The national system of innovation concept: An ontological review and critique

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The construct 'national system of innovation' (NSI) is used to characterise a country's collective efforts towards fostering technological innovation. Since appearing in the 1996 White Paper on Science and Technology, the term has been used widely in South African policy discourses. This study makes a contribution towards an increased understanding of the meaning and implications of the NSI as a policy construct. The preponderant themes that emerge from this analysis underline the importance of fostering quality networks within the NSI. The NSI philosophical framework provides a solid foundation for organising the country's collective efforts in science and technology in a much more integrated and holistic fashion. Innovation policies and plans should aim to bring about synergy within the various elements of the NSI, particularly within small developing economies such as South Africa, in order to build robust innovation-driven economies.

Introduction

The 1996 White Paper on Science and Technology introduced the notion of a 'national system of innovation' into South Africa's formal public policy discourse. The White Paper became the cornerstone of government policy on science and technology. In this White Paper,[1] the national system of innovation (NSI) is conceptualised as 'a means by which a country seeks to create, acquire, diffuse and put into practice new knowledge that will help that country and its people achieve their individual and collective goals'. The development intent of the country's science and technology policies was declared in this definition of the NSI, thus setting the scene for a system that would focus on creating and applying knowledge for the nation's social and economic advancement.

The NSI approach towards understanding how technological innovation operates within national economic systems is relatively new. There is therefore a need to develop theoretical tools to sharpen our understanding of this conceptual framework. The purpose of this paper is to contribute to the understanding of the NSI by undertaking an ontological exploration of the NSI concept. This exploration is done, firstly, by analysing the definitions that are found in scholarly works; and secondly, by analysing the component terms of the construct, in order to reconstruct the full import of the composite term.

The ontological approach

Ontology is a term that is generally applied to the examination of the nature of 'being' and the relations involved. Here it is used to describe a phenomenological review of the NSI as an entity that exists within South Africa's economy. An approach that is used in this review is that of subjecting the constituent concepts of the 'national system of innovation' construct into an intuitive analysis of its fundamental properties. In this way a deconstruction and reconstruction of the term is accomplished in order to tease out its salient connotative features.

Origin of the national system of innovation concept

In order to trace the genesis of the term, an effort has been made to establish the origins of the concept 'national system of innovation' in scholarly literature. While there seems to be no contention on the matter of its origin, there is nevertheless something of a dilemma in identifying the individual who first coined the term. As far as this research effort could determine, Christopher Freeman credits Bengt-Ake Lundvall whereas Lundvall credits Freeman for introducing the term in the literature. A meticulous analysis of the published works reveals that there may be an amicable resolution to these courteous claims, or rather, disclaims. It appears that Freeman was the first to use the term, albeit in an unpublished paper that he prepared for the Organisation for Economic Cooperation and Development expert group on Science, Technology and Competitiveness in 1982.[2,3] In Freeman's paper, the term was used to emphasise the important role of government in developing a country's technological infrastructure.

Ten years later, in a published book which he edited, Lundvall[4] used the term to describe the interdependence between technical and institutional change, having undertaken extensive studies of institutions and nation states in North America and Europe. Consequently, Lundvall's notion of the NSI concept is largely shaped by the peculiarities of the developed world context, where he conducted his initial studies. The usefulness of the term in developing world contexts is a significant point for further research and deliberation. A case is yet to be made for the appropriateness or expediency of the NSI concept as a conceptual framework for understanding and shaping the behaviour of knowledge-driven institutions within a developing country. In this paper, I devote some attention to the usefulness of the NSI concept in developing world contexts, under a relevant topic below.

Coming back to the origins of the term, there is evidence from the literature which suggests that the concept 'national system of innovation' may actually precede the two contributions discussed above, although the term may not have initially been constructed in the same exact words. Back in the 1800s, Friedrich List, an American economist born in Germany, published a book entitled *Das Nationale System der Politischen Ökonomie*, which, translated, means 'The National System of Political Economy'. In this book, List[5] criticised the work of Adam Smith who advocated the view that the fortunes of a country's economy should be left to take shape in the hands of the vagaries of the market forces. Instead, in this work List argued for an integrated view of national actors in the economy, including the knowledge producing institutions, the productive sectors, technology and infrastructure.

