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LMIP WORKING PAPER 4

Skills, Competencies and Capabilities in the Innovation System

Reconfiguring the Post-School Sector

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PREFACE

One of the gravest economic challenges facing South Africa is high unemployment and, at the same time, a skills mismatch. The market demand for skilled labour is greater than the number of individuals completing post-school education and training. Prospective employers often complain that the education system does not give individuals the necessary skills to be productive in the workplace or to start their own enterprises.

Government acknowledges that the unemployment crisis is a systematic problem and cannot be addressed by ad hoc interventions scattered across line departments. With this 'big picture' thinking in mind, the Department of Higher Education and Training (DHET) aims to create broad and equitable access to a full spectrum of post-school opportunities and lifelong learning – encompassing adult education and training, workplace training, the further education and training (FET) college system, artisan and technical training, higher education and innovation.

The ability of the DHET to create these learning opportunities requires a network of partners to gather and maintain a labour market intelligence system. Such a system can provide analytical insights to support policies and intervention programmes.

In February 2012, the DHET commissioned an HSRC-led research consortium to support its capacity to create and maintain a labour market information and intelligence system, guided by the National Delivery Agreement 5.

The primary focus is the development of a 'strategic intelligence capability' towards the establishment of 'a credible institutional mechanism for skills planning'. The HSRC-coordinated research project is organised in terms of six interlocking research themes, two of which focus on labour market information and four of which focus on labour market intelligence:

- Theme 1: Establishing a foundation for labour market information systems in South Africa;
- Theme 2: Skills forecasting: t#he supply and demand model;
- Theme 3: Studies of selected priority sectors;
- Theme 4: Reconfiguring the post-schooling sector;
- Theme 5: Pathways through education and training and into the workplace; and
- Theme 6: Understanding changing artisanal occupational milieus and identities.

One of the consortium's goals is to create a living community of practice that researches and debates education, skills and labour market issues.

The dissemination of working papers is intended to encourage more individuals to join the research community. The consortium looks forward to individuals' comments, which can be emailed to Kmotha@hsrc.ac.za.

Welcome to the research community!

CONTENTS

LIST OF TABLES AND FIGURES

ABBREVIATIONS AND ACRONYMS

DHET	Department of Higher Education and Training
DUI	doing, using and interacting
FET	further education and training
GDP	gross domestic product
HSRC	Human Sciences Research Council
NICs	newly industrialised countries
NIS	National Innovation System
NTCs	National Technological Capabilities
R&D	research and development
RIS	Regional Innovation System
S&T	science and technology
SETA	Sector Education and Training Authority
SIS	Sectoral Innovation System

INTRODUCTION

The overarching purpose of the Labour Market Intelligence Partnership programme Theme 4 projects is to explore how diverse types of education and training institutions in the emerging post-school terrain are responding to increasingly changing and complex labour markets (Kruss 2012: 1). The current post-school sector comprises public and private further education and training (FET) colleges, public and private higher education institutions, adult education institutions and the regulatory and quality assurance framework. As illuminated in the 2012 Green Paper (DHET 2012) and the National Development Plan 2030 (National Planning Commission 2011), the post-school sector in its current form has been described as incapable of meeting the skills development needs of both the society and the economy, hence the comprehensive plans to reconfigure the sector. This is attributed to post-school sector provisions that are of inadequate quantity, diversity and, in some instances, quality (DHET 2012). The post-school sector is central to tackling the skills-shortage problem in the country through the twin responsibilities of producing qualified and competent graduates and by generating research and innovation. Improving education and skills levels is not only necessary to boost workforce productivity, but also for improving the innovative capacity of the economy; this would facilitate the absorption and diffusion of new technology in order to propel economic growth (Fisher & Scott 2011).

Although there has been a radical shift in policy in the post-democratic era, structural flaws of the past persist in the post-school sector. The misalignment between institutions in the post-school sector and a further misalignment between the sector and the labour market has been attributed to the diverse historical trajectories of the institutions, rooted in racially divided educational administration (Kruss 2007; Kraak 2012). These adverse effects persisted into the post-democratic era even after the institutions were joined under one unified administration, leading to a deeply differentiated post-school system in terms of institutional culture, history and resource allocation (Kraak 2012). The result is a relatively well-resourced university system on one side, and very limited institutional opportunities for other forms of post-school education and training on the other, implying an uneven capacity to interact with industry (Kruss 2012).

As a result, a large proportion of the population possesses inadequate skills, thus perpetuating the problem of skills shortages and contributing to high levels of youth employment (Kruss 2012). Given the existence of institutions that can be regarded as pockets of excellence with the capacity to provide a foundation for development, the challenge is how to strengthen institutions with low capabilities and weak linkages. It has been argued that firms find it difficult to enhance their absorptive capacity, which refers to the extent to which external knowledge can be internalised. Higher education institutions also struggle to enhance their interactive capabilities through building linkages with industry and other social partners to facilitate the transfer of knowledge and technology to address economic and social developmental demands (Kruss 2010).

The specific intention of Project 1 of Theme 4 is therefore to provide insights on:

> *how the institutional capabilities, structures and mechanism in the public and private higher education, FET and SETA* [Sector Education and Training Authority] *skills development systems interact with labour market stakeholders, labour market*

> *institutions and intermediary organisations in order to inform how we can strengthen the links and match between supply and demand* (Kruss 2012: 2)

The study is built upon the recognition of the central role and benefits arising from efficient knowledge generation and knowledge flows across various actors and networks of the system. The challenge then becomes identifying the most appropriate method that will allow for an investigation of these actors and interactions.

We have proposed that the National Innovation System (NIS) framework would be a useful conceptual and analytical tool for the analysis of the actors, their capabilities, networks and interactions (Gastrow 2012). This background paper will build upon this proposal, arguing that the NIS framework will provide insight into the complexities of the relations between education and training systems and the changing skill demands of firms (Kruss 2012). The basic innovation system approach defines innovation to be an interactive, non-linear process in which actors such as firms interact with a number of other organisations such as research institutes, customers, authorities, financial organisations and institutions (e.g. intellectual property rights, regulations, culture). The complex process characterised by reciprocity and feedback mechanisms ultimately determines the extent of success of innovation and hence, economic and social development (e.g. Freeman 1987, 1988; Lundvall 1992; Nelson 1993). By mapping out the agents and their interaction in knowledge production and absorption, and analysing their interactions with the institutions, it is possible to identify actors and mechanisms promoting innovation, thereby making it possible to pinpoint areas of concern (Woolthuis et al. 2005).

This background report is intended to identify and delineate some of the key concepts central to the conceptualisation and design of the empirical study using the proposed NIS framework to study skills development in the South African post-school sector. It introduces the NIS framework as a theoretical and analytical tool that will frame the implementation of the study. Most importantly, it presents the Sectoral Innovation System (SIS) approach for the selection and delineation of the study unit of analysis to explore knowledge and technological bases and linkages in the different sectors. It offers an introduction to, as well as a clarification of, main concepts emanating from the literature to enhance our understanding of the main actors, institutions and knowledge linkages, functions and key characteristics of the SIS framework. Understanding the basic structural elements and functions of the SIS approach is important if the ultimate goal is to identify the institutional composition of the SIS with a specific focus on capabilities, institutional linkages and interaction with the purpose of revealing possible avenues for policy intervention.

The report also provides a conceptualisation of the 'capability approach', which is central to understanding the interactive capabilities of different actors in the post-school sector. This will be based on Sanjaya Lall's (1992) conception of technological capabilities based on the firm-level technological capabilities framework. The report briefly consider show these approaches could be used to generate analytical tools for conducting empirical research in the post-school sector.

