Positioning the South African Economy for New Industries: Policy Lessons from East Asia

Rendani Mamphiswana

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Abstract

The South African system of innovation in the post-apartheid dispensation remains in the apartheid trajectory – small and exclusive. Lock-in and path dependency are common in innovation and economic systems and, as a result, they reproduce the past. The development of new industries remains a challenge; manufacturing's contribution to gross domestic product (GDP) has declined significantly over the years. South Africa adopted the concept of a national system of innovation (NSI) to distribute socio-economic benefits widely. Opportunities for ruptures and discontinuities, which could have enabled disruption, have come and are now gone. The emergence of the fourth industrial revolution (4IR) offers yet another opportunity; however, it is likely to be missed unless there is development and implementation of a suite of targeted policies for new industries. The common theme among countries that successfully adopted the NSI concept is active and bold policies, with directed investment towards selecting new industries for competitiveness. This study reviews the policy of countries that succeeded in adopting the NSI concept since the 1980s to offer lessons on how to position the South African economy towards new industries. The research develops and proposes a framework for launching new industries. Implications for policy are also presented.

Keywords: National systems of innovation, New industries, Fourth industrial revolution, Innovation policy, Industrial policy

JEL codes: L5; L6; O1; O2; O3

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1. Introduction

South Africa (SA) arrived in 1994 from a decade of declining gross domestic product (GDP), driven largely by international economic sanctions on the then apartheid-led government (Du Plessis and Smit 2007). Following the democratic transition in 1994, the economy was opened to international trade, including the flow of capital, and a predictable macroeconomic environment-initiated economic recovery. On average, the GDP growth rate was 3.1% from 1994 to 2004 (Du Plessis and Smit 2007). Using data for the period from 1980 to 2014, the average GDP growth rate, including the World Bank forecast for 2014, was 2.8% (Sandrey 2013). Although comparable to that of Brazil, at 2.6% for the same period, South Africa's GDP growth rate was significantly lower when compared to that of China and India, at 10% and 6.1% respectively.

South Africa's exports are also significantly lower when compared to those of China and India (Sandrey 2013). Their exports are driven by a strong and competitive manufacturing base. As a share of GDP, manufacturing's contribution has declined significantly, by about 60% since the 1980s (Department of Trade, Industry and Competition [DTIC] 2018; Marwala 2020). Regarding manufacturing exports, South Africa's high-tech sector contributes only 5.2%, while it is over 30% in China and South Korea (National Advisory Council on Innovation (NACI) 2020). In global comparison, the unemployment rate in South Africa is abnormally high, while manufacturing continues to poorly perform (Bhorat and Rooney 2017).

Without manufacturing intensity and a sophisticated economy, South Africa would find it difficult to significantly reduce its high unemployment (Bhorat and Rooney 2017). Innovation determines long-term economic development (Freeman 1995). South Africa adopted the concept of a national system of innovation (NSI) as a policy instrument in 1996, with the intention that it would guide and inform innovation policy for socioeconomic development (Department of Arts, Culture, Science and Technology (DACST) 1996). This mandate of transforming the South Africa economy using innovation has reached limited success (Department of Science and Innovation (DSI) 2019).

Other countries, such as those in East Asia, have succeeded to a greater extent in utilising the NSI concept in guiding the development of new industries and subsequently have achieved higher economic growth. This study investigates countries in East Asia that have used the NSI concept as a guide to develop new industries with the intention to extract key policy themes for South Africa to consider for local adaptation. Considering that South Africa has not succeeded in utilising the NSI concept as intended, the hope was that the East Asian countries would offer learning and reflective insights on what has worked in other regions. The 2019 White Paper on Science, Technology and Innovation (STI) retains the NSI concept as impetus for socioeconomic development (DSI 2019).

According to Bhorat and Rooney (2017), a highly competitive South-East Asia and a lack of skills in South Africa resulted in the declining performance of the manufacturing sector in SA.

The aim of this research is to develop an approach, using the NSI concept as guideline, to position South Africa towards new and globally competitive industries. Previous studies critiquing the NSI concept in South Africa have placed emphasis on research and development (R&D) comparisons (Makhoba and Pouris 2016), R&D indicators such as patents (Pouris and Pouris 2011; Sibanda and Straus 2020), STI indicators, including a focus on informal markets as impetus in the economy (Manzini 2015; Kraemer-Mbula 2016; Kraemer-Mbula and Sehlapelo 2016; Pouris 2020), and on the sectoral level, such as failure to commercialise and scale water technologies (Habiyaremye 2020).

Manzini (2012) argues that failure to initiate and sustain quality networks among innovation actors is the key impediment to widely driving innovation in South Africa. After all, the foundation of the NSI concept lies in interactions and learning among innovation actors (Dosi et al. 1988). This research is unique in that it offers an approach to position the department of science and innovation (DSI) to better foster interactions across the NSI and widen them. The 2019 STI White Paper (DSI 2019) attempts to do this; however, it does not succeed in articulating national structural changes to enable the realisation. This research is aligned with the findings of Mazzucato (2013) in relation to the role of government in leading and shaping the direction of new markets. It differs from it and enhances it in that it offers the 'how' element for South Africa. Sibanda and Straus (2020) recommend that the South African government should take a more active role in international technology transfer to accelerate rebuilding the manufacturing base.

The organisation of the rest of the paper is as follows. Section 2 offers a background to the South African NSI and some efforts to develop new industries. Section 3 briefly reviews the NSI literature and contextualises it for the South African economy. Section 4 presents the rationale for the case study and desktop research methodology, while Section 5 unpacks the rationale for case selection and extracts policy themes from selected countries. In Section 6, there is a reflection on policy themes from selected cases and a reflection on South Africa's local dynamics for adaptation. Lastly, Section 7 provides concluding remarks and implications for South Africa and developing countries in the global South.

2. South African Economy and Attempts to Develop New Industries

South Africa's response to Covid-19 followed strict restrictions, resulting in the economy's contraction by 7% in 2020 and an estimated expansion of 3.3% in the GDP in 2021 (United Nations Department of Economic and Social Affairs [UNDESA] 2021). South Africa is a developing and upper-middle-income country (United Nations 2014). Therefore, exports are essential for growing the economy (Bulagi et al. 2015). However, exporting primary goods does not allow for the kind of sophistication required for long-term development. Equally, exporting assembled products, such as automobiles by South Africa, without localising a large part of the value chain has limitations (Barnes et al. 2004).

South Africa seems to have gained economic performance and price for local consumers from this selective policy of assembling automobiles (Barnes et al. 2004). It has included local sourcing of some components into the assembly, bolstering local manufacturing even for exports. On the other hand, the importation of a German nuclear pebble bed reactor did not yield the anticipated industrialisation outcome. In contrast, the commercialisation of the previous nuclear weapon reactor to produce medical isotopes was successful (Adam 2020). Interestingly, a similar selective policy did not work for the textile industry (Barnes et al. 2004). Although the square kilometre array (SKA) radio telescope project appears to be a success so far in global terms (Adam 2020), its contribution to local inclusive development is questionable (Chinigò and Walker 2020).

Prototyping and market access are among the critical success factors for SKA and for the production of medical isotopes (Adam 2020). Interestingly, the joule electric vehicle (EV) did not benefit from successful prototyping, or by winning international awards – signal for a market – for the best car (Swart 2015). These are some of the South African NSI projects that showed mixed results in creating new industries. The development of the NSI concept took place in the 1980s, in Japan, the United States of America (USA), and other newly industrialised countries (NICs) in Europe (Dosi et al. 1988). As already indicated, the concept focuses on interactions and learning as determinants of innovation and puts innovation at the centre of long-term economic development.

South Africa adopted the NSI concept in 1996, through a White Paper on Science and Technology (S&T) (DACST 1996). Nevertheless, manufacturing's contribution to GDP has declined by more than 60% since the 1980s (DTIC 2018; Marwala 2020). Based on the referenced studies, the decline in manufacturing as a share of GDP comes as no surprise. The NSI in South Africa has struggled to cross the innovation chasm (Swart 2015), a trend similar to that observed for water technologies (Habiyaremye 2020). Compared to other middle-income countries, the predominantly services-based South African economy is an anomaly (Sibanda and Straus 2020).

