South Africa:

IP Management and the Commercialization of Publicly Funded Research Outcomes

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[1] The authors thank the Edison Fellowship program at the George Mason University School of Law for supporting this project. They also thank Jay Kesan, Mark Schultz, Kerry Faul, Sebastian Lohse, and Kaveri Marathe for their feedback on earlier versions of this paper. All errors and omissions are the authors' alone.

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INTRODUCTION

The question as to how best to commercialize the output of publicly funded research and development (R&D) has attracted significant attention among policymakers in developed and developing nations alike. Commercialization, which often involves the patenting and licensing of inventions, is an important process by which R&D outcomes are applied in the industrial domain. It ensures that the benefits of R&D investments can accrue to the economy and to society at large. The commercialization process depends to a large extent on the availability of enabling legislative and policy frameworks that support the effective identification, protection, and management of any intellectual property (IP) associated with the R&D results.

Starting with Israel in the 1960s, countries across regions and at all levels of development have established policy frameworks to facilitate the transfer of public research outcomes to actors with the capacity and resources to further develop them, in order to bring new products and services to market (WIPO 2011; Zuniga 2010). One such country is South Africa, which has prioritized the establishment of an inclusive National System of Innovation (NSI) since its transition to democracy in 1994. The White Paper on Science and Technology (White Paper) in 1996 and the National R&D Strategy (R&D Strategy) in 2002, together with subsequent policy documents, explicitly identify IP management as a tool for development. At the same time, they single out the protection and commercialization of IP emanating from publicly financed R&D as important objectives. They set the stage for adoption of the Intellectual Property Rights from Publicly Financed Research and Development Act (IPR Act) in 2008 and the related creation of the National Intellectual Property Management Office (NIPMO) in 2010, to manage the implementation of the IPR Act.

This paper begins by presenting an overview of enabling frameworks for the protection and commercialization of publicly funded R&D outcomes. Subsequently it analyses the policies that South Africa has adopted to this effect since the transition to democracy. The paper then looks at the impact on the South African NSI of these policies, in particular the IPR Act, which has been in force since August 2010. It presents new data that indicate encouraging progress in patenting and other aspects of commercialization involving public research organizations (PROs)[2] in South Africa, before setting forth a summary of the analysis as well as conclusions.

Developing countries often express skepticism about the relevance of IP management for development. However, the example of South Africa provides insights as to how IP rights (IPRs) can be leveraged in the service of inclusion and other public policy objectives, and demonstrates that a long-term concerted approach is required to transform innovation systems. Therefore the present case study of South Africa may be useful to other countries that are designing policy frameworks to support the commercialization of publicly funded R&D outcomes. In addition, the original

[2] PROs comprise universities, also called higher education institutions (HEIs), and public research institutions, often referred to in South Africa as science councils.

evidence presented in the paper could inform future IP-related policymaking in South Africa, for instance the work of elaborating and executing the South African IP Policy. Finally, the case study could contribute to ongoing global discussions, for instance at the World Intellectual Property Organization (WIPO), about IP for development.

COMMERCIALIZATION OF PUBLICLY FUNDED RESEARCH OUTCOMES

"An idea or scientific principle is not, by itself, of any importance for economic practice." – Schumpeter

The process of innovation consists of two essential components: invention and commercialization (Schumpeter 1947). Invention involves a creation or discovery phase giving rise to a new idea that addresses a specific challenge or responds to an opportunity. Such an idea need not necessarily be a technology solution; an invention can also involve changes in production organization or the appearance of markets (Abeltina 2007). Nonetheless, technological progress seems to have a particularly important and positive multiplier effect; the OECD has observed that "scientific advances and technological change are important drivers of recent economic performance" (OECD 2000).

Commercialization is the process of turning a new idea into a marketable product or service (Tanha 2011). Innovations are those inventions that ultimately produce a profit or satisfy a market demand (Abeltina 2007), or that have been applied so as to generate a positive social impact. Often requiring skills that differ from those required for the invention or discovery phase, commercialization centers on generating a tangible product, process or service, securing financing in order to scale, and ensuring market appropriateness readiness and access. The inventors may not always be best equipped to translate a breakthrough to market.

Box 1 What is IP management?

Intellectual property is a valuable strategic and financial asset for every innovative organization. Like any other resource, IP needs to be properly managed. Otherwise, the organization may be unaware of its knowledge-based assets, the value or benefits thereof, and of potential risks. An ongoing task, IP management includes the following elements:

- Identification of the knowledge-based assets of the organization, including those researched or developed by the organization itself, acquired through inward licensing, and purchased from third parties;
- Identification of the available forms of protection for the knowledge-based assets, and decision-making as to the most appropriate, including registered protection (e.g. patents, trademarks, registered designs) and/or unregistered protection (e.g. trade secrets, copyright, circuit layout, database rights); and
- Decisions as to whether the knowledge-based assets will be commercialized by the organization, used internally on an operational basis, licensed out to the public or an industry partner, or offered to the public for free.

Commercialization often requires skill sets that reside in a completely different organization, whether an established industry player or a spin-off company

established for that purpose. “Technology transfer” is thus part of the commercialization process, involving the application of know-how, skills, technical knowledge, procedures, methods, and expertise to move a promising idea from one organizational setting to another (Roessner 2000). Depending on the context, effective technology transfer assumes the existence of IP associated with the idea, necessitating appropriate IP management approaches ranging from protection to licensing to assignment (Box 1). Legislative and policy frameworks that facilitate IP management and technology transfer provide predictability and legal certainty to interested parties along the innovation value chain, thereby enhancing the commercialization of inventions, whether emanating from privately or publicly financed R&D (Box 2).