1 THE NATIONAL INNOVATION SYSTEMS FRAMEWORK

Following early efforts to understand variations in country development and growth patterns through conventional neoclassical approaches, there has been an emergence of a series of unorthodox perspectives emphasising the role of innovation in economic development. The National Innovation System (NIS) approach is a sub-approach within a broader neo-Schumpeterian tradition, which has rapidly diffused since the 1970s (Gammeltoft 2003). Niosi (2008) traced back the concept of NIS to the work of Christopher Freeman (1995, 2002), Bengt-Åke Lundvall (1992) and Richard Nelson (1993).

The literature reveals some historically significant moments, when the adequacy of mainstream economics frameworks assuming a linear model of technological development to explain innovation and economic development were called into question. Such linear models assumed that societal knowledge and skills for technological development are determined by the knowledge frontier, which can be expanded through a knowledge creation process (Mytelka & Smith 2001).

These moments were characterised by the failure of neoclassical approaches to account effectively for factors behind innovation, growth and productivity trends, particularly in newly industrialised countries (NICs) (Gammeltoft 2003; Lundvall et al. 2002; OECD 2007). This included the extraordinary success experienced by NICs and the collapse of the socialist economies of Eastern Europe (Freeman 1995; OECD 2007). Specifically looking at Japan, there is evidence attributing the country's economic success to a shift away from a 'product-based' understanding that emphasises the rate of outputs, to a 'process-based' understanding that emphasises the structure of the innovation process (Tether et al. 2005: 76). It also became clear that in contrast to the traditional linear models of innovation, the Japanese approach was neither linear nor sequential, with some processes such as research and development (R&D), marketing and production engineering occurring simultaneously. This also meant a variety of skills had to be widely distributed throughout the firm and that R&D was not the only skill critical to innovation. Moreover, the innovation process was distributed between a series of firms and other organisations.

Freeman (1995) also pointed out that despite large investments going to R&D in the industrialised and semi-industrialised countries between the 1950s and 1960s, 'evidence accumulated that the rate of technical change and of economic growth depended more on efficient diffusion than on being first in the world with radical innovations and as much on social innovations as on technical innovations' (Freeman 1995: 10). This provides a basic illustration of the non-linear nature of the innovation process, the importance of other forms of innovation other than technical and radical innovation and the fact that the skills necessary for innovation are located throughout the different levels of the organisation.

This evidence induced fresh thinking about 'innovation' as well as the skills necessary for successful innovation. The NIS approach therefore emerged as an unorthodox framework that conceptualised technological development by underlining the significance of the interactions or linkages among the people and institutions involved in technology development, in translating into inputs and outputs (Feinson 2003; Gammeltoft 2003; Lundvall et al. 2002; OECD 2003).

1.1 What is innovation?

Innovation has been defined in various ways. In line with Schumpeter, Dosi (1988) described innovation

as the research, discovery, experimentation, development, imitation and adoption of new products, processes and ways of organising resources. Other writers simply define innovation as a successful exploitation of new ideas and that the wider benefits of innovation are therefore derived through wider diffusion of these new products and processes throughout the economy (Tether et al. 2005).

According to the Oslo Manual, innovation is firstly, the implementation of

> *technologically new products and processes and significant technological improvements in products and processes* (OECD 1997: 47, in Toner 2007: 9).

Secondly,

> *an innovation has been implemented if it has been introduced on the market (product innovation) or used within a production process (process innovation). Innovations therefore involve a series of scientific, technological, organisational, financial and commercial activities* (OECD 1997: 47, in Toner 2007: 9).

Thirdly,

> *an innovating business is one that has implemented technologically new or significantly technologically improved products or processes during the period under review* (OECD 1997: 47, in Toner 2007: 9).

Innovation can therefore be defined as the implementation of technologically new or improved products or services, production processes and organisational and managerial processes. Notably, innovations are therefore not necessarily novel or new to the world, but simply new to the user (Lundvall et al. 2009: 60). For any entity (at a country, regional or organisational level) to develop, it needs to exhibit the ability to continually introduce new products, improve on existing ones and develop new processes to support such new developments.

Furthermore, as Lundvall (2000: 8) remarked, innovation is 'a ubiquitous phenomenon in the modern economy'. That is, there are always ongoing processes of learning, searching and exploring of technology in some parts of the economy, leading to the development of new products, new techniques and new forms of organisation.

Innovation manifests in different forms. Toner (2011) distinguishes between technological and non-technological innovation. *Technological innovation* broadly includes products, services and processes, whereas *non-technological innovation* includes organisational and managerial processes that are designed to improve the performance of the enterprise. Examples include implementation of quality systems and improved business diagnosis or performance measures. These broad categories can be subdivided as follows:

- *Product innovation* is the introduction of a product or service that is new or has improved performance characteristics. It entails activities such as design, R&D, acquisition of patents, technology, licenses and trademarks, as well as tooling up and industrial engineering. It also refers to significant improvements in technical specifications, components, materials, software, user friendliness or other functional characteristics (Toner 2008, 2011). Notably, product innovation can be converted into process innovation. For example, a production robot is a product when produced but is transformed into a process when used in a production process (Edquist 2001).
- *Process innovation* refers to the implementation of new or significantly improved production or delivery methods. This includes investment in new technology through new machinery or equipment, new software, supply chain management and training of staff to offer new services to customers (Toner 2008). Process innovation can therefore be technological or organisational (Edquist 2001).
- *Organisational innovation* refers to the implementation of a new organisational method in a firm's business practices, workplace organisation or external relations, with the intent of increasing the firm's performance by reducing

administrative costs, transaction costs or the cost of supplies or by improving workplace satisfaction (Toner 2011).

- *Marketing innovation* is the implementation of new marketing methods involving significant changes in product design or packaging, product placement, product promotion or pricing. These are mainly aimed at meeting the customer needs and opening up new markets in order to increase the firm's sales (Toner 2011).

Innovation activity can be divided into two types:

- *Radical innovation* often leads to major technological, economic and social change and is an outcome of large investments and high scientific skills. Radical innovations are typically characterised by great uncertainty, largely in terms of the size of the potential market or even the existence of a market for the new product or service. This also makes these undertakings risky, as the return from investing in the invention, commercialisation or marketing of an innovation cannot be guaranteed (Toner 2011). Examples of radical innovation include the development of agriculture, printing, railways, electricity, motor vehicles, the transistor, contraceptive pill, telecommunications, biotechnology and atomic power.
- *Incremental innovation*, on the other hand, involves continuous minor modifications and improvements to existing products (Rosenberg 1994). Incremental innovations are typically characterised by the use of existing technologies and products to improve on products and services with highly predictable development costs and market potential. Notably, the implementation of incremental innovation largely involves direct production workers who are either producers or users of these goods and services.

Recently, there has been a series of emerging focuses and new forms of innovations studied in the literature:

- *User innovation* refers to the innovation of goods and services by users (e.g. firms or consumers) rather than suppliers (e.g. producers or manufacturers) to suit their needs. This is in contrast to common conceptions of producers as the main drivers of innovation (Von Hippel 2005). Gault (2012, in Iizuka 2013: 7) states that knowledge is transferred from users through their interaction with producers, by users starting their own business operation or through information-sharing with a community of practice.
- *Social innovation* has been defined as 'any novel and useful solution to a social need or problem, that is better than existing approaches (i.e. more effective, efficient, sustainable, or just) and for which the value created (benefits) accrues primarily to society as a whole rather than private individuals' (Phills et al. 2008: 39). The central concept in the definition is 'social'. That is, innovation should be driven by the needs of the society.
- *Public-sector innovation* is the process of improving the efficiency and productivity of the public sector and supporting organisations in its delivery of services to citizens (Gault 2012, in Iizuka 2013).
- *Innovation for inclusive development* has been defined as 'the development and implementation of new ideas which aspire to create opportunities that enhance social and economic wellbeing for disenfranchised members of society' (George et al. 2012: 663). This concept has grown alongside other related concepts such as grassroots innovation, innovation for bottom (base) of the pyramid and frugal innovation (Iizuka 2013).