The services-based economy is biased towards employing graduates with a high level of education. However, as the Covid-19 pandemic has shown, a robust local manufacturing industry is essential. Positioning the NSI in South Africa for new and globally competitive industries is imperative. As the reality suggests, departmental policy efforts so far have not yielded significant results. The subsequent section critically reviews the literature on the NSI.

3. Literature Review of National Systems of Innovation

South Africa was among the first countries that did not belong to the Organisation for Economic Co-operation and Development (OECD) to introduce the NSI concept into its policy lexicon. Of importance to the concept are dynamic interactions and differentiated learning among innovation actors (Dosi et al. 1988). The premise is that innovation is the driver of long-term competitiveness, even in a globalised society (Freeman 1995; Lundvall 2010; Moses et al. 2012).

Prior to the adoption of the NSI concept, economic performance was largely viewed as driven by external factors – those beyond the control of the country (Nelson 1993). A closer study of the emergence of Japan revealed that economic growth was largely endogenous. This realisation was important, as it implied that countries had a strong hand to play in their destiny. The studies conducted on the founding of the NSI concept were predominantly historical (Dosi et al. 1988; Nelson 1993; Freeman 1995), in that they were conducted after the fact and only a few had been conducted at the time of the adoption of the NSI concept by South Africa.

Studies from the global South found useful elements in organising the economy, while warning about the direct importation of the NSI concept (Da Motta 1999; Arocena and Sutz 2000). The NSI concept was adopted rapidly across the globe, even though it lacked clarity in terms of its definition, theoretical grounding and measurements (Niosi et al. 1993). Over two decades later, some of these concerns have not been addressed adequately (Acs et al. 2017). When functional and effective, the NSI concept is positioned for a robust response to economic shocks, as observed in Europe (Filippetti and Archibugi 2011).

A highly specialised high-tech sector and financial system, and a workforce at the forefront of technological know-how, appear to hold such an NSI together. The reality of the global South is that it largely lacks these ingredients, but they could be developed sufficiently over time. It appears that a functional and effective NSI concept contributes significantly to countries succeeding in industrialisation (Nelson 1993; Freeman 1995). China's rise to dominance through tech giants leveraging artificial intelligence (AI) for scaled digitalisation hinders the progress of small and medium sized NSIs (Lundvall and Rikap 2022).

The private sector, as observed in the USA and China, plays a critical role of introducing innovations to the market. While 65.4% of South African companies reported engagement in innovation activities in the period from 2005 to 2007, more than half failed to introduce innovation to the market (Moses et al. 2012). Compared to their European counterparts, innovation investment is lower among South African companies, which leverages international partners to achieve the same level of innovation output (Rooks et al. 2005).

Relying on external actors for financing the early stages of innovation has implications for the host country (Christensen 2010). Taking advantage of a window of opportunity and shaping it is paramount, as in the case of China, with tech giants and a corporate system of innovation (Lundvall and Rikap 2022). Some of the earlier NSI studies put emphasis on the R&D system (Andersen 1992), while the important role of non-R&D activities in innovation was realised later on (Moses et al. 2012). Investment in R&D is important for innovation, but not enough unless coupled with investment in non-R&D activities to improve innovation performance (Mazzucato 2013).

It is over a quarter of a century since South Africa adopted the NSI concept, and there have several iterations since then, as show in Figure 1 below.

Figure 1: Evolution of South Africa's Innovation Policy

Source: Mustapha et al. (2017)

The 2019 STI White Paper finds that the NSI remains small and exclusive and that its contribution to economic performance is insignificant (DSI 2019). A draft STI decadal plan to implement the White Paper has been put on the table for public comments. Strengthening the NSI through mainstreaming STI across all spheres of government is a top priority.

This research looks at lessons from successful East Asian countries to contribute to shaping the evolution of the NSI concept in South Africa. Emphasis is placed on new and globally competitive industries. Considering the high maturity of certain industries and technologies on the global stage, South Africa could leverage the highly dispersed nature of innovation at this stage of the life cycle to start off by strengthening existing industries (Audretsch and Feldman 1996). This could then position the country for new and competitive industries in which the production of new knowledge is decisive in the early stages of the life cycle (Tavassoli 2015).

The literature section is brief, as the case study in Section 5 is a literature review relevant to each selected country included in the case study. The subsequent section outlines the research methodology.

4. Research Methodology

The focus of this research is the NSI concept and its application in enabling new industries. A case study approach was employed for the research. The case study methodology allows for data gathering from multiple sources, offering several perspectives on the topic of enquiry (Tellis 1997). The research is both exploratory and collective in its enquiry. Arocena and Sutz (2000) warn about direct importation of the NSI concept from other countries, as the findings should only be a starting point and for testing to see what works. The study is collective in that five countries compose the case study (more details in Section 5.1).

Considering that each country is unique and that each NSI takes a unique path, a single country study of the NSI would not offer sufficient insights for South Africa. Previous studies on elements of the NSI drew comparisons with Ireland on introducing innovations to market (Moses et al. 2012) and with Europe on innovation spending at the company level (Rooks et al. 2005). In this research, emphasis is on the mechanisms that enabled each country to succeed in utilising the NSI concept to stimulate and promote new industries.

The case (Johansson 2007) in this research is the NSI concept. Several NSIs are studied to gain deeper insights into how to succeed in launching and sustaining new industries. Case studies entail a comprehensive exploration of what is yet to be sufficiently understood (Meyer 2001). The reality of the NSI concept in the global South suggests little understanding of how to make it work. Several studies have criticised its full use in the global South, as indicated in the introductory section.

The desktop approach to the case is limited, as it looks only at publications. The reality is that certain key insights into establishing and sustaining an NSI remain undocumented, or are not in the public domain. At the same time, studying several countries attempts to moderate this effect. In studying the different countries, the research searches for structural changes that are fertile for positioning the DSI in South Africa to guide the NSI in a manner that stimulates new and competitive industries.

In this research, new industries refer to those that are new in the South African context and in which there currently is no market. The next section gives the rationale for the case selection, unpacks each case and summarises key policy themes for consideration.

5. Case Study

5.1 Selection

The last four decades have seen a shift in the global economy, away from the USA and Europe to Asia. Japan became the second-largest economy in the 1980s, with China shifting Japan into second place in 2010 (Barboza 2010). Like Japan, South Korea achieved remarkable economic growth in the post-World War II period (Campbell 2012). South Korea became the 12th largest economy and 4th largest in Asia in 1995. Taiwan experienced similar rapid economic growth post-World War II, with a structural change from agriculture to industry (Yu-Kang and Schive 1995).

Like the other four countries, Singapore's economy took off in the 1960s, and it now specialises in high-value manufacturing and financial services (Siddiqui 2010). Between 1965 and 2002, Singapore's GDP expanded by a factor of 24. These Asian economies have achieved a significant level of catching up, which African countries – including Ghana and Nigeria, which achieved independence by the 1960s – have not been able to reach. The five selected Asian countries have structurally transformed their economies. Although they executed their strategies differently and under different conditions, South Africa could take policy lessons to create new industries, significantly transform the economy and transition to a high-income country.

The study is primarily interested in what has worked in Asia, rather than what has not worked. Although there is value in learning from failure, the emphasis here is on best practices when it comes to utilising the NSI concept to create new industries. Even though globalisation has dominated economics analysis, history shows that the NSI concept is the sharper lens to look through to shape an economy (Freeman 1995). Ultimately, and regardless of external forces, endogenous innovation shapes long-term development. At the heart of this innovation is understanding new technologies and applications to foster new industries (Freeman 1995).

