country, with a reported lack of equipment and adequate infrastructure (GoS, 2014; MoET, 2015) in TVET and other academic institutions. For instance, UNISWA reported that due to a lack of adequate funds, the university fails to provide an adequate research environment as it lacks equipment and machinery (UNISWA, 2016). This impedes the use of up-to-date and technology forward equipment, and the conduct of R&D.

4.2 Research and Development (R&D)

Results from the R&D Survey show that Swaziland’s Gross Expenditure on R&D (GERD) is E139,013,458.34 (Fig. 4.2.1). This is only 0.26% of the country’s GDP in 2015, which is lower than the continental target of 1% of GDP. Total business enterprise expenditure on R&D (BERD) was lowest at E 1,480,252.93 (Fig. 4.2.1). Most firms did not conduct R&D in-house. Generally, firms outsource R&D because of a lack of capacity and finances. Others, especially multi-national companies conduct R&D at the company headquarters or group level outside Swaziland. Government expenditure on R&D was the highest, at E55,865,737.33 followed by higher education at E43,143,216.89 and the private and non-profit sector at E38,524,251.20 (Fig. 4.2.1). Worth noting is that the government further provides funding for R&D for higher education.

Figure 4.2.1: Research and Development Expenditure by Sector

![Research and Development Expenditure by Sector](Swaziland National R&D Survey (2017))
Foreign (mainly development) partners are the largest contributors to the funding of R&D activities in Swaziland. They are the source of 42.5% of R&D funds, whilst institutions that use their own funds are (39.2%), business enterprises fund 0.13%, and government provides only 17.1% of the total sources of R&D funds. The study found that a big portion (52%) of the expenditure on R&D goes to labour costs, with low investment on capital goods like machinery and equipment at 9% and even lower on software at 2% (Fig. 4.2.1).

**Figure 4.2.2: R&D Expenditure distributed by sector and activity**

There is a high correlation between the types of R&D performed in the country and capital investment. In particular, basic and experimental development research is associated with high investment in capital goods. Swaziland performs more applied research than it does basic or experimental development research (Fig. 4.2.3). The government funds more applied than basic research, whilst higher education has relatively balanced funding in applied and basic research (Fig. 4.2.3). Experimental development is very low in the R&D system in Swaziland, which symbolises a lack of effective mechanisms and structures for the application of knowledge for the production of goods and services.
Figure 4.2.3: R&D Expenditure by type of research

In addition, the survey found that Swaziland’s R&D expenditure is highest in the economic and business sector (41.13%) and lowest in agriculture at 5.51% for government and public research institutions. Private and non-profit institutions invest more in health sciences (67.16%), while business enterprises invest in electrical engineering and electronic engineering (47.5%) and higher education in agriculture, forestry and fishery (26.36%). This suggests that there is no funding set aside for R&D as per the aspirations of the NDS which identifies agriculture, manufacturing, and services for STI development. Nevertheless, R&D is successful when coupled with a high calibre of skill and human capital.

4.3 Human Capital Development

The type of R&D and work force are important in understanding the technological capabilities of a country. The innovation survey shows that firms that had innovations had a more skilled labour force (73%) than firms with no innovations (41%). The study found that there are 757 R&D personnel. Of this, 360 are researchers, 92 are technicians, and 305 are support staff. There are also more male R&D personnel than there are females, at 435 and 322, respectively (Table 4.3.1).

Table 4.3.1. Headcount of Research and Development (R&D) Personnel

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
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<tbody>
<tr>
<td>Researchers</td>
<td>211</td>
<td>149</td>
<td>360</td>
</tr>
<tr>
<td>Technicians</td>
<td>52</td>
<td>40</td>
<td>92</td>
</tr>
<tr>
<td>Support</td>
<td>172</td>
<td>133</td>
<td>305</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>435</strong></td>
<td><strong>322</strong></td>
<td><strong>757</strong></td>
</tr>
</tbody>
</table>

Source: Swaziland National R&D Survey (2017)
There is a lower representation of women with postgraduate qualifications (PhD and masters) compared to bachelor’s degrees (see Fig. 4.3.1). In full time equivalent (FTE), PhDs spend less time in R&D (39.92 FTE) compared to bachelors (82.51 FTE) and Master’s degrees (74.36 FTE). Overall, total FTE is 438.30, compared to a headcount of 757. This means that most researchers spend less time conducting research.