Friedrich List saw the state as the most important actor in generating sustained economic well-being for a country. He argued that the state, as a matter of priority, ought to pursue this goal by concentrating on developing its productive capacities, even at the expense of short-term gain within a generation. List put emphasis on industrial development through technological innovation, as a means to accomplish enduring economic well-being. His thinking, as demonstrated in his book, dovetails with the dominant thought today on the key drivers behind the wealth of nations. In this sense, the works of Lundvall, Freeman and others that embrace the NSI perspective, build on a foundation that was laid at least a century and a half ago.

Definitions of the national system of innovation

Since the first appearance of the term 'national system of innovation' in the literature it has found widespread acceptance. A systematic survey and analysis of how the term is being used elicits the subtle nuances that have made the use of the term popular, and the concept expedient, as a national policy construct. The meaning of the term and the connotations it carries, have far-reaching implications for public policy choices in science and technology. The purpose of this analysis is to lay bare the substance of the meaning of the term as used in scholarly and policy discourses.

Mytelka[6] defined the NSI as 'a network of economic agents, together with the institutions and policies that influence their innovative behaviour and performance'. In the same work Mytelka further characterised the innovation system as:

> …an evolutionary system in which enterprises in interaction with each other and supported by institutions and organisations such as industry associations, R&D, innovation and productivity centres, standard setting bodies, universities and vocational training centres, information gathering and analysis services, and banking and other financing mechanisms play a key role in bringing new products, new processes and new forms of organisation into economic use.[6]

Wangwe[7] defined the NSI as:

> A set of interrelated institutions the core being those which generate, diffuse and adapt new technological knowledge. These institutions may be firms, R&D institutes, universities or government agencies. Institutions mark boundaries, which have an influence on uncertainty [*sic*].

Similarly, Niosi[8] views the NSI as 'a set of interrelated institutions; its core is made up of those institutions that produce, diffuse and adapt new technical knowledge, be they industrial firms, universities, or government agencies'. According to Freeman[9] the NSI is a 'network of institutions in the public- and private-sectors whose activities and interactions initiate, import, modify and diffuse new technologies'. Lundvall[4] defined the NSI as the 'elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge [*sic*]…'. And Nelson and Rosenberg[10] view the NSI as the 'set of institutions whose interactions determine the innovative performance of national firms'.

Niosi et al.[11] defined the NSI as a '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'. Patel and Pavitt[12] described the NSI as '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'.

A contribution from Metcalfe[13] proposed the NSI as:

> 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.

Metcalfe[13] went further to suggest that the NSI is 'a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies'.

An analysis of the above definitions reveals several crucial themes in the manner in which the NSI is conceived and employed among scholars. These themes are: a variety of institutions; interactions; and technological learning. These cross-cutting themes, which emanate from the definitions of the NSI reviewed above, are discussed below.

A variety of institutions

All the definitions indicate that the NSI is composed of a range of institutions that serve a variety of functions within an economy. The institutions can be private or public, which presupposes that they may be driven by divergent economic motives. In fact, in this consideration, some may be competing firms within an economy. The organisations may be big or small. In developing countries, the small enterprises are usually constituted by the informal sector whose contribution to national innovation is not always fully understood or accounted for.

The participating institutions in the NSI may be operating at different levels. Some may be involved in knowledge production by way of basic research or directed research, such as the universities and public research organisations. Some may be involved in technological development and other activities relating to the acquisition, adaptation, generation and diffusion of technology. Some scholars include, within the ambit of the NSI, bodies as diverse as the standard-setting institutions and the banking sector. In addition, there is a variation of another sense in the use of the term 'institutions'. The term refers not only to organisations but also to a set of 'habits, routines, rules, norms and laws, which regulate the relations between people, and shape social interaction'[14]. This aspect underlines the importance of system governance and the efficiency of both the written and unwritten rules of engagement that characterise the nature of interactions among the components of the NSI.