In the process, new and relevant competencies are developed (Johnson et al. 2004). Regional dynamics and timing play a role, although these fall beyond the scope of this paper; the paper focuses on the internal change that a country must initiate to launch and shape a successful NSI for new industries (Dosi et al. 1988). As observed in South Korea, Taiwan and Singapore, small and late industrialising countries have used the NSI concept differently for a quick catch-up (Wong 1999).

The sequence in which the countries are discussed is as follows: Japan, South Korea, Taiwan, Singapore and China. The rationale was to start with the country that was among the first studied in relation to the NSI concept, and to finish with China, the leading economy of the time among those selected for the study.

5.2 Japan

Among the critical success factors for Japan was its ability to import, improve, develop and diffuse technologies to several of its products and services rapidly and intelligently (Freeman 1995). Globalisation makes certain technologies and know-how available for the global village; however, it does not automatically move from one country or region to the next. It is not a free good, and countries must invest in bringing these technologies within their borders and diffusing them accordingly (Johnson et al. 2004). To do so successfully requires a complex set of interactions among a diverse group of innovation actors.

The role of government policies – innovation, industrial, or a combination – is imperative in encouraging knowledge-intensive companies to relocate and help create local companies. The ministry of international trade and industry (MITI) was the leading arm of the Japanese government in this regard (Freeman 1995). There is no single factor that helps explain the success story of Japan; it is a combination of factors. Sequentially, though, the relevant skills were an essential base from which to launch development. MITI led student exchange programmes to key strategic research and technology areas (Johnson 1982).

Large companies have the resources to invest in internal R&D; however, this has implications for less-resourced small companies and the creation of new markets (Motohashi 2005). Japan reduced its NSI dependence on large companies’ R&D and fostered university and industry collaboration with small companies (Motohashi 2005). In parallel, the country created knowledge-intensive companies for new industries and skills development in frontier knowledge. Before policy reform of university and industry collaborations, knowledge transfer occurred via technical consultation and personal ties (Fukugawa 2017).

The policy allowed for a systemic approach and a level of prediction on the outcome side. An NSI concept is not about homogeneity among actors; the diversity of actors matters and makes the system more dynamic (Motohashi 2005). Both large and small firms have a role to play in an economy. Government policies must recognise this reality and they must be shaped accordingly. Policies foster integration across the three anchor poles of the NSI: science, technology and market (Kumaresan and Miyazaki 1999). When there is integration among the three poles, the NSI is a more robust network, as observed with the robotics industry in Japan (Kumaresan and Miyazaki 1999).

Eventually, the realisation of the value of innovation occurs when there is market adoption – the hallmark of a system that has bridged the innovation chasm. Because the innovation process is complex and dynamic, continuous monitoring is imperative to better understand how to achieve a high-performing NSI.

5.3 South Korea

The rise of South Korea in terms of industrialisation matches that of Japan. The country emphasised intensive investment in the education system, company-level R&D, infrastructure for modern communication technologies and embedding new technologies in various sectors of the economy and society (Freeman 1995). When comparing South Korea to the Netherlands' triple helix indicators – university, industry and government nexus – South Korea's investment yielded positive results. The NSIs' outputs in research and technology were superior and dominated by knowledge-intensive companies (Park et al., 2005). The differentiator and success factor for South Korea, in comparison to the Netherlands, was developing knowledge-intensive companies.

Resources are limited; each country must make strategic choices. It is not about immediately jumping to an emerging area without understanding how to take advantage of the opportunity. Through government interventions, South Korea succeeded in decentralising its NSI away from the capital city and creating other R&D hubs (Shapiro et al., 2010). The government interventions incentivised research collaboration across the entire NSI, enabling an integrated network.

Comparing South Korea and Brazil, the former pursued active learning (Viotti 2002). South Korea does not wait for things to happen; it actively develops and shapes its NSI to achieve strategic objectives. Proponents of globalisation suggest that a country has little to no control over its destiny in globalised society (Freeman, 1995). This thinking is limiting as the comparisons between South Korea and the Netherlands and Brazil bear testimony to the role and relevance of a national lens in a globalised society. The notion of active learning implies continuous learning, regardless of system performance. South Korea coupled intensive investment in R&D with trade and industrial policies for companies to raise R&D outputs to market (Viotti 2002).

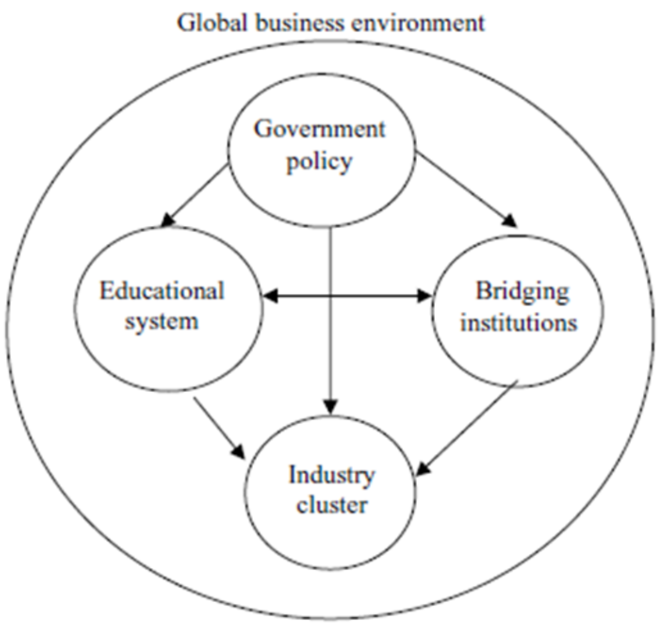
Trade and industrial policies strengthen university, industry and government interactions. The government not only funds public research at universities, but also takes an active role in enabling diffusion to industries. The Asian crisis of 1997 shook South Korea's strong NSI; however, it reconfigured itself for long-term competitiveness (Kim 2001), which provides a demonstration of the importance of government playing an active role given a constantly changing global world.

5.4 Taiwan

The Taiwan NSI shows that different times of the system life cycle require different approaches (Lee and Von Tunzelmann 2005). In the case of Taiwan, it further illuminates that a strong NSI can respond to external shock. The integrated circuit industry shows that Taiwan S&T policies support local industry and global ambition (Lee and Von Tunzelmann 2005), including borrowing technologies from the global market. It is not about doing what has worked in the past, but also what each moment requires.

In 2002, Taiwan was among the global leaders in the machine tool industry, at number five and six on exports and output respectively (Yeh and Chang 2003). Using the machine tool industry as a lens for the NSI, its effectiveness in the diffusion of new technologies within the industry was rooted in a handful of factors – an education system aligned with and responsive to industry clusters, government policy synchronising and connecting related institutions, and positioning for global markets (Yeh and Chang 2003). Figure 1 shows these essential ingredients within the Taiwan NSI.

Figure 2: Essential Ingredients of the Machine Tool Industry in the Taiwan NSI



Source: Yeh and Chang (2003)

A key feature in Figure 2 is that the Taiwan NSI is endogenous and highly networked. Although export intensive, R&D intensity was low, resulting in production largely in the simple and low end of product hierarchy (Yeh and Chang 2003). In this scenario, cost became the primary variable for competitiveness. The industry also relied heavily on imports of complex components for production, equally raising operations costs. The information technology (IT) industry attracted foreign R&D to respond to the low intensity (Chen 2007). Under the leadership and guidance of the Taiwan government, some multinational companies (MNCs) moved their R&D to connect suppliers that the Taiwan NSI helped develop.

A functional and forward-looking interface between government, research and industry is essential for the NSI. At the same time, incubation in Taiwan evolved to effectively coordinate policy and help embed research outputs in new, high-growth businesses (Tsai et al. 2009). The incubation process created a market pull for research outputs and shaped suitable government policies, emerging as the glue for the top-down and bottom-up approaches. In the process, dynamic capabilities were developed among innovation actors within the NSI. As the NSI matures, the dynamic capabilities are positioned to launch new trajectories (Wong 1999).