Technological and non-technological innovations are conditioned by different factors. It is therefore critical to disaggregate by different types in order to map and understand the determinants of innovation (Edquist 2001). Moreover, the discussion points to the importance of intangible innovations such as organisational innovation that are also crucial for economic development.

1.2 Defining National Innovation Systems

Whilst there is currently no consensus regarding the definition of NIS, some commonalities can be noted

across the definitions (Table 1). Most definitions reflect a web of interactions between institutions that produce, diffuse and adapt new technical knowledge (Rooks & Oerlemans 2005) within the system involving the flow of technology and information among society, firms, universities and government institutions (Monroe 2006).

It is for this reason that three concepts – institutions, interactions and technological learning – have been identified as common across the varied definitions of NIS (Gammeltoft 2003; Manzini 2012: 3).

Table 1: Definitions of National Innovation Systems

'The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies' (Freeman 1987, in Niosi 2002: 292)
'The elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge, and that a national system encompasses elements and relationships either located within or rooted inside the borders of a nation state' (Lundvall 1992, in Niosi 2002: 292)
'The set of institutions whose interactions determine the innovative performance of national firms' (Nelson & Rosenberg 1993, in Niosi 2002: 292)
'The national system of innovation is constituted by the institutions and economic structures affecting the rate and direction of technological change in the society' (Edquist & Lundvall 1993, in Niosi 2002: 292)
'The system of interacting private and public firms (either large or small), universities and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, protection, financing or regulation of new science and technology' (Niosi et al. 1993, in Niosi 2002: 292)
'The national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country' (Patel & Pavitt 1994, in Niosi 2002: 292)
'That set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies' (Metcalfe 1995, in Niosi 2002: 292).
'A set of organisations, institutions and linkages for the generation, diffusion, and application of scientific and technological knowledge operating in a specific country' (Galli & Teubal 1997: 345)

The differences in the conceptualisation of the NIS approach are primarily due to the types of institutions and activities considered to be part of the system (Johnson et al. 2003). Lundvall (1992) identified two schools of thought regarding the definition of NIS:

- The narrow definition focuses on science and technology only; and
- The broad definition also considers learning and competence-building at various levels.

The narrow view is concerned only with the activities of organisations and institutions involved in searching and exploring technology. These include R&D departments, technological institutes and universities (Gammeltoft 2003). The broad definition is regarded as the most applicable to developing countries, as it includes all aspects of the economic structure and institutional settings that affect interactive learning and the competence-building process in the economy, such as education and training, industrial relations and labour dynamics (Gammeltoft 2003; Gu & Lundvall 2006, in Szogs 2010; Lundvall 1992: 12; Niosi 2008: 615).

Linked to the different perspectives in conceptualisation of NIS is the distinction between two forms of learning – learning by doing, using and interacting (DUI), and learning through science and technology (S&T). The S&T mode relates to the narrow definition of innovation systems with its emphasis on R&D and codified knowledge. The DUI mode of learning relates to on-the-job learning through problem-solving and interacting with external customers or any other external linkages; this mode of learning plays a greater role in developing countries than in developed countries. However, Szogs (2010) laments the limited opportunities for spontaneous, interactive learning processes to take place in developing countries, owing to the weakness (and even the absence) of linkages among the actors in the system.

1.3 Main components of National Innovation Systems

One of the consequences of adopting such a broad and amorphous definition of NIS is the difficulty of discerning what is deemed important building blocks of the system. Having advocated the adoption of the broad definition of NIS, the fundamental question that Edquist (2001: 4) puts forward is 'What is a system?'

The two main components of innovation systems commonly cited across the literature are organisations and institutions.

Galli and Teubal (1997) note that NIS *organisations* are formal structures comprising:

- Political bodies, such as ministries or national councils for S&T;
- Bureaucratic bodies, for example, public agencies and offices implementing innovation policy;
- Regulatory bodies, for example, for standards, norms, and certification;
- Social bodies, such as academies and professional associations;
- Educational bodies, such as universities and schools;
- Knowledge-oriented bodies without economic goals (e.g. government laboratories in the area of defence or health) or non-profit organisations with economic goals (e.g. technical centres or experimental stations of an industrial association);
- Profit-oriented firms (can be suppliers, customers or competitors) including R&D companies, joint ventures and consortia; and
- Bridging bodies connecting the S&T realm with the needs of business firms, such as innovation centres associated with chambers of commerce or industrial associations, or the industrial liaison units of universities (Galli & Teubal 1997: 4).

Institutions, as defined by North (1994: 360), are 'humanly devised constraints that structure human interactions'. Institutions have been described as a set of common habits, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups or organisations (Edquist & Johnson 1997) in a specific country. These institutions can be formal or informal and play a significant role in delimiting the incentive structure of S&T and innovation/diffusion activities (Galli & Teubal 1997; Lundvall et al. 2002).

Examples of formal institutions are formal constraints, such as patent laws and formal criteria for allocating resources to science, peer review procedures and technical standards and norms, whereas informal institutions include norms of behaviour or traditions, conventions, codes of conduct and their enforcement characteristics (Edquist & Johnson 1997; North 1994). Measuring the impact of informal institutions on the overall innovation process is a challenge because unlike formal institutions, they are often uncodified.

1.4 Functions of the National Innovation Systems

Recent developments in the innovation system approach perspective include attempts to identify the 'functional boundaries' of an NIS, over and above its core function, which is of producing, diffusing and using technology (Carlsson et al. 2002; Feinson 2003).

This follows the direction espoused by Edquist (2005) in suggesting that it is the 'functions' of the system that should be analysed rather than merely identifying and describing elements of the system and relations between them. This is to say, the performance of the innovation system can be evaluated based on how well it is performing these functions.

Table 2 provides a summary of attempts to identify and specify functions of innovation systems. Johnson and Jacobsson (2000), for example, identified functions that are to be fulfilled for the growth of an industry to be successful, whereas Johnson (2001) distinguished between 'basic' functions, which are directly linked to the innovation process, and 'supporting' functions, which relate to those activities that indirectly support the innovation process.

Taking this further, Archibugi and Michie (1999) point to six important characteristics that determine the behaviour, as well as the successes, of the NIS:

- Education and training – participation rates and distribution of students by disciplines vary between countries;
- Science and technology capabilities – for example, the percentage of GDP spent on R&D, the split of R&D expenditure between government and business;

Table 2: Functions of innovation systems

Johnson & Jacobsson (2000)	Rickne (2000)	Liu & White (2001)	Johnson (2001)
To create new knowledge	To create human capital	Research (basic, developmental to engineering)	Basic functions
To guide the direction of the research process	To create and to diffuse technological opportunities	Implementation (manufacturing)	Identification of the problem (e.g. bottlenecks)
To supply resources and competence.	To create and to diffuse products	End use (customers of the product or process outputs)	Offers solutions through the creation of new knowledge
To facilitate the formation of markets	To incubate in order to provide facilities, equipment and administration support	Linkage (bringing together complementary knowledge)	Supporting function
	To facilitate the regulation of technologies that may enlarge the market and enhance market access	Education	Supply incentives for innovative work in the firm
	To legitimise technology and firms		To facilitate resources (basically financing and training)
	To create markets and diffuse market technology		To guide direction of research
	To enhance networking		To recognise the potential for growth
	To direct technology, market and partner research		To facilitate the exchange of information and knowledge
	To facilitate financing		To stimulate and create markets
	To create labour markets that new technology-based firms can utilise		To reduce social uncertainty (to solve or prevent conflict)
			To counteract resistance to change and to legitimise innovation

Sources: Edquist (2001: 9–10); Johnson (2001: 12–15); ICT (no date)

- Industrial structure – for example, the proportion of larger vs smaller firms, the level of domestic competition influencing R&D investments;
- S&T strengths and weaknesses – for example, specialising in areas of leading technology vs areas of diminishing returns;
- Interaction and coordination within the innovation system; and
- Capacity to absorb foreign knowledge – increasing international integration will continue to influence NIS, but countries vary in their ability to take advantage of foreign knowledge.