Interactions

A theme that cuts across all the given definitions of the NSI is that of the presence of interactions among the members of the NSI. The use of the term 'network' in the characterisation of the NSI suggests a profile that is embedded in a milieu of free-flowing communication and interlinked functionality. It conveys a sense of connectivity, as in a spider's web, where an effect on one part induces a change in the other parts of the network. It also connotes a concurrence of intents, a pooling of resources and a coordination of efforts. Therefore, system characteristics and behaviour can only be borne out of a synergistic sum of the constituents of the NSI. This conception underscores the importance of rich connections between the different components of the system. In this respect the role of information and communication technologies in supporting knowledge systems cannot be overemphasised. More importantly though, it is the quality of those interactions, rather than their mere physical presence, that is crucial. System components, in order to optimally respond to the needs of their economic environment, have to 'listen' with keen discernment to one another so as to respond efficiently to the social and economic needs of the society in which they operate.

Technological learning

A further thread that runs through the definitions is that of technological learning. There is a strong sense that the NSI is composed of institutions that interact in such a way as to bring about a technological *change* in the economy. Although the definitions do not explicitly state this component, it comes through in the wording that is used. The picture of the NSI that emerges from the analysis is that of organisations and institutions, each playing a role towards a process that ultimately results in a collective property that none of the individual parts singularly has. The process itself can be characterised as that of codiscovery and colearning. The ultimate outcome is a change in the technological state of the economy. On one level, this change manifests in the generation of a strong pipeline of new or improved products, services and production processes. On another, perhaps not so obvious level, the change is reflected in a new configuration or qualitative enhancement of networks and interactions among the system components. In this way, with each success or failure, the system's capability improves to make it more adept at accomplishing even better outcomes. This process may explain the 'virtuous cycle' of innovation that is observed by Muchie[15] in the knowledge-based economies.

To take further the ontological explication of the NSI concept, it is necessary to examine its component terms.

Unpacking of the NSI concept

In order to conduct an in-depth analysis of the NSI concept, it is useful to examine the connotative meanings of each component of the term. Each of the words that make up the term – 'national', 'system' and 'innovation' – carries a significant import for the NSI as a conceptual framework. It is thus appropriate to unbundle the composite term and conduct a thorough examination of each of the constituent words that form it. To this end, it is expedient to start with the central term that gives substance to the enterprise of the NSI, namely 'innovation'.

Innovation

The term 'innovation' is a noun that is used to signify a process or a product of that process. In the former sense, innovation is defined as 'the creation, diffusion and use of new ideas applied in the economy'; and in the latter it refers to 'new production processes, new products, new forms of organisation and new markets'[16]. In the context where new production processes and products are accomplished, it is further qualified as 'technological innovation'.

Innovation can be an incremental or a radical process, as Wangwe[7] describes:

> Innovation is a cumulative process gradually making use of pre-existing possibilities and components according to the principle of path dependence. However, innovations may result in a radical break from the past rendering obsolete a substantial part of accumulated knowledge.

Technological innovation has become the hallmark of economic development in modern economies. Entrepreneurial activity brings about value in an economy through

the introduction of higher value goods and services, accomplished through more efficient production processes and other input savings. The beneficiation of mineral and agricultural products, for example, can be accomplished through the application of technological innovation.

One of the consequences of innovation is what Schumpeter[17] termed 'creative destruction'. When new products and services enter the market, they inevitably threaten long-standing technologies and products by introducing more cutting-edge technology and better product functionality. Creative destruction was responsible for the demise of monopolies, such as Xerox in photocopying and Polaroid in instant photography, when inkjet printing and digital cameras, respectively, challenged the central business models of these erstwhile global industrial giants. Creative destruction is often attributed not only to the superior advantages of a new technology: a closer inspection of the incidences of creative destruction reveals that the decisive factor is the capacity of the decision-makers to manage the new innovations with insight and foresight. For instance, failure by management to recognise the market potential of an innovation, may spell the beginning of the end of the company, should that innovation prove to be of a disruptive nature.

The process of innovation is often depicted as a chain that consists of three distinct but interrelated activities: the generation of ideas; the selection, development and conversion of ideas into commercially viable products or services; and the actual process of diffusion through commercialisation and other dissemination activities. With respect to technological innovation, idea generation often takes the form of scientific research, and idea conversion is often accomplished through technological development. While the innovation chain provides a useful depiction of the key activities involved in the innovation process, it does not imply that innovation always follows the same order of activities. Within an organisation, the challenge of successfully managing the interplay between the different processes in the value chain is as important as developing and sustaining strong capacity in the individual processes.