Evidence from Taiwan is that there are different approaches to developing and shaping an NSI to cater for different industries' needs and being cognizant of global dynamics.

5.5 Singapore

The biotechnology sector in Singapore shows that it is not enough to allocate resources and establish functional institutions; market demand is equally important (Chaturvedi 2005). To meet the expert skill requirements of the biotechnology sector, Singapore went further to incentivise global universities to establish local branches. These universities are largely in the same locations as the sectors; where there is market pull, this arrangement has bolstered the creation of new industries (Chaturvedi 2005). As industries mature and exploit existing knowledge, there is stagnation in knowledge and skills. At the beginning of the new millennium, Singapore faced this challenge, requiring educational reforms to remain globally competitive (Luke et al. 2005).

The education and research arm of the NSI must balance the industry needs of today and those of tomorrow. The evolution of the Singaporean NSI invited MNCs to expand their operations and opened a window of opportunity for knowledge and skills transfer (Wong and Singh 2008). Singapore developed its technological capabilities along the "technology adopter to innovator" trajectory. Coupled with infrastructure development, Singapore rapidly developed its human resources for accelerated technological absorption and exploitation (Wong and Singh 2008).

Singapore's innovation policy broadly integrates industry, trade and competition (Wong and Singh 2008). The government continues to play a leading and shaping role in the country, not only in setting up targets, but providing support even at the sectoral level. In the building sector, which consumes 50% of national energy, the government is shaping the introduction of green technologies (Siva et al., 2017). The leading role played by the government is not without resistance, especially when dealing with incumbents in the sustainability space. Singapore's sectoral approach enables an understanding of fundamentals, further developing suitable support instruments and mechanisms for each sector.

Construction companies play an essential role in putting new industries on the ground. Although their target goal of maximising profits determines the kind of innovation they engage in, it also locks their innovation strategies (Na 2007). To ensure that current knowledge is employed when installing new industries, the government shapes and directs the entire research cycle – basic, industrial and strategic applications (Na 2007). The government contributes significantly to the capacity to innovate (Wang 2018), and positions its policy landscape to nurture big business. As shown with the sustainability roadmap for the building sector, the government's credibility allows it to shape a new direction at the sectoral level when needed. Singapore has the ability to reposition its NSI for sustainable development (Kılkış 2016).

In developing learners to meet future skills requirements, the government centrally plans and executes pilots for innovation and enterprise within the education system (Ng and Tan 2006). Despite its challenges during implementation, it strives for a flexible education system to support the country’s direction. The challenges include balancing the system with the traditional examination requirements, which is necessary to ensure alignment from basic research to innovation for an effective NSI (Kılkış 2016).

5.6 China

China recognised the use of the NSI concept in the 1990s, with a triple helix lens (Leydesdorff and Guoping 2001). It soon became apparent that it was not sufficient to deploy technologies and launch industries widely. The government developed and implemented clear incentives for science parks, incubators and special economic zones for high-tech development (Leydesdorff and Guoping 2001). These interventions guided the flow of knowledge and enabled associated upgrading to suitable technologies. As the NSI evolved, the government placed great emphasis on removing barriers to developing new markets. When deemed necessary for developing new markets, it introduced new laws within the shortest time possible. In China, the government coordinates the knowledge flow from university to market actors.

Science and technology policies in China reinforce the motive force of the research actors of the NSI by developing innovativeness among market actors and a strong link among research and market actors (Xiwei and Xiangdong 2007). Giving each government department the autonomy to develop the relevant market has resulted in mismatched and poor coordination. Furthermore, a great emphasis on developing new markets has resulted in the unintended consequence of neglecting the basic research space (Xiwei and Xiangdong 2007). This will make it challenging to create new industries in the future, as they would lack entirely new knowledge.

China's approach further deepened the uneven development of the NSI (Fan 2014). Balancing the national needs of today and those of tomorrow is a difficult task. China's strategy for selected industries was in-house R&D during the early development of the NSI, and global integration at the mature stage (Fan 2014). Depending on the global balance of forces at the time, the strategic approach offers certain advantages. Once the NSI is globally competitive, it is much easier to negotiate favourably. China's large population allows for this strategic approach and, because it is large, unevenness is likely to reside in the NSI.

The unevenness predominantly affects rural sectors, although China recognised and has bolstered R&D expenditure in these sectors (Wu et al. 2017). The data from 1998 to 2009 shows high levels of labour mobility, which has supported rural-based entrepreneurship. Implementing changes in technology policies and NSI structural modification have effectively supported the rural sectors (Wu et al. 2017). For one, rural areas typically do not have universities and industries. Understanding local economic activities therefore becomes vital, along with positioning for low-technology solutions to kickstart development.

Looking at the IT sector in China, there has been wide and fast deployment of new technologies (Hung 2009). Institutions and their dynamic interactions are at the heart of an efficient Chinese NSI. It is this dynamism that enables institutions to respond towards agreed national objectives. Clarity on and alignment with national objectives give direction to sector prioritisation. The development of national objectives accounts for regional and global opportunities, thereby understanding the advantages a nation brings to the global society (Sun and Liu 2010). The Chinese NSI transformed its funding from government to industry through the government, thereby enabling the triple helix to be industry led (Sun and Liu 2010).

However, the industry does not do as it pleases; it operates to help achieve national objectives. Achieving this level of credibility and legitimacy on the part of the government appears to be imperative. At the same time, it does not guarantee the full development of society. While experiencing tremendous progress in certain industries, overall development is uneven in China (Fuller 2009). When a nation selects certain industries, other industries are likely to suffer. Opening the economy for other actors to develop technologies and industries is imperative. This balancing act is hard. The government should consider including industries outside of national priorities in other forms, as they could be critical in the future.

Consequently, there is less innovation and learning among companies working closely with the government (Fuller 2009). Although the technological trajectory has been uneven, technology has been the cornerstone of developing the Chinese economy (Fan 2014), as currently observed with AI (Lundvall and Rikap 2022). China has been able to position its NSI for economic development and has been effective in transforming investment in R&D and human resources into exports in high-tech, services and certified patents. Furthermore, the NSI has incentivised for the seamless flow of science between research and industry and coupled it with a balance between technology imports and local efforts in R&D (Fan 2014). Chinese institutions have played an essential role in this balancing act.

5.7 Discussion

Some themes have emerged from the five selected East Asian countries. To enable the successful launching of new industries, a sectoral focus within the NSI is essential. Sectors are unique because of the varied drivers, players and requirements applicable to each. Therefore, generic government policies are simply insufficient. For example, Taiwan focused on integrated circuit and machine tools for export. Following the establishment of an export market, Taiwan leveraged external actors to meet export demand. At the same time, incubation was the cornerstone for launching new sectors through high-growth businesses. Singapore’s sectoral approach supports the thriving of big businesses, as they already have market demand.

In Japan, smaller companies were capacitated to be the carriers of new technologies and to create new sectors. The drive for Japan was ensuring a diversity of actors within the NSI. South Korea placed emphasis on the wide deployment of new technologies across several sectors. This approach was driven by the national desire to decentralise the NSI and achieve even development. China struggles with uneven development, although new investments have been made for rural areas to catch up. In all the countries, and at the sectoral level, there is a strong link between research and market, which the government coordinates.

R&D approaches are mixed. Japan centralised R&D and took control of the knowledge flow from research to market using smaller companies. For new industries, MITI made use of technology imports to complement internal R&D activities. Taiwan imported both technologies and R&D to meet export demand. South Korea focused on local company-level R&D to drive knowledge-intensive industries. The drive was to be at the forefront of modern technologies. Singapore imported its knowledge base and drove its transfer to localise capabilities. China started off with internal R&D and made use of incubation, science parks and special economic zones as knowledge carriers to drive industrialisation.