However, differences in the NIS structures and strategies of economically successful countries indicate that there is no universal best practice or model NIS (Edquist 1997, in Fromhold-Eisebith 2007; Nelson 1993). Consequently, the most successful innovation systems are the best coordinated and are rarely the most complete (Luz & Salles-Filho 2011). The innovation system is therefore said to exist as long as there is some form of coherence between organisations' agendas and orientation (with a number of organisations with common development trajectories, feedback loops and complementary competencies between agents) (Edquist 2004).

1.5 Key features of National Innovation Systems

1.5.1 Actors

The theoretical foundation of an NIS is based on the premise that various actors are involved in knowledge creation and diffusion and that understanding the interaction and linkages between the different actors is central to improving innovation and technology performance (Lundvall et al. 2002). This perspective emphasises the role of actors and notes the complex processes in which different actors, over and above firms, interact to produce innovation (Oerlemans & Pretorius 2006).

Even though all elements of the system are important, the core of the innovation system is constituted by (a) firms and (b) organisations belonging to the knowledge infrastructure –those involved in science-related activities and those that support competence-building through education and training (Lundvall 2008). Firms are placed at the

centre because of their potential to develop, absorb and use new technology (Iizuka 2013; Lundvall et al. 2002) and are perceived to be sites where knowledge is translated into goods and services and therefore where wealth is created (Arnold & Bell 2001).

While firms have generally been regarded as the main sites of interactive learning, Gammeltoft (2003) argues that the learning process taking place in supporting institutions should not be disregarded – such organisations may undertake the role of being mediators of externalities. Furthermore, he stresses the 'institutions' in firms and between firms at a national level as the second important dimension of the innovation system. Often referred to as 'rules of the game' or 'codes of conduct', institutions are important because they shape the interactions and maintain a conducive environment for innovation efforts to take place.

Moreover, the NIS perspective stresses the interdependencies between multiple actors in the system, as well as the non-linear nature of the innovation process. 'Firms do not generally innovate in isolation' (Edquist 2001: 3), as the innovation process is often distributed across a number of firms or agents rather than depending on a single firm acting alone.

> *It is well recognised that the variety of assets and competencies which need to be accessed [for innovation] is likely to be quite large, even for modestly complex technologies. To produce a personal computer, for instance, a company needs access to expertise in semiconductor technologies, display technology, disk drive technology, networking technology, keyboard technology and several others. No company can keep pace in all of these areas by itself* (Teece 1986: 293, in Tether et al. 2005: 76).

The extent of innovation is therefore dependent on cross-functional integration within the firm (each with its own organisational characteristics and culture), in combination with close interrelations with suppliers, customers or users, plus commercial partners and other sources of technology such as universities or public sector institutes. This means that individual companies are unlikely to be able to master and remain abreast of developments in several technological fields at once (Kodama 1992, in Tether et al. 2005).

This framework perceives the process of converting knowledge into new products or production processes as non-linear and characterised by complicated feedback mechanisms and interactive relations involving science, technology, learning, production, policy and demand (Edquist 2005), rather than linear, that is, moving from basic research to applied research and eventually to development and implementation of new processes and products.

The very relationships between the different actors and between actors and systems are perceived to be carriers of knowledge. In the quest to innovate, actors interact with one another to gain, develop and exchange various kinds of knowledge, information and other resources with other organisations which might be other firms (suppliers, customers, competitors) or universities, research institutions, investment banks, schools, government ministries and so on (Edquist 2005). It should not be forgotten that these interactions take place in the context of institutions such as laws, rules, regulations, norms and cultural habits. Therefore, innovations are determined by the elements of the system together with the interactions between them.

To illustrate the importance of the interdependency of the different actors and institutions in the system, Lall (2000: 22) uses the concept of 'low-skill equilibrium' to explain a situation where a poor education system produces a large proportion of students with low literacy and numeracy skills, and where an inadequate post-school sector fails to correct these deficiencies when students enter the workforce. This means that the efficiency of the higher education system depends on the quality of the primary and secondary education provided to students. Therefore, without good basic education, a country can fall into a 'low-skill trap' (Lall 2000: 21), as it will be unable to learn and adopt new knowledge and consequently to penetrate new markets (Niosi 2008).

The introduction of knowledge requires active learning by all actors in the innovation system, indicating that innovation can take place anywhere in the system (Toner 2008; Gammeltoft 2003; Lundvall et al. 2002). It is for this reason that Lundvall views the NIS as the learning system of national economies. This knowledge is not only a product of purposive activities such as R&D but is also a part of daily economic activities, inside and between firms. Lundvall et al. (2002: 215) argue that 'the new knowledge needed for innovation did not come directly from universities and technical research and in many industries not even from universities and experimental development but rather from other sources like production engineers, customers [and] marketing.'

It should be noted that knowledge accumulation can either be intentional (investments in R&D, training and education programmes) or unintentional. Unintentional knowledge accumulation is often a side effect of intentional investment. It occurs through learning DUI and knowledge gained from own experience in the workplace (Engelbrecht & Darroch 1999: 284).

Recent evidence from the literature shows that the broader workforce – those not involved in S&T – plays a very important role in the innovation process (Toner 2011). That is, they take part in developing and diffusing technical and organisational innovation, particularly through incremental innovation. This accounts for much of the economy's productivity growth and dynamism. Incremental innovation occurs both in the direct production process and in final consumption. This means workers and consumers all contribute by adapting goods and services to suit their needs and by providing feedback to equipment and service producers (von Hippel 2005). Lundvall (2009) explicitly emphasises the role of the final users of technology in his user–producer approach by refuting models that assume that workers and consumers are passive beneficiaries in the development of new technology, instead of being active participants in processes of innovation. According to Lundvall (2009), workers, consumers and the public sector – not only the traditional actors in innovation studies (individual entrepreneurs and R&D laboratories) – are central to the development of new technology.

1.5.2 Knowledge

The capacity to engage in incremental innovation depends on the technological absorptive capacity of the workforce, which relates to the ability to adopt, adapt and diffuse new or improved products, production processes and organisational innovations. The increased rate of innovation across economies therefore requires the workforce to possess both technological competences and generic skills (problem solving, teamwork and communication).

Several factors determine the contribution of the workforce not involved in S&T towards innovation at the firm level. These include primary and secondary education quality, post-school vocation training, incentives for training and work organisation that encourages their continuous participation in product and process innovation (Toner 2011).

Even though developing countries can solicit knowledge from foreign firms, the expansion of national absorptive capacity through various components of the NIS is necessary for sustained economic development. The emphasis on absorptive capacity shifts the emphasis for developing economies from innovation to passive and active learning. Passive learners 'absorb the technological capabilities for production, using a kind of "black-box" approach' while active learners master 'technology and its improvements through a deliberate effort' (Juma et al. 2001: 633, in Feinson 2003: 21). The choice of either passive or active learning strategy has implications for a country's economic and social development.