**Figure 4.3.1: R&D Personnel by Qualification and Sex**

![R&D Personnel by Qualification and Sex](image)

**Source**: Swaziland National R&D Survey (2017)

Scientists and engineers are the main players in the advancement of science and technology, especially in the development and adoption of technologies. Yet, R&D capacities are very low in engineering and natural sciences (Table 4.3.2), making 9.5% of the total R&D personnel, these figures are even lower for women. This compromises the achievement of an STI driven economy and industrial development. The largest R&D personnel is in agriculture, also reflected by agriculture’s high enrolment at UNISWA. The agricultural sector is male dominated unlike the health and social sciences, which are female dominated (Table 4.3.2).

Similar to Singapore and South Africa (see ASTAR, 2014; DST, 2017), Swaziland has a relatively youthful research labour force with the largest group between the ages of 25-34 years old (43%) followed by those on the 35-44 years category (23%) (Table 4.3.3). The group under 25 years is low, at only 11%. This shows that Swaziland needs to invest in programmes that will increase the engagement of this group in R&D with a focus on enhancing skills and capacities of the large group, especially through PhD programmes in sciences and engineering.

The absence of the Human Development Indicative Framework is a challenge to human capital development in the country. Presently there is a reported disconnect between skill demand and skill supply for
industry (GoS, 2014). The Swaziland Labour Force Survey shows that there is a low absorption of youth in industry (MoLSS, 2013). This means that while the government is providing scholarships for young people to advance their education in relevant fields outside the country, the industry is unable to absorb them, which has resulted in high youth unemployment (51.6%) and continued the brain drain of highly qualified S&T personnel. Hence, the need for incentives, structures, and strategies for human capital development in the country.
**Table 4.3.2: Research Personnel by field of science and sex**

<table>
<thead>
<tr>
<th>Field of Science</th>
<th>Government or public</th>
<th>Private or non-profit</th>
<th>Business enterprise</th>
<th>Higher Education</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>Total</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>Natural Sciences</td>
<td>11</td>
<td>2</td>
<td>13</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Engineering and Technology</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Medical and Health Sciences</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>25</td>
<td>49</td>
</tr>
<tr>
<td>Agricultural Sciences</td>
<td>113</td>
<td>47</td>
<td>160</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Social sciences</td>
<td>37</td>
<td>40</td>
<td>77</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>Humanities and Arts</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Not specified (inter or multidisciplinary)</td>
<td>18</td>
<td>10</td>
<td>28</td>
<td>28</td>
<td>42</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>185</strong></td>
<td><strong>103</strong></td>
<td><strong>288</strong></td>
<td><strong>79</strong></td>
<td><strong>125</strong></td>
</tr>
</tbody>
</table>

Source: Swaziland National R&D Survey (2017)

Notes: M and F denote male and female, respectively

**Table 4.3.3: Research Personnel by age and sex**

<table>
<thead>
<tr>
<th>Age Category</th>
<th>Government or public</th>
<th>Private or non-profit</th>
<th>Business enterprise</th>
<th>Higher Education</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>Total</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>under 25</td>
<td>30</td>
<td>24</td>
<td>54</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>25 - 34</td>
<td>59</td>
<td>44</td>
<td>103</td>
<td>54</td>
<td>96</td>
</tr>
<tr>
<td>35 - 44</td>
<td>56</td>
<td>23</td>
<td>79</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>45 - 54</td>
<td>36</td>
<td>10</td>
<td>46</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>55 - 64</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>65 and more</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>185</strong></td>
<td><strong>103</strong></td>
<td><strong>288</strong></td>
<td><strong>79</strong></td>
<td><strong>125</strong></td>
</tr>
</tbody>
</table>

Source: Swaziland National R&D Survey (2017)

Notes: M and F denote male and female, respectively

20
4.4 The innovation environment

R&D capacities and skill development are vital where knowledge and skill produce products and services that improve lives and facilitate development. Governments strive to provide a conducive innovation environment. However, the innovation survey reveals that in Swaziland no company received any form of financial support for their innovations from government. Likewise, Fig. 4.4.1 shows that the biggest barrier to innovation in Swaziland is the lack of financial resources. This is corroborated by the Swaziland economic census of 2010, which reported that 40.2% firms in the country used their own savings to start companies as opposed to 12.8% who used formal financial sources (CSO, 2011). Other barriers to innovation in Swaziland include the lack of STI policies and regulations and information on technology, suggesting that the country’s NSI lacks a strategy for supporting firm-level innovations in terms of priorities, funding, support structures, and incentives. As a result, 64% of the product and 56% of the process innovations originated outside the country while 12% of all innovative firms abandoned their innovations.