Box 2 The Bayh-Dole Act in the United States

The 1980 Bayh-Dole Act brought about a major change to the ownership of IP rights in federally funded research in the United States. It was enacted to promote technology transfer by conferring to universities, small businesses, and other research institutions the ownership of the patent rights emanating from federally funded research. Under the legislation, their ownership is subject to a number of conditions, including the obligation to take steps to commercialize the invention, compliance with reporting requirements related to management of the relevant IP, and an obligation on the part of universities and other nonprofit institutions to share royalties with the actual inventor. Prior to the Bayh-Dole Act, patent rights were in principle retained by the funding agencies themselves, with patent policies that varied considerably. Because of the ensuing uncertainty, many inventions resulting from federally funded scientific research remained unexploited. An estimated 27,000 federally owned, patented technologies were sitting on the shelf before the law’s entry into force.

The Act has been credited with unlocking discoveries and inventions arising from federally funded research, thus stimulating the commercialization of significant new technology solutions across sectors and especially in the bio-pharmaceuticals space. Supporters point to evidence that the Bayh-Dole Act was followed by significant increases in patenting and licensing by US universities, along with the creation of jobs and startups.

Critics of Bayh-Dole have warned that the use of patents in such areas as basic biological research may compromise basic principles of open science. They raise the concern that the failure to distinguish between downstream inventions that lead directly to commercial products and fundamental research discoveries could give rise to the risk of blocking patents on foundational discoveries and indispensable research tools. In response to these concerns, Congress amended the Act in 2002, specifying *inter alia* that the law needs “to be carried out without unduly encumbering future research and discovery”. Criticism of the framework established by Bayh-Dole has also been directed at mismanagement by universities of publicly funded intellectual property, the “double taxation” of offerings derived from public research due to higher prices, possible conflicts of interest when academics participate in commercialization, and the neglect of research outcomes and market segments with less commercial potential.

Sources: McManis & Noh 2012; Sweeney 2012; Economist 2002.

Commercialization of publicly funded R&D outcomes, the focus of this paper, can produce positive economic and technical spillovers, such as job creation through spin-offs, commercial activity with a direct or indirect impact on GDP, improved health, food security, sustainable energy or sanitation outcomes, follow-on innovation, and the stimulation of more demand for follow-on R&D. There is also the potential for commercialization to generate new revenue streams accruing to inventors and to the PROs (Montobbio 2009; Zuniga 2010). Beyond generating revenue, in a developing-country context, commercialization of public research outcomes may be aimed at transforming research into products and offerings that advance social and economic welfare.

The above benefits can be unlocked in the presence of public policy frameworks allowing for IP management and technology transfer of public research outputs. In light of concerns regarding the interplay of IPRs and access to health and food, such frameworks can enable institutions and governments to retain a degree of control over how certain technologies are deployed and to ensure their broad diffusion, especially in critical areas like healthcare or agriculture (Montobbio 2009).

Both formal and informal channels contribute critically to technology transfer. With regard to formal channels, exclusive licenses can allow for additional investments to be accessed to support commercialization, as well as any further supporting R&D that must be undertaken (Montobbio 2009). Decisions as to whether or not to grant exclusivity are generally taken by technology transfer officials after much consideration and in order to strike the right balance on IP management. Informal channels include conferences, personal interactions, recruitment by industry of students involved in relevant R&D, and the public domain through publication (Montobbio 2009; So *et al.* 2008; Zuniga 2011). Overall, technology transfer officials at PROs seek to use IP tools to translate knowledge to the market without unduly disrupting pre-existing relationships with the private sector or upsetting informal channels for knowledge transfer.

Complex and arduous, the technology transfer process rarely follows a linear path. It is characterised by numerous “stop/go” decision points, and by multiple feedback loops and dependencies. Possible dependencies include the quality of R&D results, stage of development of the technology, geographic proximity to potential partners and markets, participation of the inventor(s) in the technology transfer process itself and the sharing of tacit knowledge, adequacy of business skills, availability of venture capital (VC) and other forms of funding, as well as the competitive advantage provided by the IP compared to competing solutions (Montobbio 2009; Audretsch 1998). Other factors include the partner entity’s absorptive capacity, i.e., its ability to recognize the value of new information, assimilate it, and apply it to commercial ends (Cohen & Levinthal 1990). Government procurement can also influence technology transfer in that it can be used as a tool to prioritize adoption of locally sourced innovations.

Small and medium-sized enterprises (SMEs) are important actors in the technology transfer of publicly funded R&D. Often, the purpose of startups is to commercialize cutting-edge solutions that established firms are not in a

position to readily integrate into their existing product offerings or ongoing R&D activities. They have been found to be more flexible than larger firms, thus allowing them to respond more rapidly to signals from the market (Revilla 2012; Thomä & Bizer 2013). In other instances, however, particularly where the R&D results require significant resources for additional R&D, or they are readily aligned with existing industry R&D activities, established firms may be more suitable technology transfer partners.

Much of the evidence regarding the IP management of inventions emanating from publicly funded R&D is based on experiences from developed countries, where there are effective IP protection and enforcement systems, adequate research capacity and absorptive capacity of firms, financing for startups, spin-offs and other innovative ventures, functioning technology and IP markets, and a well-developed culture of entrepreneurship. These features are not necessarily present in most developing countries, where technology transfer from PROs is still in the earliest stages (Montobbio 2009; Zuniga 2011). This stark difference explains the criticism that has been directed at the importation of legislation modeled on Bayh-Dole to such countries, with some arguing that IP management alone will not enhance the entrepreneurial output of PROs in lower income countries (So *et al*. 2008).