Considering that innovation 'is rooted in learning, and learning in routine activities' (Lundvall 1992: 12), technological development is more likely to take place in areas in which a firm or a country's economy 'is already engaged in routine activities' (Lundvall 1992: 10). Knowledge accumulation has been described as both cumulative and integrative – the more that is invented, the greater the probability of future inventions in a particular area. As the stock of knowledge grows, so does human

capital (Engelbrecht & Darroch 1999). This is because the development of knowledge bases is a costly and lengthy process and only possible through processes of learning and adaptation, in which firms build up experience with specific technologies. This is clearly in contrast with the linear neoliberal models that disregard the importance of the stock of existing knowledge. This relates to the evolutionary characteristic of NIS, that is, it assumes the innovation process to be path-dependent over time and to develop along certain trajectories (Edquist 2001).

The NIS model acknowledges that some elements of knowledge critical for economic performance are localised and not easily moved from one place to another. This flows from the assumption that knowledge is more than information and that it includes tacit elements. Some elements of knowledge are embedded in the minds and bodies of individuals or groups or communities of practice engaging in routine activities (Johnson et al. 2003; Wenger 1998, in Tether et al. 2005); this is often referred to as 'embodied knowledge' (Engelbrecht & Darroch 1999: 284). Disembodied knowledge, on the other hand, is contained in research papers, patents, licences, trademarks and so on.

Cohen and Levinthal (1990: 128) defined absorptive capacity as 'the ability of a firm to recognise the value of new external information, assimilate it and apply it to commercial ends.' Zahra and George (2002) argue that absorptive capacity consist of four distinctive capacities:

- *Acquisition*: The search for new knowledge;
- *Assimilation*: Understanding new knowledge;
- *Transformation*: Exploring how the new knowledge can be used in the context of firms' situation and existing knowledge; and
- *Application*: Relating the implementation of actions acquired through the new knowledge.

Again, the economy's absorptive capacity influences the ability of a country to adopt either embodied or disembodied knowledge. If absorptive capacity is highly dependent on the already existing stock of knowledge, this concept draws attention to two further requirements of the technological capability accumulation process:

- The ability to interact with external agents; and
- The ability to identify and adapt external technological knowledge.

The emphasis on the centrality of external sources of knowledge to development is underlined by the fact that most innovation results from borrowing rather than invention, particularly in developing countries (Cohen & Levinthal 1999).

2 THE UNIT OF ANALYSIS

Systems of innovation may be delimited in different ways:

- Geographically;
- Sectorally; or
- According to the breadth of activities considered.

Geographically defined innovation systems may be local, regional, national and supranational. This type of demarcation assumes that the area under analysis has some level of 'coherence' or 'inward orientation' with regard to the innovation process (Edquist 2001: 14).

2.1 Regional Innovation Systems

The Regional Innovation System (RIS) approach emphasises the differences in innovation performance between regions (Cooke et al. 2004, in Doloreux et al. 2008). These differences are attributed to the existence or absence of spatially bounded externalities or agglomeration economies characterised by localised knowledge spillovers.

This framework is based on the premise that all countries have a few regions that accumulate dynamic institutions and organisations (Fromhold-Eisebith 2007; Varblane et al. 2007). Defined as a constellation of industrial clusters,[1] which are surrounded by innovation-supporting organisations (Asheim & Coenen 2005), the RIS emphasises advantages associated with assembling similar or related organisations within close proximity (Malmberg & Maskell 2002, in Doloreux et al. 2008; Maskell & Bebir 2006, in Doloreux et al. 2008). For instance, there is evidence that innovation is likely to take place in metropolitan regions because of their major concentration of R&D activities. In addition, other specialised services, industries, technological infrastructure, suppliers, formal and informal networks and a qualified workforce place them in a better position to stimulate innovation.

Although the perspective is built on the same assumptions as the NIS framework, the RIS approach supplements the disregard of the critical role of regionalised processes of achieving collaboration-based success. Moreover, the RIS approach focuses on the localised nature of the interactions amongst actors, emphasising the tacit component of knowledge. Knowledge is considered embedded in specific institutions, where local recipients share values, visions and organisational forms that allow them to interpret the tacit knowledge available to them. This increases their ability to tap into tacit knowledge. A region therefore imposes many systemic elements external to firms, which in turn influence their technological competence and growth. Thus, interactive learning is facilitated by physical proximity (Doloreux et al. 2008).

2.2 Sectoral Innovation Systems

Based on the acknowledgment that patterns of technical change, innovation and economic performance are diverse across sectors, Malerba (2002, 2004) has advocated the Sectoral Innovation System (SIS) approach. The SIS approach suggests that sectors are characterised by a specific knowledge base, technologies, production processes, complementarities and demand by a population of firms and non-profit organisations (Tuncel 2012). The focus on knowledge bases and learning processes instead of industrial structure enriches the understanding of the dynamics of knowledge, competencies and sectoral competitiveness with regard to market structure (Luz & Salles-Filho 2011).

Within the SIS framework, a sector can be broadly defined as a set of activities that are united by some related product groups for a given or emerging demand, with a common knowledge base. This definition implies that that whilst firms in the sector share some commonalities, they also exhibit some heterogeneity in terms of learning processes and capabilities, differing significantly along several dimensions related to technology, production and demand, as well as by the extent and type of innovation taking place.

Building on the main elements of the NIS approach, the SIS framework is characterised by the following seven elements:

- Agents (firms and non-firms in the sector);
- Networks;
- Demand;
- Institutions;
- Knowledge;
- Basic processes of interaction, variety generation and selection; and
- Coevolution.

2.2.1 Defining Sectoral Innovation Systems

An SIS is composed of a 'set of heterogeneous agents carrying out market and non-market interactions for the generation, adoption and use of new or established technologies for the creation, production and use of productions that pertain to a sector' (Malerba 1999: 4). It therefore has a specific knowledge and technological base and key links amongst products, knowledge and technologies, which in turn affect the creation, production and use of sectoral products. The notion of the sectoral system places emphasis on the structure of the system in terms of products, agents, knowledge and technologies, as well as on its dynamics.

2.2.2 Main components of Sectoral Innovation Systems

Building on the elements of the NIS, each sector is composed of diverse firm and non-firm agents who are all characterised by specific learning processes, competencies, beliefs and objectives. All the agents interact through processes of communication, exchange, cooperation, competition and command and their interactions are shaped by (and they shape) institutions. Firm agents include organisations who might be users, producers and suppliers.

However, the literature on the SIS framework notes that firms are not always the most appropriate unit of analysis for some sectors. That is, some sector agents might be studied at a different level of disaggregation. In biotechnology, for instance, the key unit of analysis might be a university department, the research laboratory or individual scientists, depending on the research project and objectives.

The other types of agents in the sector who are from non-firm organisations include universities, financial institutions, government, local authorities, trade unions and technological and industry associations. These organisations play a supporting role to innovation, diffusion of new technology and production in firms within a sectoral system.

However, their roles also differ by sector. For instance, universities might play a critical role in sectors such as biotechnology, whilst trade unions might be central to innovation in other sectors.

Within the sectoral system, firms are connected variously through market and non-market relationships. Knowledge *networks* and flows are also seen to be important sources of innovation. They provide means for knowledge-sharing and competence dissemination among firms and educational organisations within the sector.