Among the five countries, there is alignment on manufacturing in that it all happened within the country. Japan, Taiwan, Singapore and China incentivised MNCs to establish branches within the countries, while South Korea focused largely on developing local brands. In Japan, MNCs helped accelerate the development of local knowledge-intensive companies through technology transfer. In China, efforts were led by a group of companies working closely with the government. Education is the foundation of the knowledge economy. South Korea invested heavily in education under the theme of “active learning”. China prioritised internal knowledge production, while Taiwan and Singapore retained a flexible education system, supported by external actors to meet market dynamics and demand. In Japan, MITI was responsible for driving education to support new industries, including sending students to top international universities.

Looking at the population in the selected countries and their global ranking: China is number 1, with 1.4 billion people; Japan is at number 11, with 126 million people; South Korea is at number 28, with 51.3 million, while Taiwan is at number 56 with 23.9 million, and Singapore is at number 114, with 5.9 million people (World Population Review 2021). Using the same dataset, South Africa is number 24, with 60 million. Only China appears to have benefited from a large local market and could afford to delay opening the NSI.

In view of the themes emerging from the case study, the subsequent section begins by reflecting on South Africa's policy context, followed by policy proposals to position for new industries.

6. Policy Options for South Africa

6.1 Policy Context

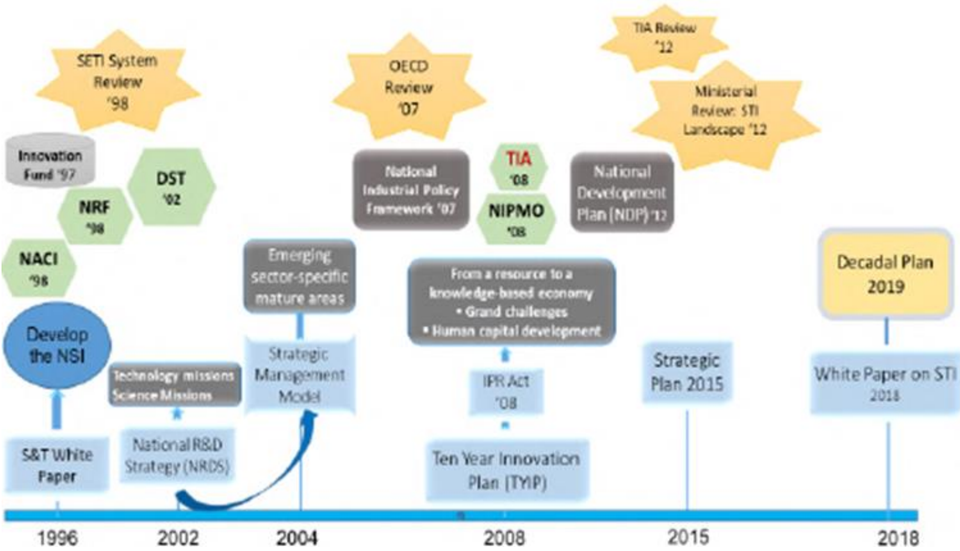
South Africa has a sectoral focus, driven by the Department of Trade, Industry and Competition ([DTIC] 2021). The DTIC leads sectoral industrial masterplans and special economic zones. The work of the DTIC is largely linked to incumbents and existing industries. Since 2008, the DTIC has made use of the Industrial Policy Action Plan (IPAP) (DTIC 2018). The 2018/2019 to 2020/2021 IPAP recognises that the NSI is maturing, along with the important role played through the DSI's agency, such as the Technology Innovation Agency (TIA) and the Council for Scientific and Industrial Research (CSIR), in getting technologies ready for market adoption.

The DSI is seen as the custodian of the NSI concept in South Africa. The 2019 STI White Paper recognises the need to align with the IPAP to ensure the wide deployment of technologies and the full functioning of the NSI (DSI 2019). On the DSI side, the focus is largely on technology push, as can be observed in relation to hydrogen energy technology, fuel cell technology, biotechnology and nanotechnology-related strategies (Motari et al. 2004; Mathe 2006).

Following the identification of the NSI's deficiency areas back in 2002, the national R&D strategy set out five technology missions, namely "biotechnology; information technology; technology for advance manufacturing; technology for and from natural sectors; and technology for poverty reduction" (Kaplan 2004: p. 279). Beside a focus on "technology for advanced manufacturing", confidence in the manufacturing sector by the business community has been at 50% and below since 2011 (DTIC 2018). Furthermore, the manufacturing sector has been heavily affected in terms of employment since the 2008 financial crisis and now employs 320 000 fewer people compared to 2008.

Despite the challenges, the South African government must be applauded for conducting several reviews of the NSI, followed by new acts and associated institutions, as shown in Figure 3 below.

Figure 3: Policy and Institutional Trajectory of the NSI



Source: DTIC (2018)

The 2019 STI White Paper recognises the need for innovation policy in terms of a "whole-of-government" approach (DTIC 2018: p. 96). As cautioned by Kaplan (2004), to do so would require the DSI to overcome much more powerful departments, such as the DTIC.

As it stands, the DSI makes technologies ready for market and for the DTIC to embed them in the market. The decision to embed lies with the DTIC. According to Christensen (2016), the DTIC could be caught in the "innovator's dilemma", where it prioritises its current customers – incumbents and existing industrial actors. It is much more likely to introduce technologies aligned with their needs for competitiveness and growth. To succeed in launching a new techno-economic paradigm, away from the old, requires "distancing" from the old (Freeman and Perez 1988).

Using the conceptualisations of the innovator's dilemma and techno-economic paradigm, the DTIC might not be the suitable entity to drive new and radical industries. It appears that there is a gap between the sectoral focus of the DTIC and the technology focus of the DSI. Another NSI deficiency back in 2002 was the low R&D investment, at 0.7% of GDP, and the decline in private sector investment in R&D (Kaplan 2004). The 2017/2018 data was at 0.83% of GDP, and public sector funding was at 54% (NACI 2020). Although investment in R&D does not automatically translate into innovation (Mazzucato 2013), innovation outcomes are bound to be low as well when it is low. The drive towards competitiveness in a knowledge-based economy would be hampered.

There has been lots of progress on the institutional level, as shown in Figure 3. It is disappointing that investment in R&D has not followed a similar trend. The introduction of intellectual property rights (IPR) saw a rise in the registration of patents by South African higher education institutions (Sibanda and Straus 2020). Surprisingly, 89% of patents in 2017 were granted to non-residents (NACI 2020). Although Sibanda and Straus (2020) argue for the South African government to play an active role in international technology transfer, such an effort is likely to face much resistance. There is no evidence to suggest that the registered patents by non-residents are aligned with South Africa’s technology strategy.

In terms of education, some progress has been made since identifying a lack of capable human resources as a deficiency of the NSI in 2002 (Kaplan 2004). In 2018, doctoral degrees in engineering constituted only 7% of all doctoral qualifications in the country (NACI 2020). At a time when mainstreaming STI is core for the running of the government, this is a concern, as it makes it difficult to support international technology transfer and guide the launching of new knowledge-intensive industries. In 2012, a target was set to move from 28 doctoral graduates per million per year to 100 doctoral graduates per million per year by 2030 (Perold et al. 2012); the country produced 1 051 doctoral graduates in 2018 (NACI 2020).

As already mentioned earlier in this section, South Africa's innovation policy is within the ambit of the NSI and the DSI. The DSI aspires to and is moving towards a “whole-of-government” approach (DTIC 2018; DSI 2019). As it stands, there is a weak link between the NSI and IPAP. The 2019 STI White Paper recognises this reality and recommends developing joint implementation plans to align with the IPAP (DSI 2019). How this would happen is unclear, as cross-departmental policy coherence is a difficult task. In a fragmented government reality, harmonisation is a challenge (Kaplan 2004).

It would be essential, while reflecting on the fourth industrial revolution (4IR) and its technologies sweeping the global village, to take note of the current government fragmented reality. South Africa established a Presidential Commission on the 4IR in 2019 to help position the economy for global competitiveness. Revolutions – industrial or otherwise – create a new order (Marivate et al. 2021). Could this be the opportunity for South Africa and the rest of the global South to effect NSIs for new industries? The rise and dominance of China through AI (Lundvall and Rikap 2022) opens a window of opportunity to leverage the maturing and advancing technology.