Indeed, for most developing countries, setting the optimal approach for IP management of publicly funded R&D outcomes is a necessary but not sufficient condition to stimulate technology transfer. It is imperative that, in addition to putting in place enabling commercialization and IP policy frameworks, governments in developing countries invest in improving the quality of scientific research outputs, while enhancing human capital and research capacity through targeted capacity-building activities (Montobbio 2009; Zuniga 2010). Investments in associated research infrastructure are likewise critical. Governments can also enact policies that encourage more interaction between PROs and firms, support SME establishment and growth, boost levels of public R&D and innovation funding, and stimulate the emergence of VC.

This paper examines the case of South Africa, a relatively sophisticated middle-income country that has been actively engaged in strengthening its NSI since the end of apartheid. The Government of South Africa has followed through on promises made in 1996 (White Paper), then reaffirmed in 2002 (R&D Strategy) and 2008 (Innovation Plan, IPR Act; Technology Innovation Agency Act), to take action to ensure that government R&D spending benefits all citizens, including through the establishment of commercialization frameworks that further this goal. As other developing countries consider how to effectively manage and derive benefits from the IP generated by their PROs, it is hoped that this case study can provide useful insights about what can work in a developing-country context.

THE EVOLUTION OF IP MANAGEMENT FOR THE COMMERCIALIZATION OF PUBLICLY FUNDED RESEARCH IN SOUTH AFRICA SINCE 1994

Socio-Economic Context in 1994

The post-apartheid government in South Africa faced significant challenges in relation to economic and social advancement. These were compounded by the fact that a large part of its people – especially historically disadvantaged groups – had long been excluded from the economy. The post-apartheid democratic government elected to pursue a so-called "mixed economy" approach, characterized by the co-existence of free markets and government intervention, while placing science and technology at the center of socio-economic development (Sibanda 2017). Aligned with this approach, a new South African innovation policy was set forth with the publication in 1996 of the White Paper on Science and Technology. The new, post-1994 South African government adopted the new paradigm for the NSI as a conceptual framework for reform and for redressing some of the legacies of the past; these imperatives drove the creation of a new process to strategically redefine the country's NSI (Maharaj 2010; OECD 2007).[3] Its implementation would require overcoming challenges including, *inter alia*, inadequate human capital, a lack of appreciation of IPRs as tools for wealth creation, and IP management practices across PROs that differed considerably in terms of their composition and effectiveness (Sibanda 2017).

At the time of the transition, South Africa's NSI appeared to have some strong elements upon which to build (Maharaj 2010). The country had well-developed centers of innovation related to a limited number of industries, notably defense, extractives (mining), and large-scale agriculture (Marais & Pienaar 2010). In these areas, the government had made substantial investments in public research and had launched national technology "missions". Furthermore, with 58 per cent, the share of private sector spending in overall R&D spending was relatively high, indicating a promising level of absorptive capacity in the private sector (OECD 2007).

At first glance, South Africa had a well-established scientific research community that was engaged in high quality research, despite the country's isolation in the final years of apartheid. South African publications ranked in the top 1 per cent of global citations (OECD 2007). However, the size of the research community was low by international standards, at less than one researcher for every thousand members of the workforce, compared to five in Australia and ten in Japan (R&D Strategy 2002). Most importantly, the research community was not inclusive, which was unsurprising given that

[3] The OECD, in its 2007 review of the South African national innovation system, described this process as being "about reshaping a relatively strong innovation system serving one set of social, economic and political goals towards another strong system serving a very different set of goals" (OECD 2007).

most South Africans had been denied access to education under apartheid. It consisted primarily of older white males, who would be difficult to replace due to low levels of educational attainment by the vast majority of South Africans (OECD 2007). Moreover, public R&D spending as a share of GDP had fallen from 1.1 per cent to 0.7 per cent during the 1990-1994 period (R&D Strategy 2002). Part of this fall was due to the expiry in 1995 of the technology "missions" launched under the pre-1994 government.[4]

To a limited extent, at the time of the transition to democracy, intellectual property tools were being used to promote the commercialization of publicly funded research outcomes. A case in point was the Support Programme for Industrial Innovation (SPII) established in 1993. Operated by the Department of Trade and Industry (DTI), the SPII aimed to promote the development of innovative and commercially viable technology products. In particular, its objective was to facilitate the commercialization of such inventions through financial assistance. SPII also provided support to innovative firms on a matching grant basis, in varying ratios depending on the type of organization applying for support. It set targets for patent registration for products and processes that had been developed with SPII support (Sibanda 2007), although in relation to certain of the projects such targets (*e.g.* to file a PCT application) may have been unrealistic.

To sum up, some foundational elements for the country's future national innovation system were present. However, they constituted an inadequate basis for improving the country's competitive position in the global economy over the long term, or for driving social and economic development.

Post-1994 efforts thus focused on redirecting resources and policies to create a more inclusive and sustainable NSI that would serve the needs of and engage the whole population. A key priority was to increase the number of qualified researchers, in order to increase knowledge production that could be applied to address the many challenges that South Africans were facing. This strategy bore fruit: by 2015, the headcount of full time equivalent (FTE) R&D researchers had risen to 72,400, more than twice the figure in 2001 (Figure 1).