The key role played by the networks in a sectoral system is reflected in the definition of the 'sectoral structure'. This 'sectoral structure' is different from that in industrial economics, which is related to concentration and vertical integration. In the sectoral systems perspective, the 'sectoral structure' refers to links among the artefacts and to relationships among agents. Consequently, Malerba (1999: 17) argued that the sectoral system is composed of 'webs of relationships among heterogeneous agents with different beliefs, competencies and behaviour that affect their actions and these are stable over time.'

In a sectoral system, a *demand* may be local or international. The SIS framework puts emphasis on

the role of users and consumers more strongly than the NIS framework. This focus puts a different emphasis on the role of the 'demand' in the sector. The demand is not seen as an aggregate set of similar buyers, but as made up of heterogeneous agents with specific characteristics, knowledge and competencies who interact around their needs and specifications to the producers. The demand is therefore composed of individual consumers, firms and public agencies that could be in different countries, from varied NIS characterised by different sizes, knowledge, learning processes and competencies and influenced by different social factors and institutions. Consequently, the boundaries of the SIS are always changing, owing to transformation in knowledge, changes in competition and demand, as well as knowledge gained by firms.

Whereas the NIS is delimited more or less clearly by national boundaries, a sectoral system approach would claim that the boundaries of the innovation process in sectors have local, national and global dimensions (Malerba 2004). Often these three dimensions coexist in a sector.

Sectoral systems also differ greatly in their *institutions*, whether formal or informal. These influence the actors' thinking and behaviour and shape their interactions (Malerba 2002). The three sets of formal institutions defined in the SIS deal with:

- The provision of basic goods, directly involved in innovation activities, for example, in the production of scientific and technological knowledge (e.g. intellectual property rights);
- The organisation of financial aspects and corporate governance mechanisms in innovation such as financial markets and banks; and
- The provision of human resources, responsible for industrial relation systems such as labour market regulations and the education system of the country.

Networks and agents are therefore embedded in social norms and institutions that mediate their effects (Polanyi 1957, in Molina 2011). The success of agents can be nurtured or hindered by institutions. For instance, adequately skilled labour might be available for employment by firms, but they might find obstacles due to government regulations. It has, however, been noted that the SIS complements the other innovation system lenses (Malerba 2002). Piirainen and his associates (2012) argued that national, regional and sectoral innovation systems are interconnected and, to some extent, hierarchical. This is because the NIS sets the framework and playing field, the RIS specialises within the national system within the limits of their autonomy and local resources and the SIS may cut across regions or reside within them.

Though many institutions are national, there are also sector-specific institutions that are found in different sectors. National institutions such as the patent system may have different effects in the various sectors, owing to the varied nature of agents, as well as the technology type and knowledge used in the sectors. Sectoral institutions include the sectoral characteristics of the labour market or sector-specific financial institutions such as disclosure agreements.

The relationship between the national institutions and sectoral systems is important in many sectors. Often the characteristics of national institutions will favour specific sectors that correspond better with the specificities of national institutions. It is therefore possible that some sectoral systems become predominant in a country because they are favoured by certain national institutions. In other cases, national institutions may constrain the development of specific sectors, or mismatches between national or sectoral institutions and agents may occur (Malerba 2004). This partly explains the different paths and patterns of industrial development between regions and sectors (Marques & de Oliveira n.d.).

The analysis of SISs also requires a careful understanding of the *process of interaction, competition and cooperation*, since innovation is considered a process that involves systematic interactions among a variety of actors for the generation and exchange of knowledge. Interactions include market and non-market relations taking place outside the market. Notably, over time, sectors

undergo a process of change and transformation through the coevolution of their various elements.

The SIS approach stresses the role of knowledge and its structure as key elements in the sectoral system. The assumption is that the knowledge base may differ greatly across sectors and affects the innovative activities, organisation and behaviour of firms within a sector (Malerba 1999). For instance, science is the driving force of knowledge in some sectors, while in other cases learning by doing and experience are the main causes of growth of knowledge. In some sectors, the main agents in knowledge generation are universities (Munoz & Encinar 2008).

Nelson and Winter (1982) argued that there are three dimensions of knowledge that differ in sectors:

- Accessibility;
- Opportunity; and
- Cumulativeness.

Knowledge therefore has different degrees of accessibility, which can be understood as opportunities of gaining from 'knowledge sources external to the firm' (Iammarino et al. 2009: 4). Sources of technological opportunities therefore vary among sectors. In some sectors, opportunity conditions are related to major scientific breakthroughs in universities; in others, opportunities to innovate will flow from advancements in external R&D. Alternatively, external sources of knowledge such as suppliers or users may play a critical role.

To summarise, the SIS framework suggests that different industries may not only have different competitive advantages and interactive and organisational boundaries, but are also characterised by different sources of innovation and user needs. However, because of technological spillovers, SIS in some sectors is able to facilitate not only sectoral performance but also the economic performance of the whole economy (Tuncel 2012).

The SIS perspective lays emphasis on the role of knowledge and the way it is structured, and argues that different sectors possess varied knowledge bases. This perspective also stresses the significance of identifying the extent and the causes of the differences of the agents' (firm and non-firm) learning processes, competencies, structure and behaviour. It observes the role of non-firm organisations and the role of national and sector-specific institutions. Additionally, it pays attention to the networks, relationships and interdependencies amongst actors in the system and argues that these are what define the boundaries of the system.

2.3 Comparing the national, regional and sectoral approaches

Table 3 compares the national, regional and sectoral approaches, showing where they differ in emphasis and coverage. It is an important aid to deciding on the most appropriate framework for the purposes of research in the post-school sector.

Table 3: Comparison of the three innovation system frameworks

	NIS	RIS	SIS
Main actors	Industry	Universities Industrial enterprises Public research organisations	Firms Non-firm organisations Individuals
Institutions	Government Education and research organisations National policies Laws National finance support	Informal institutions depending on trust and reliability among actors	Regulations Standards
Main interaction	Joint industry activities R&D collaboration Technology diffusion Personnel mobility	Interfirm interactions External interaction between firms and research organisations R&D collaboration	Interindustry interactions between firms and non-firm organisations

Source: Gao and van Lente (2008)

So far, this report has highlighted the systems analytical frameworks and key concepts that are useful for a multi-layered exploration of capability development in the economy. The next section concentrates on firm learning capabilities.

3 THE CAPABILITY APPROACH

There is an extensive innovation systems literature that researches firms' development of technological capabilities in developing countries like South Africa. Firms are continuously evolving as they try to adapt to the changing environment (Marques & de Oliveira n.d.). Broadly, the technological capability approach relates to 'dynamic competence-building activities firms undertake to generate new products, processes or services' (Marques & de Oliveira n.d.: 4).

Competencies are defined as inputs to produce goods and services, whereas *capabilities* involve learning and accumulation of new knowledge at the firm level and also the integration of behavioural and socio-economic factors embedded in a specific context (Iammarino et al. 2009). Competencies thus refer to a 'potential' rather than 'actual performance' (Kruss 2007: 11; von Tunzelmann & Wang 2003), while capabilities are products of adaptive learning processes that have been localised. Von Tunzelmann (2007) pointed to the absence of a direct relationship between competencies and outcomes, arguing that converting competencies into interactive capabilities depends on abilities and circumstances. According to the INGINEUS report (2010: 10), competencies are 'specific sets of skills and knowledge which are usually generated outside the firm, for example through education institutions, but can also be generated inside a firm, for example through internal training programmes.' Capabilities on the other hand are viewed as the 'functional capacity of (people inside) a firm to complete specific tasks,' which are strictly built within the firm (e.g. through experience) in order for a firm to fulfil its role as a supplier, producer or consumer (INGINEUS 2010: 10). This means that a qualification (e.g. a diploma) would represent a 'competency', whilst a 'capability' would relate to what one could do with the qualification.