Figure 4.4.1: Barriers to Innovation

Source : Swaziland National Innovation Survey (2017)
Notes : Finance from outside refers to external sources of funding which may include venture capital, partners or public sources of funding.
The innovation environment has proven to be unfriendly to new innovators. Fig 4.4.1 shows that non-innovative firms experience more barriers than innovative firms do. For instance, the lack of qualified personnel is a barrier for innovative firms while the lack of information on markets and collaboration partners is a barrier for non-innovative firms. The survey reveals that there is a lack of trust in the business environment in Swaziland, as local firms mostly developed their own innovations or work with staff from their subsidiaries, sister enterprises or headquarters on innovations than they collaborate with other entities. Likewise, Brixiova et al., (2014) identify a number of barriers that hinder entrepreneurship in the country, and networking is one of them. This has resulted from a challenging business environment, according to MoSCYA, (2015).

4.5 Interactions and Linkages

Whilst interactions are essential to the flow of knowledge and skills, in Swaziland collaboration is largely one-sided, with government interacting with higher education and the private or non-profit sector. The government receives funds from the business sector but does not fund it, denoted by the homogeneity in the bars on Fig. 4.5.1. Additionally, university-industry linkages are silent. Whereas countries like South Africa, Singapore, and South Korea have strong university-industry linkages that are central to efficient innovation processes, Swaziland does not. This is corroborated by the innovation survey data on Fig. 4.5.2 that shows that local firms are less engaged in collaborative activities with higher education institutions, at (10%). Similarly, R&D is largely conducted in isolation. As well, research departments are either not fully operational or where they are, they focus on conducting market research.

Figure 4.5.1: Sources for R&D funding

![Figure 4.5.1: Sources for R&D funding](source: Swaziland National R&D survey 2017)
Fig 4.5.2 shows that international collaboration in innovation activities is very weak, especially with the governments of other countries. The diagram shows that collaboration is skewed towards the rest of Africa, especially in the supply of equipment and materials, and the use of consultants and private R&D institutions. National statistics on imports and exports identify South Africa as the main collaborator in the supply of goods and services for Swaziland (CBS, 2016). Furthermore, Fig 4.5.2 shows a lower acquisition of supplies and equipment within national boundaries. Local firms depend on the international markets to source consultation services. This signifies low industrial production of equipment and material and an inadequate supply of R&D institutions and skilled consultants locally. This is illustrative of an underdeveloped industrial sector, characterised by a high importation of inputs.

**Figure 4.5.2: Firm’s Collaborative Partners for Innovation**

![Diagram showing collaborative partners for innovation](image)

Source: Swaziland National Innovation Survey 2017

The dissemination and diffusion of knowledge is an important component of knowledge and technology flow in NSI literature (Carvalho, et al., 2015). Technology flow mechanisms are strongest through knowledge embodied in human resources and organisational structures (57%). Table 4.5.1 shows that external sources such as suppliers, customers, competitors, and consultants are important mechanisms for knowledge flow in the NSI. Government institutions follow at 19% and industry associations at 17%. Plus, Table 4.5.1 shows that the use of R&D information is relatively low, illustrated by the low percentage of firms using scientific journals (8%), networking
platforms (13%) and universities (15%). This has an implication on the level of firm innovation in the country.

Table 4.5.1: Important sources of information for innovation by innovative firms

<table>
<thead>
<tr>
<th>Sources</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sources within your enterprise or enterprise group</td>
<td>57%</td>
</tr>
<tr>
<td>Suppliers of equipment, materials, components or software</td>
<td>40%</td>
</tr>
<tr>
<td>Clients or customers</td>
<td>40%</td>
</tr>
<tr>
<td>Competitors or other enterprises in your sector</td>
<td>30%</td>
</tr>
<tr>
<td>Consultants, commercial labs or private R&amp;D institutes</td>
<td>28%</td>
</tr>
<tr>
<td>Universities and Technikons</td>
<td>15%</td>
</tr>
<tr>
<td>Government and public research institutes</td>
<td>19%</td>
</tr>
<tr>
<td>Conferences, trade fairs, exhibitions</td>
<td>13%</td>
</tr>
<tr>
<td>Scientific journals and trade/technical publications</td>
<td>8%</td>
</tr>
<tr>
<td>Professional and industry associations</td>
<td>17%</td>
</tr>
</tbody>
</table>