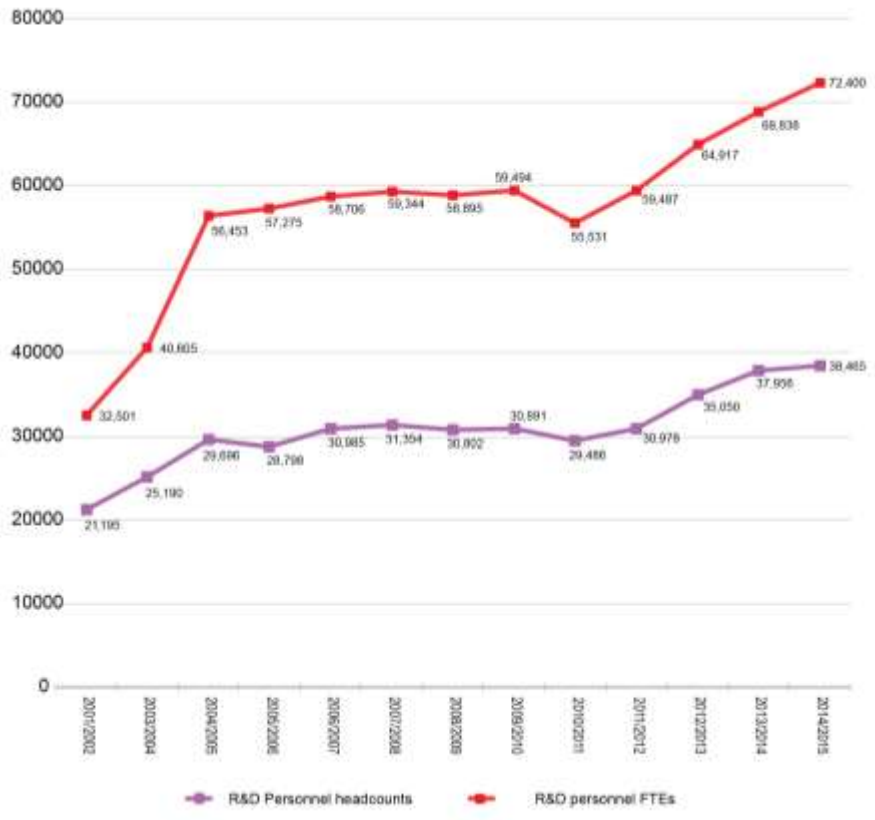
Between 2001 and 2015, public spending on R&D as a share of R&D expenditure increased, reaching 43.9 per cent of total spending by 2015 (CeSTII 2017). This development can be attributed to growing public spending on R&D, coupled with a relative decline in the sectors that traditionally attracted private sector R&D spending (Kaplan 2009; CeSTII 2017). During this same period, private sector R&D expenditure fell, reaching 40.8 per cent of total R&D spending by 2015 (Figure 2).[5] Further investments will likely be needed, given that, despite these increases, public R&D spending and research capacity remain insufficient to generate a significant pool of R&D that can be effectively commercialized. Investments should be calibrated to reflect the efficiency of the current system, in particular its ability to absorb

[4] Public sector spending was further affected by developments such as abandonment of the Pebble Modular Reactor in 2010.

[5] A slight increase in private sector spending in 2014/2015 may be attributable to the private sector taking advantage of an R&D tax incentive that the government had recently put in place (Sibanda 2017).

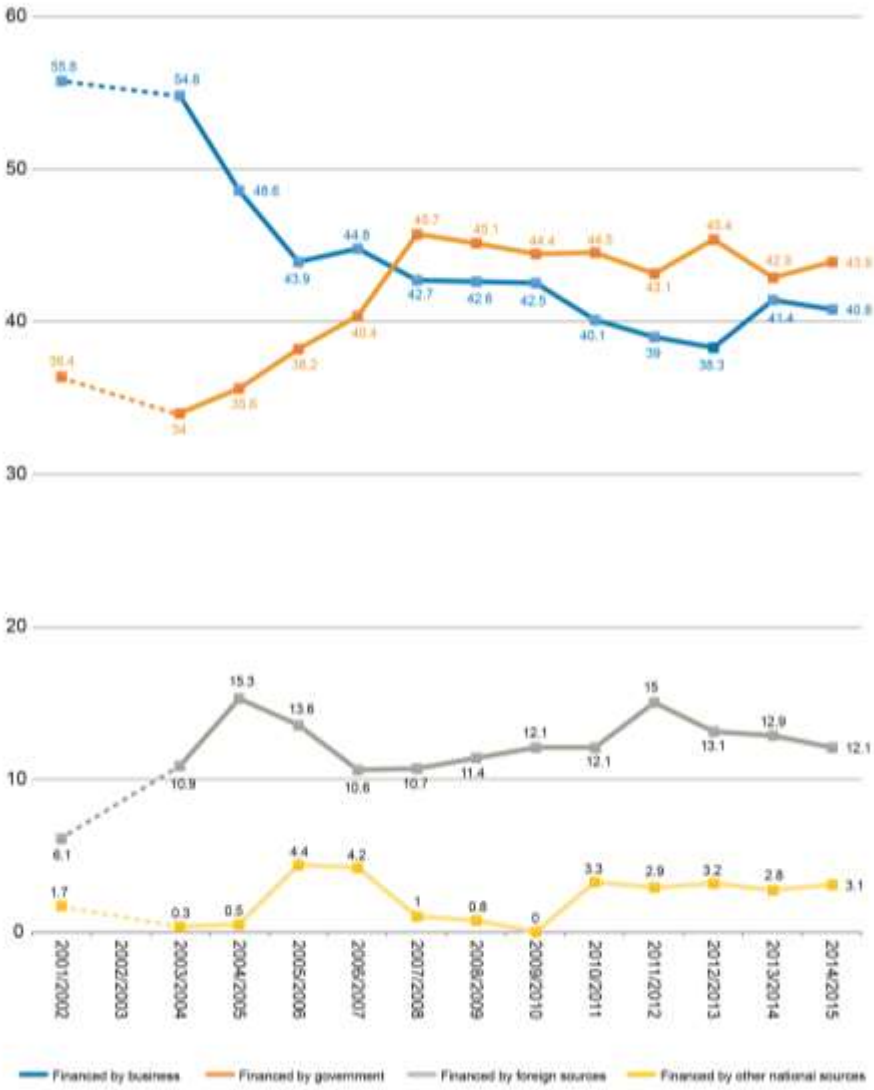
funding increases, as well as evolution the technology transfer environment, which should reduce over time the likelihood that public research outcomes remain unexploited.