Here we refer to competencies as specific sets of skills and knowledge which are usually generated outside the firm, for example through education institutions, but can also be generated inside a firm, for example through internal training programmes.

The capability approach challenges the view that only developed countries should be concerned with technological development. Developing countries are importers of knowledge in the form of machinery, equipment designs, patents and blueprints. The misconception is that developing countries only need to open up their economies and then adopt new technology, with no further technological efforts required (Lall & Kraemer-Mbula 2005). The capability approach asserts that even though developing countries do not innovate, they still have to invest in technological efforts in order to master, acquire, adapt and improve upon existing technologies. This is because technology acquired from developed countries need some form of adaptation for use in developing countries. It has been noted that technological knowledge, owing to its complex nature, cannot be transferred in its entirety. The buyer will inevitably receive less complete information compared to information possessed by the seller, thus forcing the importing country to develop local technological capability through R&D efforts (Lundvall et al. 2009). This is no easy task, particularly in developing countries where firms may have low absorptive capacity.

3.1 Lall's capability theory

Lall's (1992) 'capability theory' states that capability-building occurs throughout the occupation levels of a firm. The literature focuses on the process of firm learning and technological accumulation of firms (Bell & Pavitt 1995; Fransman & King 1984; Lall 1992). Based on the assumption that acquisition of

new machinery and equipment does not automatically result in productive growth, these authors emphasise the acquisition of capabilities by developing countries to generate and manage technological change as a decisive factor in their ability to catch up (Bell & Pavitt 1995). Moreover, they analysed the varied capability development trajectories during industrialisation stages, observing that whilst technological change is endogenous or internal to the firm, learning dynamics are capable of capturing external innovation (Fransman 1984, in Marques & de Oliveira n.d.; Oliveira 2005, in Marques & de Oliveira n.d.).

There are several definitions of technological capability. Panda and Ramanathan (1996: 562) defined it as 'a set of functional abilities, reflected in the firm's performance … and whose ultimate purpose is firm-level value management by developing difficult-to-copy organisational abilities.' Bell and Pavitt (1995: 78) defined technological capabilities as the specialised resources – skills, knowledge, experience and institutional structures and linkages – that are needed to generate and manage technological change. They classified capabilities as either routine or innovative.

Augier and Teece (2006) suggested that a company's performance is impacted by its ability to continually build, combine, integrate and reconfigure resources and competences.

The most often used definition of technological capabilities is by Fransman (1984, in Marques & de Oliveira n.d.) in which he pointed out that technological capabilities are skills, knowledge and experience required by firms to:

- Search for available technological alternatives and select the most appropriate ones;
- Dominate the selected technologies successfully;
- Adapt those technologies to specific conditions of production and local demand;
- Achieve subsequent improvements through incremental innovations;
- Institutionalise R&D activities; and
- Carry out more basic technological activities (basic research).

The process of building capabilities in developing countries starts with importing and using technology from developed countries (Sato & Fujita 2009). This means that initially the main technological challenge is to master, adapt and improve on the imported knowledge and equipment. Lall (1992: 166) pointed out that gaining mastery of new technology requires skills and intensive efforts by the importing firm. However, the extent of mastery achieved is uncertain. It is only after the country has mastered basic imported technology that firms gradually start adapting technology in order to meet local needs (Kim 1997, 2004, in Sato & Fujita 2009).

Lall (2001) noted that firms do not have access to full information on technical alternatives and operate on imperfect information. This renders technological knowledge difficult to locate and expensive, especially because the transfer cannot be wholly embodied in equipment or instructions. Once technology has been found, its efficient use requires firms to undergo another costly, risky and lengthy process of developing new skills and new knowledge to master its tacit elements. This is characterised by externalities and coordination problems, for instance there is a possibility that skills and technology might leak to other firms. Thus, the learning process can come across market failures, which might limit the process.

Firms tend to move along particular trajectories in which past learning contributes to particular directions of technical change and in which experience derived from the past reinforces existing stocks of knowledge and expertise (Bell & Pavitt 1993: 168; Lall 1992). This means that the stock of past capabilities and routines provides a base on which firms develop the capabilities to cope with new technology change. Capability-building involves efforts at all levels of the firm, as well as knowledge diffusion. Technological development does not only arise out of R&D activities, but also because of informal activities at all levels of a firm (Lall 1992). Successful innovation is thus a product of the efficiency of workers at all levels.

The successful transfer of knowledge is a prolonged process involving local learning, because the embodied elements can only be competently used if

they are complemented by locally developed tacit skills (Nelson 1990, in Lall 2001).This means that even when instruction and support on using new technology has been provided, there is a still a need for local learning. Technological learning therefore requires purposive efforts in searching, exploring and accumulating new skills (Lall 2001).

The more purposeful the technology efforts are, the deeper and more complex the accumulated capabilities will be. Such technological capability is likely to lead to more original and scientifically intensive results (Lall 2000, in Costa & Queiroz 2001). Lall argues that as much as the doing mechanism is important, it is not enough to condition and to strengthen the technological capabilities in all stages of technological development, thus emphasising the significance of purposeful technological efforts. Ultimately, capability development is an active process, which requires purposeful efforts in order to appreciate its benefits widely.

3.2 Matrix of firm-level technological capabilities

Lall (1992) also presented a more practical analytical tool for capabilities and capability formation through a matrix of firm-level technological capabilities (Table 4). According to this matrix, the degrees of complexity may be basic, intermediate or advanced. Levels of formality and purposefulness of technological efforts define these degrees. Basic technological efforts are accumulated through simple production activity routines, that is, through doing or experience-based mechanisms. Intermediate capabilities are built upon adaptive duplicative activities, which are purposely carried out. Finally, advanced capabilities are developed though research-based activities, implying higher risks and uncertainties.

In addition to the degree of complexity, Lall's matrix classified technological capabilities with regard to their functions in facilitating particular productive activities:

- *Investment capabilities*: These are skills and experience required to identify, prepare, design, set up and commission a new industrial project. They determine the cost of the project, the appropriateness of scale, technology and equipment selected. Investment capabilities have two further elements – pre-investment and project execution. The positive relationship between a firm's investment in technological innovation and its performance has been supported by various arguments. This is because investment enables a firm to achieve greater capability to meet the changing demands of domestic and international markets.
- *Production capabilities*: These include the skills and experience required to operate the plant – process engineering, product engineering and organisational/industrial engineering. Process engineering comprises necessary activities for production, which includes activities required to produce and improve products. Industrial engineering involves monitoring and control functions for process and product engineering. Production capabilities influence the productivity of labour and capital, as well as efficiency in material and energy use (Shan & Jolly 2010).
- *Linkage capabilities*: These are skills, knowledge and experience required to facilitate transmission of knowledge, skills and technology to and from wider institutional networks (Shan & Jolly 2010; Siyanbola et al. 2012). External linkages may increase the firm's ability to appropriate returns from innovation. Powell (1998, in Shan & Jolly 2010: 6) argued that external linkages stimulate creativity, thereby reducing risk, accelerating and upgrading the quality of innovation made and signalling the quality of firms' innovation activities. Firms' linkages within the economy involve abilities to organise procurement of goods and services, knowledge and technology transfer with suppliers and S&T links with research institutions, universities and other organisations. Lall (2000, in Costa & Queiroz 2001) further draws a distinction between operational and innovation capabilities. Operational capabilities are the skills and knowledge required to use technologies developed by others, whereas innovation capabilities are related to more complex technological capabilities, as they refer to the ability to understand technology