The continuous generation of new innovations is the lifeblood of a growing knowledge economy. The resurgent economies of the last few decades were characterised by high levels of technological innovation. The bourgeoning rents earned from the export of hightech products in vast markets across the globe, result in the growth of the wealth of domestic economies. The social consequences of this economic growth for the countries concerned, namely higher employment levels, better paying jobs, improved health provision and better education systems, create a positive feedback cycle that ensures sustained economic and social development.

In the context of globalisation, which characterises the current world economic order, not to innovate is a sure way to economic stagnation, as better products from other countries are guaranteed to supplant local products, resulting in the erosion of market share and income potential for local companies.

Lundvall et al.[16] argue that developing countries that aim to compete successfully in the global economy need to move rapidly into the fast-growing sectors that are characterised by the use of advanced technologies. The appropriation of information and communication technologies by countries in the Far East bears testimony to how such economies could rapidly grow. There is, however, a need to invest in skills development and infrastructure as a prerequisite to successful entry into such hightech industries.

Johnson and Lundvall[3] see innovation as 'a continuous cumulative process involving not only radical and incremental innovation but also the diffusion, absorption and use of innovation'. This view suggests that innovation is driven not only by rapid technological output but also a need to develop the capacity of an economy to absorb new innovations and technologies through a range of inter- and intra-organisational relationships and characteristics. Innovation capacity is therefore embedded in a system of supporting networks that include scientific research, public education, technological development, product development, marketing strategies, management practices and venture finance. The 'systemic embeddedness'[6] of these processes finds expression in the national system of innovation, which brings us to the discussion of the next term, 'system'.

System

Private firms are often the drivers of innovation within an economy because the production of new products and services is what keeps them in business. Competitive advantage at the firm level is created and maintained by technological innovation in the knowledge economy. Leading companies globally, in any economic sector, rely on their ability to harness new knowledge in order to keep ahead of competitors. To this end, private companies increasingly spend more resources on research and development.

However, firms cannot maintain an innovative culture in isolation. On the one hand, they need to draw on knowledge that may not be produced within their own establishments. With increased specialisation and integration of knowledge and technologies in individual products, there is a need to access knowledge and technological input from beyond the firm. On the other hand, firms need to be closer to their clients in order to keep in touch with their changing needs. These two entities are by no means the only important sets of players to maintain contact with. Firms also need to be in touch with their suppliers and very often with their competitors.[16] Meaningful interaction between all the relevant stakeholders is important for the companies to receive the feedback that they may employ in making decisions about future innovations.

In countries that are advanced in innovation, these rich interactions are an important feature of the economy. It is

this connectedness of the institutions within the economy that drives innovation. In their comparative study of the innovation system of Brazil with those of European countries, Viotti and Baessa[18] found that the interactions in the European economies were a lot more pronounced. This observation is also borne out in the study of Latin American economies done by Arocena and Sutz[19].

To illustrate the importance of linkages that form a network which constitutes a system, most definitions of the NSI refer to 'institutions'. In Mytelka's[6] definition of an innovation system, given previously, the term 'institutions' refers to 'sets of common habits, routines, established practices, rules or laws that regulate the relations and interactions between individuals and groups'.[20] According to Mytelka[6], this definition of 'institutions' is important for five reasons.

Firstly, this definition makes explicit the importance of 'actor competencies, habits and practices' which underpin linkages, investment and learning – the three 'key elements that underlie an innovation process'[6]. Therefore, the mere presence of R&D organisations within a shared geographical space, such as a country, does not, in itself, presuppose a system of innovation. Secondly, the definition builds awareness of the fact that habits, practices and institutions are learned behaviour patterns, circumscribed by historical and geographical peculiarities. As a consequence of this, learning and unlearning become important attributes of system actors. Thirdly, it focuses attention on the multidirectional knowledge and information flows as the essence of an innovation system. The drivers behind and dynamics of the flow of knowledge cannot always be determined beforehand. This focus therefore highlights the need for a 'finger-on-the-pulse' assessment of the operations of the system in order to support adaptive policymaking.

Fourthly, the definition facilitates the inclusion of the demand side as a core component of the innovation system. As a result, the distance between knowledge production and the market is diminished in such a way that all these components are constantly and dynamically engaged in coshaping the research agenda and technology demands. And lastly, it draws attention to the roles of local actors with respect to the three key elements of the innovation process, namely, learning, linkage and investment. Particularly in developing countries, small and medium enterprises should be encouraged to fully participate in the promotion of innovation.