Figure 1 South Africa R&D Personnel (headcount and FTE) (2001-2015)



Source: CeSTII 2017.

Figure 2 GERD by Source of Funding (2001-2015)



Source: CeSTII 2017.

A number of policy frameworks have been put in place by the South African government since 1994, to support the transition from an economy focused to a large extent on resource extraction, and with limited advanced manufacturing capacity, to a diversified and inclusive "knowledge economy". These are described below.

1996 White Paper on Science and Technology

Published by the Department of Arts, Culture, Science and Technology (DACST), the White Paper recognized the importance of innovation for sustainable economic growth, employment creation, and equity through redress and social development. As noted above, it set out an initial vision of a South African NSI that promotes the generation of more scientific and technical knowledge while harnessing the benefits of such knowledge to

improve human welfare, particularly among disadvantaged South Africans. The White Paper stated the prime objective of the NSI as being:

> "… to enhance the rate and quality of technology transfer and diffusion from the science, engineering and technology (SET) sector by the provision of quality human resources, effective hard technology transfer mechanisms, and the creation of more effective and efficient users of technology in the business and governmental sectors".

In particular, it identified technology transfer – along with human capital development, improved quality of research, and collaboration – as key to the success of an inclusive innovation system.

The White Paper proposed creation of an "Innovation Fund" to take the lead among government agencies in encouraging and enabling innovation projects on a large scale, involving PROs, government science, engineering, technology and innovation (SETI) entities, civil society, and the private sector. Establishment of the Innovation Fund would prove a critical development in the evolution of an effective system for the commercialization and technology transfer of public research outcomes in South Africa. According to the White Paper, the Fund would help to rationalize the government's efforts to invest in basic scientific R&D. One particular mission would be to support new programs for transforming knowledge into offerings in the marketplace.[6] As envisioned, this entity would also support South African firms' efforts to enhance their absorptive capacity so they could integrate new technologies, whether developed domestically or imported, into their activities (Box 3).

The White Paper cited IP rights as important tools to stimulate and reward investments in R&D, specifically stating that "one of the issues brought to the fore by treating innovation as a national priority is that of intellectual property rights". The White Paper called for the DACST to work with the DTI to determine how the South African IP system should be structured in order to best promote innovation, raising for example the question as to whether substantive examination of patent applications should be introduced. What is more, the White Paper confirmed the South African government's intention to align domestic IP regulations with global norms.

Box 3 Establishment of the Innovation Fund

Following publication of the White Paper, the Innovation Fund was established in order to offer funding instruments for innovation projects on a competitive bid basis. Funding came from top-slicing the budgets of the scientific research councils. Whereas the SPII had been focused more on product development, the Innovation Fund projects were typically two- to three-year applied R&D projects with a focus on the generation of new IP that could be commercialized at the end of the three years. The funding agreements placed an obligation on funding recipients to commercialize their IP and to pay five per cent of any income generated to the Innovation Fund. The Joule, South Africa's first electric vehicle, was the result of one such project.

[6] Programs covered areas such as improved competitiveness and quality of life, promotion of collaboration and networking among potential innovators, protection of the environment, and leveraging of advancements in information technology (White Paper 1996).

In 2004, the Innovation Fund set up an IP Management Office, as well as a platform for commercializing promising technologies arising from publicly funded research, called the Innovation Fund Commercialization Office. In the later part of 2005, the IP Management Office launched two new mechanisms to support innovators in securing and managing IP rights pertaining to publicly funded research outcomes. The first was the Patent Support Fund, which subsidized the acquisition of IP rights, both at the South African IP Office and abroad, by researchers and post-graduate students at publicly funded universities and PROs in South Africa. This mechanism was later expanded to specifically support SMEs and black owned businesses. The second was the Patent Incentive Fund, which provided financial rewards of up to R25,000 to each inventor named in a South African patent.

In subsequent years, the Innovation Fund was instrumental in encouraging evolution of the innovation culture in South Africa. This was particularly true in relation to PROs, which gradually shifted to value and even prioritize the use of patents and other IP tools. The Innovation Fund spurred the creation of IP and technology transfer policies at several PROs, by making patenting a requirement of receiving funding; recipients of its funding were required to manage any resulting IP and were prohibited from transferring title to such IP without prior approval from the Fund. It also played a role in the initial establishment of technology transfer offices (TTOs) at certain institutions, such as the Tshwane University of Technology. Lastly, it also supported the establishment of the Chairs in IP Management, with the first at the University of Cape Town and the second at the University of South Africa.