Source: Swaziland National Innovation Survey 2017

4.6 Level of Innovation in Swaziland’s NSI

Innovative firms in Swaziland were 60% and non-innovative firms were 40%. Of the innovative firms, 52% successfully implemented an innovation during the period under review, while 12% abandoned their innovations. Further analysis of the innovative firms shows that they introduced four different innovations within the period of the survey. These are product, process, marketing, and organisational innovations. The study confirms that though R&D is a capital good in any country, it is not always the source of innovation. The innovation survey evinces that 82% of the firms that had an innovation activity had no R&D activity, while 18% had conducted R&D. This implies that innovation activities did not draw from in-house R&D activities. Fig. 4.6.1 below shows that R&D measures low on expenditure while the acquisition of machinery and equipment is the highest innovation expenditure, suggesting that knowledge and technology are largely transferred through the acquisition of equipment in industry, which is further supported by training at 25%. However, the acquisition of external knowledge in these firms is minimal, and is largely characterised by a lack of highly technical skill (R&D survey, 2017) to allow for the adoption of modern technology to national production systems. Consequently, overall innovation expenditure was found to be 1.3% of overall firm turnover.
Figure 4.6.1: Share of Innovation Expenditure by Type of Cost

The manufacturing sector accounts for 30% of all innovations in Swaziland, making it the most innovative sector followed by the information and communication sector at 17% (Fig. 4.6.2). The least innovative sectors are the health (1%), transportation and storage (2%), real estate (3%), and energy (3%) (Fig. 4.6.2). These observations provide a stimulus to an innovation driven manufacturing sector as stipulated in the country’s NDS. However, this is currently not possible given the lack of similar innovative efforts in other sectors of the economy, such as agriculture and energy. Alongside the low innovative efforts, the effects of a weak STI framework has continually fed into the country’s slow and declining industrial development, as illustrated by the overall structure of the country’s NSI.
5 Discussion: Swaziland’s NSI

This section discusses the results of the study and uses them to map the structure and composition of Swaziland’s NSI. The results show that Swaziland has a weak NSI. First, the country has weak institutional and STI policy frameworks, compared to other countries that have used STI to drive economic growth. The country does not have a long-term strategy to deal solely with STI policy and related issues when compared with countries such as Singapore, South Africa, and South Korea who have developed long-term strategies for their STI and research agendas and have established institutions that solely deal with STI policy and related issues. For instance, the DST in South Africa and the Ministry of Science, ICT and Future Planning in South Korea. In Swaziland, the RSTI is a department under the Ministry of ICT with little funding and personnel.

Second, there is low investment in innovation and R&D. There is no national funding mechanism and support for innovation, while only 0.26% of GDP is invested in R&D. Moreover, there is a low investment in STI infrastructure and capital goods, such as equipment and materials resulting to underemployment of qualified personnel and low skill development. Contrary to what is observed in Swaziland, South Korea has addressed this issue by allocating a specific budget to STI
(which is equivalent to 1.2% of GDP) from the national budget through the NSTC, and different government ministries.

Third, the results show that Swaziland still has a lot of work to do before the economy is classified as a knowledge driven economy, as envisioned in the NDS. The country has low capacity and STI personnel. Swaziland has only 9.5% of R&D personnel as scientists and engineers compared to 68% of all R&D personnel in Singapore. The lack of researchers in the science and engineering fields means that the country is not engaging in research that could help attain the goal of having an STI powered manufacturing sector. Furthermore, it compromises the country’s ability to develop new products (goods and services) to drive industry. As a result, the country is largely dependent on imports and external sources for supplies and equipment. The country lacks mechanisms for technology transfer and increasing industry’s absorptive capacities. It lacks incentives for technology adoption in industry and high investment in STI skills, which may be attained through high quality and skill intensive STEM-oriented TVET institutions. At the very least, the large number of young people in the country’s population presents an opportunity for the development of an STI driven labour force.

Lastly, there are low linkages and collaboration within the national system of innovation. The feedback links between and among institutions are weak, and there are no established mechanisms and incentives to work together. The industry does not consider research institutions a priority partner for collaboration. In South Africa, the government has established agencies like TIA to fund innovation activities and facilitate industry-university linkages, while NIMPO has established technology transfer offices to protect knowledge and ensure effective commercialisation of R&D output. These institutions enhance innovation and maintain continuous interaction between the three actors of the NSI.