The importance of a joined-up network of organisations and institutions within a country is critical for the promotion of innovation. The strength of the industrial economies is not solely based on the core competencies of their individual institutions and organisations but also on the strong networks that exist between them. In developing countries, which historically do not have strong self-regulating mechanisms for building networks, the role of government becomes important in putting in place incentives, legislation, infrastructure and other mechanisms that promote the connectivity of the economy in order to build a strong system of innovation. This point logically leads to the recognition of the need for nationwide cooperation in innovation.

National

At a time when globalisation has become the dominant feature of big business and trade, it may be something of a paradox that the national system of innovation has become a dominant framework among policy theorists and policymakers. However, while firms may be the main actors in innovation and learning, the capacity to develop the nationwide networks that are critical for technological learning resides with government. For this reason, the nation remains a 'legitimate unit of analysis'[15] for describing the nature and performance of innovation efforts globally. The improvement of product design, manufacturing processes and the establishment of new product lines requires firm-level innovation. However, the supporting context of institutions, policies, infrastructure, logistics, technology, culture, communications, marketing, knowledge production, business environment, entrepreneurship, intellectual property protection and information and communication technology connectivity all provide a foundation upon which technological innovation could take place. A national perspective on innovation therefore provides a comprehensive purview for understanding the nature, and assessing the performance, of a country's knowledge-based production machinery. From this it could be postulated that, from a policy perspective, the promotion of innovation within a country cannot succeed if it is not driven by central players and authorities that can effect nationwide changes. For this reason, the role of government, particularly in small economies, is crucial in promoting and supporting technological innovation.[7]

Government investment in R&D can be a very strategic intervention in the economic activity of a country. Knowledge is the 'quintessential public good' whose use by one firm or individual would not diminish its availability to others.[21] In fact, the wider the circulation of knowledge within the technological networks within a country, the greater the chances for the emergence of technological progress for the country as a whole. An investment in developing an innovative society that is driven by knowledge production is likely to set in place a virtuous cycle of technological success through further enhancement of the knowledge infrastructure. Unlike information, knowledge is not easily lost as it becomes embedded within the fabric of the institutional network of an innovation system. For this reason, earlier accumulated competencies can continue to advantage the leading knowledge economies well into the future.

An additional incentive and motivation for supporting endogenous investments in knowledge production and technological innovation derives from an analysis of the investments that are made by multinational companies in the

countries in which they operate. Multinational firms invest only up to 15% of their R&D expenditure outside of their home base.[21] However, figures vary depending on the region, with the European multinationals investing up to 40% of R&D in other European Union states. Although, in latecomer countries, R&D investment by the multinationals operating within these countries remains miniscule.[22] The same trend is observed even in instances where knowledge generation and technological innovation are required to adapt products to local market conditions.

Perhaps ironically, it could be argued that globalisation may have influenced the emergence of nation states as critical players for building the capacity for industries to compete successfully in the unfolding economic order. The importance of knowledge production and technological excellence has called upon firms to cooperate with various stakeholders in order to develop an enduring competitive advantage. These partnerships involve disparate institutions such as universities, research organisations, small and medium enterprises, large firms, government departments, funding organisations, development agencies, intellectual property organisations and others. To bring into alignment such an array of organisations requires vast institutional capacity and a supporting communication and organisational infrastructure that spans across a nation, at the very least, for most nations of the world.

National policies still dominate the context in which business and trade are conducted. Proprietary, labour and fiscal policies remain within the remit of government. Bilateral and multilateral trade agreements are still brokered and serviced by nation states. Custom policies, duties, taxes and related institutional frameworks all reside within the ambit of sovereign governments. Policy and planning at the level of the nation state remains the focal point for determining the conditions of socio-economic success. The nation state therefore continues to be the pre-eminent role player in building the capability for global competitiveness, without which firms would struggle to survive in almost all industrial sectors. This struggle for survival is particularly the case for small countries, which require a complete mobilisation of their national resources towards building viable innovation-based industries.