As the case study in the previous section and policy reflections in this section point out, there are missing and incomplete elements that appear to limit South Africa in successfully launching new industries.

6.2 Towards New Industries

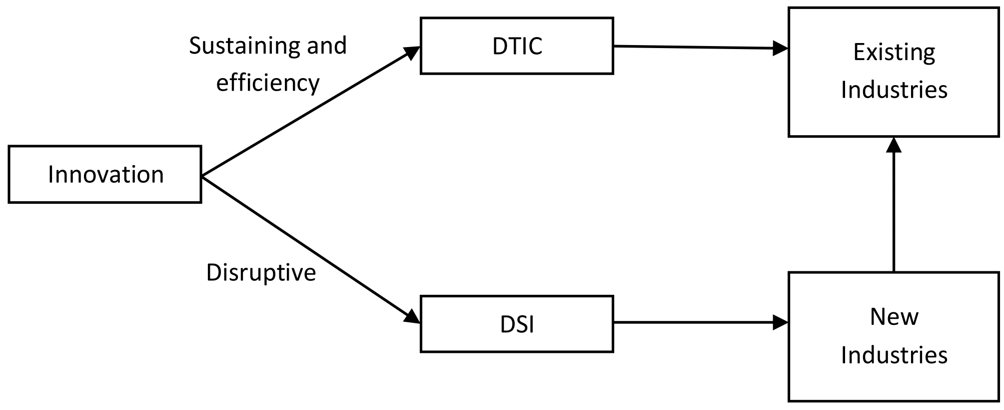
There is evidence that South Africa lost its manufacturing base, making it difficult to reduce the high unemployment rate. The manufacturing sector is struggling to compete on the global stage. To regain competitiveness requires, among others, investment in advanced and intelligent technologies (Marwala 2020). Through incentives and other instruments, the DTIC is positioned to offer a response in this regard. Alignment with the DSI on which advanced and intelligent technologies could help regain competitiveness is imperative. From the lens of incumbent industries, these technologies would help with sustenance and growth to remain competitive (Christensen et al. 2019).

Industries come and go and, as such, future competitiveness would rest on new and competitive industries. For new industries, the innovator's dilemma and techno-economic paradigm offer an important guide. In this context, new industries would be launched by disruptive technologies (Christensen 2016) and outside the current (old) techno-economic paradigm (Freeman and Perez 1988). Because new industries are new to the current and dominant industrial complex, they at first do not appear profitable and attractive to incumbent industrial actors, and thus are not pursued (Christensen et al. 2019).

Accordingly, chances are high that attempts by the DTIC to launch disruptive technologies and new industries to incumbents would face resistance. Herein lies the constraint and limitation on the part of the DTIC when it comes to driving new industries. Mazzucato (2013) reveals that incumbent industrial actors and venture capitalists (VC) take on sufficiently de-risked technological opportunities. Historically, the author (Mazzucato) argues that the government has been at the forefront of investing in disruptive technologies, creating and shaping new markets. This has been observed in the USA, the United Kingdom (UK), and now China. This case study agrees with Mazzucato (2013).

As already indicated, South Africa has STI – also referred as research, development, and innovation (RDI) – and industrial policies; RDI in the DSI and industrial policy in the DTIC. Christensen et al. (2019) categorise innovation as sustaining, efficiency and disruptive. Both sustaining and efficiency innovations are led by incumbents to command higher prices and reduce operating costs respectively. Disruptive innovations, on the other hand, create new markets. Profits in new markets start off significantly lower, making them unattractive to incumbents (Christensen 2016). In this context, sustaining and efficiency innovations are attractive to incumbents, while disruptive innovations are not. This thinking is developed as a proposal for industrialisation in Figure 4.

Figure 4: Proposed Framework for Industrialisation



The proposed framework is aligned with MITI in Japan leading industrialisation efforts. A clear direction from the case study is to import technology to kickstart industrialisation. The proposed framework could be leveraged in alignment with Sibanda and Straus's (2020) recommendation on international technology transfer to bolster local manufacturing in South Africa. Beyond the IPR Act, South Africa could do with an international technology transfer strategy. There are elements of it in the 2019 STI White Paper and the decadal plan. The strategy could be executed as part of a whole-of-government approach to ensure that technological needs across government are catered for. Positioning the strategy to equally address the skills gap is recommended, thus harmonising efforts toward creating new industries.

Although the DSI is charged with the national responsibility to drive commercialisation and innovation, its R8.9 billion budget (DSI 2021) is too small to direct and shape new industries in a tangible sense. As emphasised by Mazzucato (2013), there is a requirement that the government sufficiently de-risk technological opportunities in South Africa to consider alternatives to raising the investment for R&D. To date, the DSI has operated in terms of innovation policy and has not done so in relation to industrial policy. As such, it lacks certain competencies to succeed, as indicated in the proposed framework.

Innovation policies are largely supply driven, thus entail a technology push, while industrial policies are demand driven, thus involving a market pull (Oughton et al. 2002). In both cases, innovation activities are promoted to meet the drive. When it comes to new industries, there is no market, as it first needs to be created. Industrial policies were founded on low- to medium-tech industries such as coal and steel in Europe, while the emergence of high-tech industries demanded a focus on the broader system of innovation (Soete 2007). Industrial policies are effective when there is clarity about the industries to focus on, which means the industries must exist in the first place (Noland 2007).

Accordingly, there is greater uncertainty when it comes to launching new industries. As reflected in the previous paragraph, industrial policies may not be adequate. Incubation was utilised in the case study to navigate this uncertainty. South Africa has an incubation programme through the Small Enterprise Development Agency ([SEDA] 2018), under the Department of Small Business Development (DSBD). The focus appears to be less on managing uncertainty when introducing high-tech to the market. The approach to incubation needs to be revisited to support the DSI as per the proposed framework and as indicated in the case study.

7. Concluding Remarks and Implications

The proposed framework suggests including industrialisation in the current RDI scope of the DSI, and this could translate to RDI2. Although industrial policy may not the best candidate for new industries, it is the closest available tool. Essentially, on the part of the DSI, the proposed framework integrates both innovation policy and industrial policy as a policy approach to launching new industries. Other elements, such as an international technology transfer strategy for technology and R&D import, revisiting incubation as a knowledge and technology carrier for high-tech industries and closing the skills gap, must be prioritised equally.

The proposed framework has implications for the DSI and the DTIC. There are now two handover stages – one for technologies to support sustenance and efficiency innovations for existing industries, and the other for new industries, which later form part of existing industries under the DTIC. The expanded scope of the DSI, as suggested by the proposed framework, is in the same vein as the MITI of Japan. Because the DSI is shielded from incumbent industrial actors by the DTIC, it is positioned as the innovation disruptor of the South African economy towards new industries. The proposed framework provides ground for the DSI to act in this manner.

The shift from RDI to RDI^2 by the DSI requires different capabilities. The DTIC appears to be at the starting point for gaining these capabilities. Further research is needed to expand on how the DSI could go about gaining the capabilities to succeed as per the proposed framework. Lastly, the implications of integrating innovation policy and industrial also need to be studied further.

References

Acs, Z. J., Audretsch, D. B., Lehmann, E. E. & Licht, G. (2017). National systems of innovation. *Journal of Technology Transfer*, 42(5): 997-1008.

Adam, R. M. (2020). Technology, policy and politics: Critical success factors in high-technology infrastructure projects. *Social Dynamics*, 46(3): 378-390.

Andersen, E. S. (1992). Approaching national systems of innovation from the production and linkage structure. In B.-Å. Lundvall (ed), *National systems of innovation. Towards a theory of innovation and interactive learning* (pp. 71-96). London: Pinter.

Arocena, R. & Sutz, J. (2000). Looking at national systems of innovation from the South. *Industry and Innovation*, 7(1): 55-75.