In the policy realm, the Innovation Fund experts consistently made the case before policymakers and other stakeholders that patenting and publication can and should go hand in hand for researchers, an outcome that is entirely possible based on data from a range of countries.

Ultimately, the Innovation Fund laid the groundwork for the 2008 IPR Act and the National IP Management Office. According to a 2012 South African Ministerial Review: “The operation of the Innovation Fund has been accompanied by its own innovations, such as institutional development involving staff capacity in intellectual property management, which laid the basis for the establishment of what is now the NIPMO as well as the IPR capacity of the new Technology Innovation Agency”.

Sources: Sibanda 2007; Montobbio 2009; Ministerial Review 2012.

2002 National R&D Strategy

Drawing to a noteworthy extent on the White Paper, the 2002 National R&D Strategy (R&D Strategy) further defined the path to developing a national technology transfer framework that would protect and leverage IP emanating from publicly funded R&D. The R&D Strategy explicitly called for expanding the use of IP tools for the commercialization of publicly funded research outcomes. It also advocated better coordination of funding for basic R&D, more resources for science and technology overall, and a strategic plan for ensuring that scientific research capacity would continue to grow over time.

The R&D Strategy rested on three pillars. The first of these centered on increasing both public R&D expenditure as well as absorptive capacity, especially in the private sector. The second pillar focused on building human resources in the areas of engineering and technology through researcher training, integration of South African scientists into global research networks, and the launch of several new technology “missions” to incentivize investments in strategic areas like biotechnology and advanced manufacturing.

The third pillar focused on the creation of an effective "government science and technology system". As part of this pillar, the R&D Strategy identified the need to address the "innovation chasm", that is, the gap between local knowledge creation and the application of such knowledge by South African firms. It called for a more effective approach to commercializing publicly funded R&D outcomes in South Africa. To this end, it proposed to increase the resource base of the Innovation Fund and to define policies that guide IP ownership and technology transfer by research institutions. According to the R&D Strategy, the third pillar would leverage the expected outcomes of the other pillars, namely an enhanced technical knowledge base among both South African researchers and firms.

Under the third pillar, IP management was identified as a crucial element for advancing the commercialization of South African public research outcomes, as well as for the monetization of traditional knowledge and genetic resources, in order to create wealth and benefit South African citizens. The R&D Strategy recommended the creation of a unified, nationwide framework for the IP management of publicly funded research outcomes. Under the fragmented system that existed at the time, each research institution determined its own approach, creating significant uncertainty when dealing with industry (Reichelt 2007). Moreover, in some cases, research institutions had no technology transfer offices or clear policies as to how IP should be protected and managed (Sibanda 2009). Another challenge was securing fair remuneration for South African inventors, ensuring they could participate in the further development of their solutions, and limiting IP leakage. Often when collaborating with private sector partners, South African researchers were excluded from downstream activities and earnings (R&D Strategy 2002; IPR Framework 2006).

In order to use IP management as a tool to address such issues, the R&D Strategy proposed clear policies and more funding to help institutions to secure and manage their IP rights, whenever this would be in the national interest. It recommended that the identification of best practices in public research commercialization from abroad guide the establishment of an appropriate framework at home. The R&D Strategy gave rise to a range of complementary initiatives (Box 4).

Box 4 Innovation initiatives that complement the R&D Strategy

Following publication of the R&D Strategy, and the call to increase the resource base of the Innovation Fund, the Patent Incentive Fund and the Patent Support Fund were added to the funding initiatives managed by the Innovation Fund. Under the Patent Incentive Fund, monetary incentives were extended to inventors at South African institutions for having secured South African patents for their inventions. For the first time, government policies provided an incentive for researchers receiving public funding to consider patenting before publishing their research results.

Since 2002, the R&D Strategy has been complemented by various initiatives and sector-specific strategies, including:

- Six sector-specific innovation strategies covering information and communications technology (ICT), biotechnology, and advanced

manufacturing, among other sectors;

- Establishment of the Biotechnology Regional Innovation Centres (Brics) pursuant to the 2001 Biotechnology Strategy.[7] These provided funding for biotechnology-related innovation projects until they were merged with the Innovation Fund and two other entities to form the TIA in 2010;
- Establishment of new agencies, for instance the South African National Space Agency;
- Creation of new research facilities and infrastructure, including the South African Large Telescope;
- Launch of new R&D support programs, such as the South African Research Chairs Programme, and nearly 50 new bilateral research cooperation agreements with other countries; and
- A new strategic research program launched by the national funding agency, the National Research Foundation, formerly the Foundation for Research and Development (FRD).

Sources: Sibanda 2007; Marais & Pienaar 2010; Biotechnology Strategy 2001.

2008-2018 Ten Year Innovation Plan

Published by the Department of Science and Technology (DST),[8] the Ten Year Innovation Plan (Innovation Plan) provided further impetus to the development of a stronger, more inclusive NSI in South Africa, including in particular an effective framework for the commercialization of publicly funded research. It targeted three of the same focal areas as the R&D Strategy: human capital development, improvement of the knowledge infrastructure, and improvement of the framework for public research commercialization. Its explicit objective was to ensure that public research outputs can be leveraged to address chronic poverty and other challenges affecting a considerable part of the South African population.