Efforts at the level of the nation state are not by themselves sufficient.[16] Specific actions to support these efforts need to be introduced at levels both below and above that of the state. At a local level, communities, small enterprises and local innovation systems need to be invigorated and aligned with national policies. Beyond the state, particularly for weak states, complementary regional innovation networks should be pursued in order to buttress national competencies. The initiatives at the level of the European Union, for promoting regional innovation capacities, are a good example of supranational efforts to support national strengths. African countries would do well to embark on similar initiatives to strengthen regional innovation partnerships. The accommodation of science and technology in the Constitutive Act of the African Union and the African Union Commission, signals the continent's positive intentions in this regard.

The national system of innovation concept in the developing world

Although the NSI concept was developed and propagated from studies of developed economies such as that of Japan, its relevance has been recognised in thinking about policies for developing countries. To this end, various researchers from the developing world have embarked on research on the NSI or incorporated its ideas in policy and planning. Arocena and Sutz[19] have argued that when the NSI concept is approached from the developing world perspective, there are at least four essential aspects that need to be kept in mind:

- The concept originated from the countries of the North as an *ex post* concept, whereas for most developing countries it is an *ex ante* concept. This fact means that in the developed world, the concept was built on the evidence of empirical data while in the developing world only a few countries fit the broad description of the NSI.
- The NSI concept should be seen as carrying a normative element in that, when it is used in literature, it alludes to better ways of organising science and technology systems in an economy. In this regard, a developing country needs to conduct a thorough investigation of an approach that would best suit its needs and circumstances, rather than copy whatever policy that seems to be working for other countries.
- The concept is relational in that it emphasises the importance of connections, that is, cooperation between the various players within the country's NSI.
- The NSI concept can be an object of policymaking. The idea behind this aspect is that, while there may be a debate about how an NSI evolves, countries can decide and implement specific policies in order to influence the form and direction of their science, technology and innovation programmes.

The last point is highly pertinent for this discourse in that it alludes to the question of the origin of the NSI. All in all, the above considerations suggest that even if the NSI concept is not an accurate description of innovation systems in the developing world, the term, at the very least, serves a useful purpose in that it helps to shape appropriate policies towards the development of national science, technology and innovation.

It is nevertheless argued here that the key aspects of the NSI concept, as discussed in this paper, find resonance with South Africa's system. South Africa's NSI consists of a plethora of institutions and organisations that play various complementary roles in the production of scientific knowledge and technological innovations in the country. These institutions and organisations are embedded in a multifaceted environment consisting of a local and international complex of political, environmental, social, technological, economic and legal factors. The character of South Africa's NSI reflects how the knowledge policies,

institutions and organisations, as a collective entity, negotiate macroeconomic challenges in order to realise shared goals.

Concluding remarks

The purpose of this study was to unpack the NSI concept, in order to make explicit the meaning and implications of the key component terms. This analysis elicited the following preponderant themes:

- The NSI comprises a network of interacting policies, institutions and organisations whose holistic functionality depends on the quality of cooperation between the various component parts.
- The synergy of the interacting elements of the NSI brings about technological learning. Technological learning is the net improvement in the capacity of the NSI to innovate.
- Globalisation, particularly as manifested in the expansion of the knowledge economy, has made it essential for nations to support technological innovation by creating supportive domestic institutional frameworks and macroeconomic environments; hence the evolution of the NSI.

Furthermore, the ontology revealed that the NSI concept has introduced a new way of thinking about science and technology in South Africa. Firstly, it has made explicit the causal relationship between scientific activity and economic performance. Secondly, it has brought into a much sharper focus the need for coherence and integration in the functions and activities of the country's science and technology institutions. Thirdly, innovation – the conversion of ideas into new or improved useful products and services – has become the centrepiece of all scientific and technological effort. And lastly, the NSI concept has presented a rationale for science, engineering and technology – in the context of the government's agenda for change – to be transferred from the margins towards the centre of the country's macroeconomic policies, thereby cutting across almost all sectors of government.

From this study, it could be argued that the NSI concept provides a powerful description of key innovation activities, to science and technology policymakers and scholars, which can be used to describe South Africa's collective efforts in technological innovation. The NSI provides a solid foundation for organising the country's collective efforts in science and technology in a much more integrated and holistic fashion.

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Competing interests

I declare that I have no financial or personal relationships which may have inappropriately influenced me in writing this paper.