Table 4: Lall's firm-level technological capabilities

			DEGREE OF COMPLEXITY		
			BASIC	INTERMEDIATE	ADVANCED
			SIMPLE ROUTINE	ADAPTIVE DUPLICATE (search-based)	INNOVATIVE RISKS (research-based)
FUNCTIONAL	INVESTMENT	PRE-INVESTMENT	Pre-feasibility and feasibility studies, site selection, scheduling of investment	Search for technology source, negotiation of contracts, bargaining suitable terms, information systems	
		PROJECT EXECUTION	Civil construction, ancillary services, equipment erection, commissioning	Equipment stretching, process adaptation and cost saving, licensing new technology	Basic process design, equipment design and supply
	PRODUCTION	PROCESS ENGINEERING	Debugging, balancing, quality control, preventive maintenance, assimilation of process technology	Equipment stretching, process adaptation and cost saving, licensing new technology	In-house process innovation, basic research
		PRODUCT ENGINEERING	Assimilation of product design, minor adaptation to market needs	Product quality improvement, licensing and assimilating new imported products technology	In-house product innovation
		INDUSTRIAL ENGINEERING	Workflow scheduling, time–motion studies, inventory control	Monitoring, productivity, improved coordination	
		LINKAGES WITHIN ECONOMY	Local procurement of goods and services, information exchange with suppliers	Technology transfer of local suppliers, coordinated design, S&T links	Turnkey capability, cooperative R&D, licensing own technology to others

principles. Linkage capabilities therefore do not only affect the firm, but the entire industrial structure.

Lall (1992) extended his concept of firm-level technological capabilities to an inclusive concept of National Technological Capabilities (NTCs). Very much related to NIS, NTCs play out in a country's performance in productivity, growth and trade, because of the interaction between capabilities, incentives and institutions. Capabilities of a country therefore define its economic and technological development, whilst the incentives determine the use of capabilities. However, the national institutional framework influences both capabilities and incentives.

4 TOWARDS A RESEARCH AGENDA

The NIS framework has a host of attractive characteristics making it relevant to policy-makers in both developed and developing countries, in that it:

- Provides a systematic perspective to identify and understand the role and relationships between the actors in the system;
- Focuses learning processes and recognises the importance of already existing knowledge in the creation of the new;
- Focuses on the role of both formal and informal institutions that shape and are shaped by the behaviour and relations of actors in the system, which in turn affects the learning and competence-building processes;
- Employs a historical and evolutionary perspective, as the process of innovation develops over time; and
- Emphasises interdependence amongst the organisations and institutions; and
- Acknowledges the non-linear model of the innovation process.

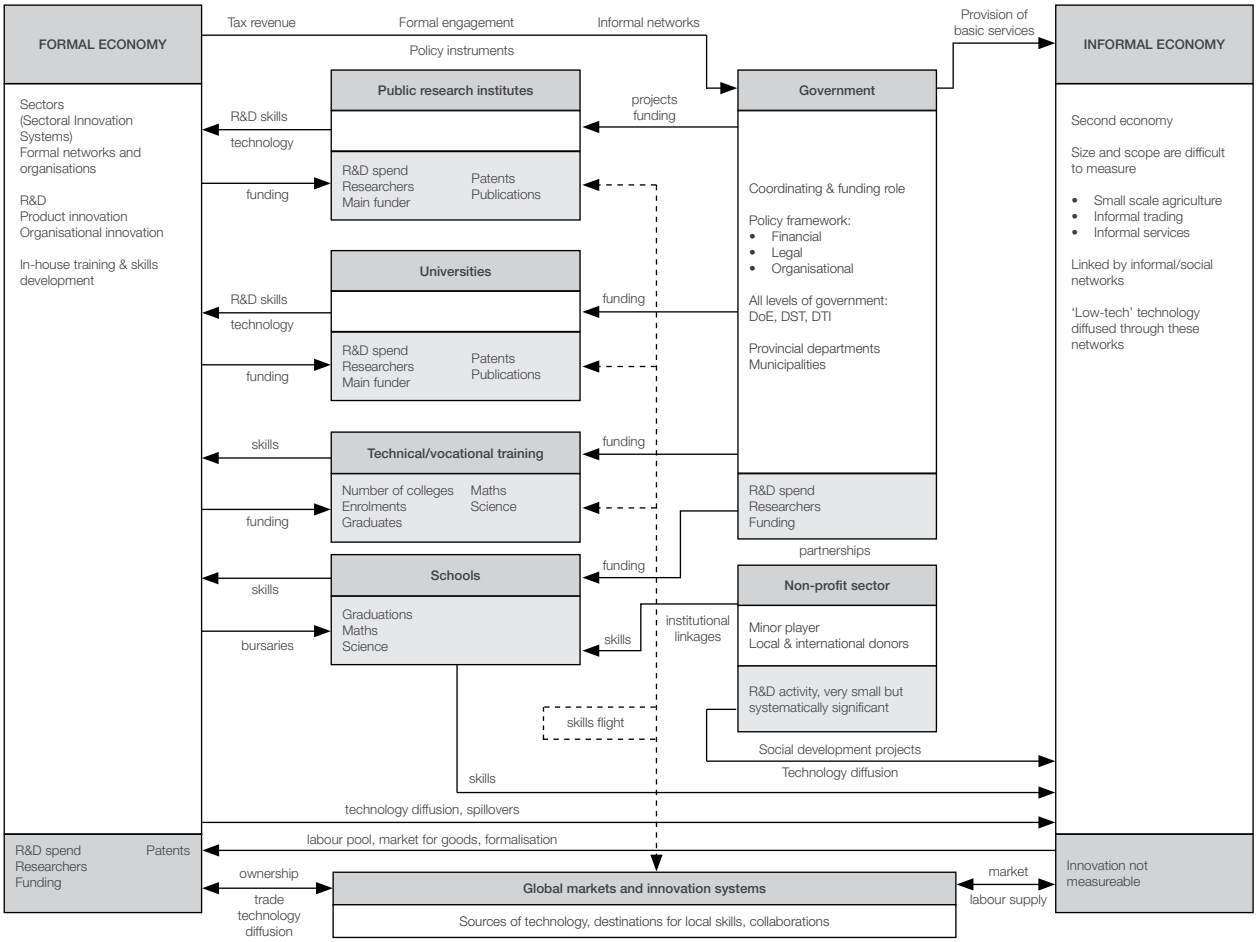
Figure 1 provides a generic illustration of the structure and actors in an NIS.

Adopting a holistic theoretical model will help us to understand the different roles and capabilities embedded in South African post-school sector organisations and institutions, as well as their relationship with labour market institutions and intermediaries in stimulating knowledge diffusion and innovation.

Such a model would acknowledge the critical role of interactive learning, networks and interdependencies in the system. It would be able to trace knowledge flows amongst the different actors and institutions – through interaction among enterprises, universities and public research laboratories, the diffusion of knowledge and technology in firms and through the movement of personnel (Toner 2007).

Mapping the knowledge flows and tracing the linkages and relationships amongst industry, government and academic institutions may ultimately lead to the ability to measure the 'knowledge distributing power' of the NIS (Toner 2007). Furthermore, tapping the factors influencing the performance and innovation of the various actors would allow for identification of system failures and areas of concern requiring targeted policy intervention. Using the SIS framework will make it possible to link micro- and meso-factors in order to understand the relationship and interaction of the various actors in the post-school sector.

Figure 1: A national innovation system



Source: Gastrow (2012)

ENDNOTES

1. Industrial clusters refer to the geographic concentration of firms in the same or related industries (Fromhold-Eisebith 2007)

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