The Innovation Plan proposed targeting R&D towards solutions to key development challenges, in order to mobilise and target resources and incite collaboration between researchers and other actors within the national innovation system. These so-called "grand challenges" were: (i) leverage the "farmer to pharma value chain" to strengthen the bio-economy and take advantage of South Africa's biodiversity; (ii) develop innovative space science and technology; (iii) pursue energy security; (iv) exercise leadership in global-change science with a focus on climate change; and (v) analyse human and social dynamics. According to the Innovation Plan, the national system of innovation should have, by 2018, competitive advantage in key areas like biotechnology and space technology, long-term investments in R&D

[7] The Brics comprised, *inter alia*, BioPAD (Pretoria), LIFElab (Durban), Cape Biotech (Cape Town) and PlantBio (Pietermaritzburg). Each was managed by a trust constituted by the DST and governed by its own trust deed and board of trustees, which reported directly to the DST.

[8] Formerly the Department of Arts, Culture, Science and Technology (DACST). In 2004, the third African National Congress (ANC) government separated the ministry of science and technology from that of arts and culture. This considerably raised the political status of science and technology as a government priority, while allowing the ministry to focus exclusively on promoting science, technology, innovation, and enhanced human capital (Marais & Pienaar 2010).

infrastructure, more absorptive capacity, and effective commercialization of public research outcomes.

The Innovation Plan again underscored the need to address the innovation chasm in South Africa, through commercialization of knowledge and better alignment of public research with local market and business needs. It called for the development of "innovation skills" – including IP management expertise – that would enable the country to increase the number of patents and products generated from publicly funded R&D, while ensuring their sound management. The Innovation Plan also proposed the creation of a new agency, the Technology Innovation Agency (TIA).[9] It was envisioned that the TIA would oversee the work of certain agencies, including the Innovation Fund, establish a network of centers able to identify opportunities for collaboration between the private sector and public research entities, and provide funding and services to connect the public knowledge base with the real economy. Subsequently, the TIA was created through a Parliamentary law, the Technology Innovation Agency Act of 2008. The TIA became an umbrella organization integrating the work of a number of agencies that reported to the DST, including the Brics and the Innovation Fund.[10]

Finally, the Innovation Plan called for establishment of a new platform to support the IP management of publicly funded research outcomes, to ensure synergy in IP and technology transfer policies across all public research institutions, and to develop the national capacity to manage technology licensing and commercialization. In the same year that the TIA Act was passed, the South African government passed the Intellectual Property Rights from Publicly Financed Research and Development Act (IPR Act) 2008, which mandated establishment of the NIPMO, both of which are discussed in detail later in this paper.

2006 IPR Framework

In 2006, the DST published an Intellectual Property Rights from Publicly Funded Research Framework (IPR Framework) that sought to remedy South Africa's weak performance in using IP rights, notably patents, to commercialize public research outcomes. The document proposed a nationwide harmonization of IP management and technology transfer guidelines for publicly funded research results through targeted government action.

As noted earlier in this paper, each research institution was at this time operating according to its own IP management policies. Only certain institutions were effective at engaging in R&D commercialization. By 2003, only four South Africa organizations with public research funding – three universities and the Council for Scientific and Industrial Research (CSIR) – had one or more full-time employees dedicated to technology transfer

[9] This had initially been proposed, without further action, in the R&D Strategy as the Foundation for Technological Innovation (FTI).

[10] The TIA was established according to terms defined in the TIA Act 2008, through the merger of the Innovation Fund, the Biotechnology Regional Innovation Centres (Cape Biotech, LIFElab, PlantBio, BioPAD), the Advanced Manufacturing Strategy (AMTS), and Tshumisano Trust.

(Garduño 2004).[11] At that time, nearly 60 per cent of university research funding came from the private sector, which typically stipulated IP ownership upfront for joint work (Wolson 2007). There were also recorded incidents of valuable IP derived from publicly funded R&D being transferred abroad, at less than market value and/or without offering potential South African partners the opportunity to take the technology forward (Sibanda 2007). Consequently, there were concerns about South African public research spending disproportionately benefitting entities abroad, and of South African ingenuity not being adequately rewarded in the context of collaborations and IP transactions.

Modeled in part on the Bayh-Dole Act, the IPR Framework aimed at closing the innovation chasm that had been identified in development plans such as the R&D Strategy. It proposed new legislation to establish uniform, mandatory rules as to how inventions derived from public research should be identified, and IP rights secured and managed, in order to support their commercialization in order to ensure that public research spending ultimately benefits South Africans. The IPR Framework, which applied nationwide to all projects receiving public funding, drove important shifts in patenting practices and cultures at PROs, as well as the hiring of dedicated technology transfer personnel (Sibanda 2009). It amplified the impact of the Patent Support Fund, an instrument put in place in 2005 by the Innovation Fund that required recipient PROs to have in place clear IP policies and benefit-sharing arrangements. This later became the Intellectual Property Fund, a fund established legislatively. With implementation of the IPR Framework, the establishment of effective IP management and technology transfer policies across South African PROs had begun to gather momentum (Alessandrini *et al.* 2013).

IP Management of Public Research Outcomes in South Africa 1991-2005

At the time the IPR Act was promulgated, there was little data as to how South African innovators, whether public or private, were using patent tools to commercialize their ideas and scientific discoveries. Available information indicated that IP tools were not being effectively deployed by South African innovators to attract partners, secure competitive advantage, and create wealth. In this regard, a relevant study is an analysis on the status of patenting in South Africa during the period 1991-2005 (Sibanda 2007). Published by the Innovation Fund, it focused on patents despite the widespread skepticism that prevailed in the country at that time with respect to their usefulness. According to the author of the analysis, patent use is a critical metric given that patents (i) are key tools for commercialization, and (ii)

[11] Established by an Act of Parliament in 1945 and located in Pretoria, the CSIR is the leading scientific R&D organization in South Africa. CSIR's shareholder is the South African Parliament, held in proxy by the Minister of Science and Technology. It undertakes "multidisciplinary research and technological innovation that contributes to the improved quality of life of South Africans" and supports achievement of government programs and objectives. Its research activities, which target diverse areas including health, natural environment, digital environment, manufacturing and industry, are aligned with the country's priorities, the CSIR mandate, and its science, engineering, and technology competences. Further information about the activities of CSIR is available at www.csir.co.za.

contain information that can indicate whether innovation and IP management practices are aligned with the country's technology and growth strategies.