References

1. Department of Arts, Culture, Science and Technology. White paper on science and technology: Preparing for the 21st century. Pretoria: DACST; 1996.
2. Freeman C. Preface. In: Muchie M, Gammeltoft P, Lundvall B, editors. Putting Africa first: The making of African innovation systems. Aalborg: Aalborg University Press; 2003.
3. Johnson B, Lundvall B. National systems of innovation and economic development. In: Muchie M, Gammeltoft P, Lundvall B, editors. Putting Africa first: The making of African innovation systems. Aalborg: Aalborg University Press, 2003; p. 13–28.
4. Lundvall B, editor. National innovation systems: Towards a theory of innovation and interactive learning. London: Pinter Publishers; 1992.
5. List F. The national system of political economy (translated from German). London: Longmans, Green and Co; 1841.
6. Mytelka LK. The dynamics of catching up: The relevance of an innovation system approach in Africa. In: Muchie M, Gammeltoft P, Lundvall B, editors. Putting Africa first: The making of African innovation systems. Aalborg: Aalborg University Press, 2003; p. 29–42.
7. Wangwe SM. African systems of innovation: Towards an interpretation of the development experience. In: Muchie M, Gammeltoft P, Lundvall B, editors. Putting Africa first: The making of African innovation systems. Aalborg: Aalborg University Press, 2003; p. 75–91.
8. Niosi J. National systems of innovations are 'x-efficient' (and x-effective): Why some are slow learners. Res Policy. 2002;31:291–302. http://dx.doi.org/10.1016/S0048-7333(01)00142-1
9. Freeman C. Technology policy and economic performance. London: Pinter Publishers; 1987.
10. Nelson RR, Rosenberg N. Technical innovation and national systems. In: Nelson RR, editor. National innovation systems. New York: Oxford University Press; 1993.
11. Niosi J, Saviotti PP, Bellon B, Crow M. National systems of innovations: In search of a workable concept. Technol Soc. 1993;15:207–295. http://dx.doi.org/10.1016/0160-791X(93)90003-7
12. Patel P, Pavitt K. The nature and economic importance of national innovation systems. OECD STI Review No. 14. Paris: Organisation for Economic Co-operation and Development; 1994.
13. Metcalfe JS. The economic foundations of technology policy: Equilibrium and evolutionary perspectives. In: Stoneman P, editor. Handbook of economics of innovation and technological change. Oxford: Blackwell; 1995.
14. Johnson B. Institutional learning. In: Lundvall B, editor. National systems of innovations. London: Pinter Publishers; 1992.
15. Muchie M. Re-thinking Africa's development through the national innovation system. In: Muchie M, Gammeltoft P, Lundvall B, editors. Putting Africa first: The making of African innovation systems Aalborg: Aalborg University Press, 2003; p. 43–61.
16. Lundvall B, Muchie P, Gammeltoft P, editors. Putting Africa first: The making of African innovation systems. Aalborg: Aalborg University Press, 2003; p. 1–10.
17. Schumpeter JA. Capitalism, socialism and democracy. New York: Harper; 1942.
18. Viotti EB, Baessa A. Innovation in developing versus developed economies: Some evidences from a comparison of the innovation surveys of Brazil and selected European countries. Paper presented at: Globelics 2005. Proceedings of Globelics 2005 Africa – Innovation systems promoting economic growth, social cohesion and good governance; 2005 Oct 31 – Nov 4; Pretoria, South Africa. Available from: http://www.globelics2005africa.org.za/papers/p0038/Globelics2005_Viotti%20Baessa.pdf
19. Arocena R, Sutz J. Looking at national systems of innovation from the South. Ind Innov. 2000;7(1):55–75. http://dx.doi.org/10.1080/713670247
20. Edquist C, Johnson B. Institutions and organizations in systems of innovation. In: Edquist C, editor. Systems of innovation: Technologies, institutions and organizations. London: Pinter Publishers; 1997.
21. Amsden AH, Cho H. Differences in national R&D systems between early and late industrialisers. In: Muchie M, Gammeltoft P, Lundvall B, editors. Putting Africa first: The making of African innovation systems. Aalborg: Aalborg University Press, 2003; p. 141–153.
22. Patel P, Vega M. Patterns of internationalization of corporate technology: Location vs home country advantages. Res Policy. 1999;28:145–155. http://dx.doi.org/10.1016/S0048-7333(98)00117-6