From the results and discussions presented in this study, it is possible to develop an understanding of Swaziland’s NSI. Fig. 5.1 gives an illustrative diagram of the different actors, activities, and interactions in the NSI. The diagram shows that even though the regional and continental frameworks for STI are rich, the national institutional frameworks and capacities are weak and uncoordinated yet they remain primal to the country’s development. Swaziland needs to pay attention to the development of national capacities, enhance interactions, and improve institutions to achieve an STI driven socioeconomic development agenda. Nevertheless, the establishment of RSTI and RSTP present new opportunities to redirect STI development in
Swaziland. Furthermore, opportunities abound for exploiting existing industry-government linkages to grow STI driven industries. Similarly, the country should utilise already existing government-university linkages to strengthen STI focussed R&D and skill development through targeted funding and long-term planning, policies, and regulation through the development and use of appropriate STI institutions.
Figure 5.1: Swaziland’s National System of Innovation

Swaziland’s National System of Innovation

Government
RSTI, Sectoral policies/strategies, Industrial development policy, Investment in R&D, Infrastructure, Education Policy, Competition law, Regulations, standards, SME Policy etc.
Weak institutional capacity, IP laws and STI policies, no national research agenda, no funding mechanisms, fragmented coordination

Activities
Low engagement in collaborative R&D, Science and Technology services, human resource development low collaboration

Intermediaries
RSTP, JA, enactus, financial system, NGOs, Donors
Lack of venture capital, access to information and financial loans, no continuity after competitions

Outputs and Outcomes
Products and services, low exports, low industrial production, low value addition, low industry absorption of graduates, high unemployment

Knowledge system
DARSS, SEPARC, UNISWA underfunded, Low STI graduates, especially girls, inadequate infrastructure and equipment

Social, political, cultural, economic environment

Industry
SMEs, MNCs, Public Business enterprises
Low R&D and Innovation expenditure, import of innovations, low entrepreneurial culture, MNCs conduct research

SDGs, STISA 2024, CESA 16-25, SADC Protocol on STI, SADC Industrialisation Strategy, SACU, PTA

Source: Author’s Own Depiction
Notes: The italicised font represents the gaps identified in Swaziland’s NSI in the study, while the un-italicised font are some of the institutions and activities mapped in the study.
6.0 Conclusion and Recommendations

This study sought to map the national system of innovation in Swaziland. It used innovation and R&D surveys to understand the actors, activities and interactions in the country’s NSI. The results highlighted in this paper show that Swaziland has a weak national system of innovation. The country’s NSI is characterised by low investment in R&D at 0.26% of GDP and a lack of support for innovation activities. From the surveyed firms 60% were found to be innovative while only 52% completed their innovations. The institutional and regulatory framework was found to be a barrier to innovation. Compounding the situation for Swaziland is a lack of qualified personnel. The study found that the number of scientists and engineers in the country is very low, which is a result of low investment in STEM education. There are observed weak linkages and interactions in the national system, especially between industry and universities.

Consequently, the study makes the following recommendations:

- Develop a national STI strategy that is embedded in the country’s national development agenda. This should spell out the innovation and R&D agenda for Swaziland’s development, priorities, funding, and available resources.
- Improve STI governance by introducing the Swaziland National Commission for Research, Science, and Technology as planned. However, the mandate, role, and influence of this institution should be considered at the level of its influence to national budgets and prioritisation of STI initiatives in the country’s development agenda.
- Establish a Ministry of Science Technology and Innovation to ensure full coordination of the funding of, and support for, R&D and innovation activities.
- Introduce a national PhD programme and form linkages with regional and international research institutions to expedite the development of researchers in the fields of science, technology, engineering, and mathematics (STEM).
- Deliberately target women in STI research initiatives to ensure a gendered national research agenda.
- Develop incentives (monetary or otherwise) to entice young researchers to stay in research.
- Provide a conducive environment for innovation by updating outdated legislative frameworks and regulatory environment for the growth of innovative firms. For instance, through the provision of tax breaks for private sector R&D, improving price
controls, eliminating monopolies and setting clear output specifications in procurement and quality standards.

- Implement programmes and incentives to sustain a continuous engagement of the private sector in R&D and innovation activities. For instance, through the establishment of contest funds, problem-solving networks, or well-designed matching funds that support innovation.
- Increase R&D investment especially capital investments with a special focus on investing in equipment and machinery to curb underemployment of existing researchers.
- Enhance regional and international collaborations in innovation activities to foster knowledge and technology transfer and the sharing of best practices.
- Reinforce efforts geared towards demonstrating the value of engaging in R&D to industry by showing the kinds of incentives that are in place to support R&D activities in Swaziland particularly given the successful completion of the Royal Science and Technology Park.
- Provide incentives to increase and foster private sector participation in R&D and funding for education to universities and STEM skills development, especially in TVET.
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