Audretsch, D. B. & Feldman, M. P. (1996). Innovative clusters and the industry life cycle. *Review of Industrial Organization*, 11(2): 253-273.

Barboza, D. (2010, August 15). China passes Japan as second-largest economy. *The New York Times*.

Barnes, J., Kaplinsky, R. & Morris, M. (2004). Industrial policy in developing economies: Developing dynamic comparative advantage in the South African automobile sector. *Competition & Change*, 8(2): 153-172.

Bhorat, H. & Rooney, C. (2017). *State of manufacturing in South Africa*. Cape Town: Development Policy Research Unit, University of Cape Town.

Bulagi, M. B., Hlongwane, J. J. & Belete, A. (2015). Analyzing the linkage between agricultural exports and agriculture's share of gross domestic products in South Africa. *Journal of Agricultural Studies*, 4(1): 142-151.

Campbell, J. (2012). Building an IT economy: South Korean science and technology policy. *Issues in Technology and Innovation*, 19: 1-9.

Chaturvedi, S. (2005). Evolving a national system of biotechnology innovation: Some evidence from Singapore. *Science, Technology and Society*, 10(1): 105-127.

Chen, S. (2007). The national innovation system and foreign R&D: The case of Taiwan. *R&D Management*, 37(5): 441-453.

Chinigò, D. & Walker, C. (2020). Science, astronomy, and sacrifice zones: Development trade-offs, and the square kilometre array (SKA) radio telescope project in South Africa. *Social Dynamics*, 46(3): 391-413.

Christensen, C. M. (2016). *The innovator's dilemma*. 3rd edition. Boston: Harvard Business School Publishing.

Christensen, C. M., Ojomo, E. & Dillon, K. (2019). *The prosperity paradox: How innovation can lift nations out of poverty*. New York: HarperCollins.

Christensen, J. L. (2010). The role of finance in national systems of innovation. In B.-Å. Lundvall (ed), *National systems of innovation: Toward a theory of innovation and interactive learning* (pp. 151-172). London: Anthem Press.

Da Motta, E. (1999). National systems of innovation and non-OECD countries: Notes about a rudimentary and tentative. *Brazilian Journal of Political Economy*, 19(4): 35-52.

Department of Arts, Culture, Science and Technology (DACST). (1996). *White Paper on Science & Technology: Preparing for the 21st Century*. Pretoria: Government Printers.

Department of Science and Innovation (DSI). (2019). *White Paper on Science, Technology and Innovation*. Pretoria: Government Printers.

Department of Science and Innovation (DSI). (2021). *Budget speech 2021/22*. Pretoria: South African Government. Available from: https://www.gov.za/speeches/minister-blade-nzimande-science-and-innovation-dept-budget-vote-202122-18-jun-2021-0000.

Department of Trade, Industry and Competition (DTIC). (2018). *Industrial policy action plan (IPAP) 2018/19-2020/21*. Available from: https://www.gov.za/sites/default/files/gcis_document/201805/industrial-policy-action-plan.pdf

Department of Trade, Industry and Competition (DTIC) (2021). *Sectors* Available from: http://www.thedtic.gov.za/sectors-and-services-2/industrial-development/sectors/

Dosi, G., Freeman, C. R., Nelson, R. R. & Soete, L. (1988). *Technical change and economic theory*. London: Pinter Publishers.

Du Plessis, S. & Smit, B. (2007). South Africa's growth revival after 1994. *Journal of African Economies*, 16(5): 668-704.

Fan, P. (2014). Innovation in China. *Journal of Economic Surveys*, 28(4): 725-745.

Filippetti, A. & Archibugi, D. (2011). Innovation in times of crisis: National systems of innovation, structure, and demand. *Research Policy*, 40(2): 179-192.

Freeman, C. (1995). The 'National System of Innovation' in historical perspective. *Cambridge Journal of Economics*, 19(1): 5-24.

Freeman, C. & Perez, C. (1988). Structural crises of adjustment, business cycles and investment behaviour. In I. McLoughlin, D. Preece & P Dawson (eds), *Technology, organizations and Innovation: Theories, concepts and paradigms* (pp. 871-901). New York: Taylor & Francis

Fukugawa, N. (2017). University spillover before the national innovation system reform in Japan. *International Journal of Technology Management*, 73(4): 206-234.

Fuller, D. B. (2009). China's national system of innovation and uneven technological trajectory: The case of China's integrated circuit design industry. *Chinese Management Studies*, 3(1): 58-74.

Habiyaremye, A. (2020). Water innovation in South Africa: Mapping innovation successes and diffusion constraints, *Environmental Science & Policy*, 114: 217-229.

Hung, S.-W. (2009). Development and innovation in the IT industries of India and China. *Technology in Society*, 31(1): 29-41.

Johansson, R. (2007). On case study methodology. *Open House International*, 32(3): 48-54.

Johnson, B., Edquist, C. & Lundvall, B.-Å. (2004). *Economic development and the national system of innovation approach*. Proceedings of the First Globelics Academy, PhD School on National Systems of Innovation and Economic Development, 25 May-4 June, Lisbon, Portugal .

Johnson, C. (1982). *MITI and the Japanese miracle: The growth of industrial policy, 1925-1975*. Stanford, CA: Stanford University Press.

Kaplan, D. (2004). South Africa's national research and development strategy: A review. *Science, Technology and Society*, 9(2): 273-294.

Kim, L. (2001). Crisis, national innovation, and reform in South Korea. In W. W. Keller & R. J. Samuels (eds), *Crisis and innovation in Asian Technology* (pp. 86-107). Cambridge: Cambridge University Press.

Kılkış, Ş. (2016). Sustainability-oriented innovation system analyses of Brazil, Russia, India, China, South Africa, Turkey and Singapore. *Journal of Cleaner Production*, 130: 235-247.

Kraemer-Mbula, E. (2016). Informal innovations and the South African innovation system. In M. Scerri (ed), *The emergence of systems of innovation in (South)ern Africa: Long histories and contemporary debates* (pp. 303-329). Johannesburg: MISTRA.

Kraemer-Mbula, E. & Sehlapelo, D. (2016). Measuring the South African national system of innovation. In M. Scerri (ed), *The emergence of systems of innovation in South(ern) Africa: Long histories and contemporary debates* (pp. 255-277). Johannesburg: MISTRA.

Kumaresan, N. & Miyazaki, K. (1999). An integrated network approach to systems of innovation – The case of robotics in Japan. *Research Policy*, 28(6): 563-585.

Lee, T.-L. & Von Tunzelmann, N. (2005). A dynamic analytic approach to national innovation systems: The IC industry in Taiwan. *Research Policy*, 34(4): 425-440.

Leydesdorff, L. & Guoping, Z. (2001). University–industry–government relations in China: An emergent national system of innovation. *Industry and Higher Education*, 15(3): 179-182.

Luke, A., Freebody, P., Shun, L. & Gopinathan, S. (2005). Towards research-based innovation and reform: Singapore schooling in transition. *Asia Pacific Journal of Education*, 25(1): 5-28.

Lundvall, B.-Å. (2010). *National systems of innovation: Toward a theory of innovation and interactive learning*. London: Anthem Press.

Lundvall, B.-Å. & Rikap, C. (2022). China's catching-up in artificial intelligence seen as a co-evolution of corporate and national innovation systems. *Research Policy*, 51(1): 104395.

Makhoba, X. & Pouris, A. (2016). Scientometric assessment of selected R&D priority areas in South Africa: A comparison with other BRICS countries. *African Journal of Science, Technology, Innovation and Development*, 8(2): 187-196.

Manzini, S. T. (2012). The national system of innovation concept: An ontological review and critique. *South African Journal of Science*, 108(9-10): 1-7.

Manzini, S. T. (2015). Measurement of innovation in South Africa: An analysis of survey metrics and recommendations. *South African Journal of Science*, 111(11-12): 1-8.

Marivate, V., Aghoghovwia, P., Ismail, Y., Mahomed-Asmail, F. & Steenhuisen, S.-L. 2021). The Fourth Industrial Revolution – What does it mean to our future faculty? *South African Journal of Science*, 117(5-6). https://doi.org/10.17159/sajs.2021/10702

Marwala, T. (2020). *Closing the gap: The fourth industrial revolution in Africa*. Johannesburg: Macmillan.

Mathe, M. (2006). *South African hydrogen economy activities – National hydrogen energy & fuel cell R&D strategy development*. Pretoria: Council for Scientific and Industrial Research.

Mazzucato, M. (2013). *The entrepreneurial state: Debunking public vs. private sector myths*. London: Anthem Press.

Meyer, C. B. (2001). A case in case study methodology. *Field Methods*, 13(4): 329-352.

Moses, C., Sithole, M. M., Blankley, W. & Labadarios, D. (2012). The state of innovation in South Africa: Findings from the South African national innovation survey. *South African Journal of Science*, 108(7-8): 15-20.

Motari, M., Quach, U., Thorsteinsdóttir, H. & Martin, D. K. (2004). South Africa – Blazing a trail for African biotechnology. *Nature Biotechnology*, 22(12s): DC37-DC41.

Motohashi, K. (2005) University–industry collaborations in Japan: The role of new technology-based firms in transforming the national innovation system. *Research Policy*, 34(5): 583-594.

Mustapha, N., Khan, F., Kondlo, L. O., Takatshana, S., Ralphs, G. P., Whisgary, D., Weyers, J., Faul, K. L. & Romanowska, E. (2017). *South African national survey of intellectual property and technology transfer at publicly funded research institutions: Inaugural baseline study: 2008-2014*. Report commissioned by the Department of Science and Technology. Pretoria: HSRC.

Na, L. J. (2007). Stimulating construction innovation in Singapore by developing the national system of innovation (PhD). Singapore: National University of Singapore.

National Advisory Council on Innovation (NACI). (2020). *South African science, technology and innovation indicators*. Pretoria: NACI.

Nelson, R. R. (1993). *National innovation systems: A comparative analysis*. Oxford: Oxford University Press.

Ng, P. T. & Tan, C. (2006). From school to economy: Innovation and enterprise in Singapore. *The Innovation Journal: The Public Sector Innovation Journal*, 11(3): Article no. 5.

Niosi, J., Saviotti, P., Bellon, B. & Crow, M. (1993). National systems of innovation: In search of a workable concept. *Technology in Society*, 15(2): 207-227.

Noland, M. (2007). From industrial policy to innovation policy: Japan's pursuit of competitive advantage. *Asian Economic Policy Review*, 2(2): 251-268.

Oughton, C., Landabaso, M. & Morgan, K. (2002). The regional innovation paradox: Innovation policy and industrial policy. *The Journal of Technology Transfer*, 27(1): 97-110.

Park, H. W., Hong, H. D. & Leydesdorff, L. (2005). A comparison of the knowledge-based innovation systems in the economies of South Korea and the Netherlands using triple helix indicators. *Scientometrics*, 65(1): 3-27.

Perold, H., Cloete, N. & Papier, J. (2012). *Shaping the future of South Africa's youth: Rethinking post-school education and skills training*. Somerset West: African Minds.

Pouris, A. (2020). STI measurements in South Africa: The state of affairs. In M. B. G. Cele, T. M. Luescher & A. W. Fadiji (eds), *Innovation policy at the intersection* (pp. 77-84). Cape Town: HSRC Press.

Pouris, A. & Pouris, A. (2011). Patents and economic development in South Africa: Managing intellectual property rights. *South African Journal of Science*, 107(11): 1-10.

Rooks, G., Oerlemans, L., Buys, A. & Pretorius, T. (2005). Industrial innovation in South Africa: A comparative study. *South African Journal of Science*, 101: 149-150.

Sandrey, R. (2013). South Africa's way ahead: Are we a BRIC? *Tralac*. Available from: https://www.tralac.org/publications/article/4576-south-africa-s-way-ahead-are-we-a-bric.html

Shapiro, M. A., So, M. & Woo Park, H. (2010). Quantifying the national innovation system: Inter-regional collaboration networks in South Korea. *Technology Analysis & Strategic Management*, 22(7): 845-857.

Sibanda, M. & Straus, J. (2020). The intellectual property system as a catalyst for socio-economic development for middle income countries – Lessons from South Africa. *European Intellectual Property Review*, 42(11): 738-750.

Siddiqui, K. (2010). The political economy of development in Singapore. *Research in Applied Economics*, 2(2): E4.

Siva, V., Hoppe, T. & Jain, M. (2017). Green buildings in Singapore; Analyzing a frontrunner's sectoral innovation system. *Sustainability*, 9(6): 919.

Small Enterprise Development Agency (SEDA). (2018). Available from: http://www.seda.org.za/WhatsHappening/Pages/Incubators,-Network-Facilitators-Service-Providers-Gazelles-impact-on-beneficiaries-and-jobs-creation-DSBD-briefing.aspx

Soete, L. (2007). From industrial to innovation policy. *Journal of Industry, Competition and Trade*, 7(3-4), Article no. 273.

Sun, Y. & Liu, F. (2010). A regional perspective on the structural transformation of China's national innovation system since 1999. *Technological Forecasting and Social Change*, 77(8): 1311-1321.

Swart, G. (2015). *Innovation lessons learned from the Joule EV development*. Paper presented at the 24th International Conference of the International Association for Management of Technology (IAMOT 2015), 8-11 June, Cape Town.

Tavassoli, S. (2015). Innovation determinants over industry life cycle. *Technological Forecasting and Social Change*, 91: 18-32.

Tellis, W. (1997). Application of a case study methodology. *The Qualitative Report*, 3(3): 1-19.

Tsai, F.-S., Hsieh, L. H. Y., Fang, S.-C. & Lin, J. L. (2009). The co-evolution of business incubation and national innovation systems in Taiwan. *Technological Forecasting and Social Change*, 76(5): 629-643.

United Nations. (2014). *World economic situation and prospects 2014*. New York: United Nations Publications.

United Nations Department of Economic and Social Affairs (UNDESA). (2021). *World economic situation and prospects 2021*. New York: UNDESA .

Viotti, E. B. (2002). National learning systems: A new approach on technological change in late industrializing economies and evidences from the cases of Brazil and South Korea. *Technological Forecasting and Social Change*, 69(7): 653-680.

Wang, J. (2018). Innovation and government intervention: A comparison of Singapore and Hong Kong. *Research Policy*, 47(2): 399-412.

Wong, P.-K. (1999). National innovation systems for rapid technological catch-up: An analytical framework and a comparative analysis of Korea, Taiwan and Singapore. Paper presented at the DRUID Summer Conference on National Innovation Systems, Industrial Dynamics and Innovation Policy, 9-12 June, Rebild, Denmark.

Wong, P. K. & Singh, A. (2008). From technology adopter to innovator: Singapore. In C. Edquist & L. Hommen (eds), *Small country innovation systems: Globalization, change and policy in Asia and Europe* (pp. 71-112). Cheltenham: Edward Elgar Publishing.

World Population Review. (2021). *Total population by country 2021*. Available from: https://worldpopulationreview.com/countries

Wu, J., Zhuo, S. & Wu, Z. (2017). National innovation system, social entrepreneurship, and rural economic growth in China. *Technological Forecasting and Social Change*, 121: 238-250.

Xiwei, Z. & Xiangdong, Y. (2007). Science and technology policy reform and its impact on China's national innovation system. *Technology in Society*, 29(3): 317-325.

Yeh, C.-C. & Chang, P.-L. (2003). The Taiwan system of innovation in the tool machine industry: A case study. *Journal of Engineering and Technology Management*, 20(4): 367-380.

Yu-Kang, M. & Schive, C. (1995). Agricultural and industrial development in Taiwan. In J. W. Mellor (ed), *Agriculture on the road to industrialization* (pp. 23-66). Baltimore, MD: John Hopkins University Press.

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