The analysis revealed that the generally low rates of patenting by South Africans had been stagnant since 1998. Furthermore, it uncovered a very low contribution by PROs to patenting activity at the South African Patent Office.[12] Among PROs, the CSIR was a leading filer, with 93 patents during the period in question. The institution had a relatively active filing strategy, which the Innovation Fund attributed to a "strong institutional IP policy on inventions emanating from research undertaken at the CSIR". Its portfolio was found to be reasonably diverse, attributable to its consisting of several business units each with a different technological focus. At the same time, patent data failed to show a single technology focus that represented a strong IP base for the CSIR.[13] The Innovation Fund suggested this be remedied, possibly through policymaking, in order to ensure that such PROs' research aligns to the fullest possible extent with national and regional innovation and development strategies.

South African universities were found to have relatively low levels of filings, having sought less than 100 patents at the South African Patent Office during the period under review.[14] Abroad, the country's universities and science councils accounted for less than 5 per cent of all European Patent Office (EPO) and US Patent and Trademark Office (USPTO) patent applications citing South African inventors (a total of 4576 for the period analysed). Only 12 patents were granted by USPTO and EPO to South African universities, and patenting activity among universities was concentrated among just a few universities. Moreover, pursuant to benchmarking studies undertaken by the DST, South African academics were obtaining patents at less than 5 per cent the rate of academics in developed countries (IPR Framework 2006). One possible explanation for this low performance is the lack of market for their inventions in these jurisdictions. However, considered together with the low level of domestic filings by HEIs, it is more likely attributable to an absence of IP management culture among HEIs in South Africa at the time.

In addition, the number of publications per university exceeded patents filed for and/or granted (Pouris 2007).[15] One possible contributing factor was that publications, contrary to patents, represent the core of subsidy determinations at universities by the Department of Education (DoE), as well as the basis for promoting academics at such institutions (Sibanda 2009).[16] In other words,

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[12] Previously called the Companies and Intellectual Property Registration Office, the name is now the Companies and Intellectual Property Commission.

[13] Commentators observed that this high filing rate was the result of implementation of a strategy to make the CSIR researchers aware of IP management. They noted that the Innovation Fund incentive for patenting was indirectly raising awareness about the value of patenting, while also criticizing it for having incentivized filings for patent rights on inventions that did not meet the intrinsic patentability requirements (in a jurisdiction without substantive examination).

[14] In comparison, for the years 2000, 2001, and 2002, filings by domestic inventors at the South African Patent Office (then "CIPRO", and today "CIPC") totaled 5204, 4905 and 4721, respectively. They accounted for roughly half of all patent filings in South Africa for those years.

[15] This is a feature shared by South Africa research institutes and counterparts abroad.

[16] As stated in a survey by a higher education institution: "There is a disjuncture between the policy approaches of the Department of Education (DoE) and the Department of Science and Technology (DST), with the DoE supporting and promoting the traditional outputs, *i.e.* publication in peer-reviewed journals, while the DST's main emphasis is on

the culture and incentive structures in the academic community appeared to be working against IP protection of research outcomes – and in favor of publication. A higher rate of publication than patenting may also have been due to the nature of the research programs. For the DST, these figures underscored "the importance of putting in place enabling legislation to encourage stronger IPR protection amongst these institutions" (IPR Framework 2006).

Analysts have identified additional factors to account for the low patenting activity among PROs in South Africa during this period, one being the lack of commercialization policies at several institutions (Sibanda 2007). In addition, inadequate resources of the existing TTOs (Sibanda 2009) and lack of market awareness among South African scientists may have diminished the use of IP tools among PROs (Cloete *et al.* 2006*).*

The Innovation Fund's study argued that a more sophisticated and strategic approach to patenting could advance commercialization of public research results while better rewarding South African innovators for their ingenuity. The author called for creation of "a culture of intellectual property awareness, protection and management, aligned with government's national priorities … [which] will result in patenting on the basis of commercial merit and for strategic reasons", thus improving the competitive position of South Africa and generating wealth.

2008 IPR Act

The DST led the process of drafting and securing adoption of the IPR Act, based on the IPR Framework, and following consultations with technology transfer experts in South Africa and abroad, and hearings at the Portfolio Committee on Science and Technology of the South African Parliament. Adopted in 2008 and effective since 2 August 2010, when the enabling regulations were published in the Gazette by the Minister of Science and Technology, the legislation pursues three key objectives:

- *First*, IP emanating from publicly financed R&D must be identified, protected, utilized, and commercialized for the benefit of South Africans;
- *Second*, South African creativity and ingenuity must be acknowledged and rewarded; and
- *Third*, the commercialization framework for publicly funded research in South Africa must provide preferential access to publicly financed IP to SMEs and BBBEE entities.[17]

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the impact of scientific endeavor in the lives of South Africans. (...) not sure if there is acceptance of the emerging role of higher education institutions as significant contributors to economic growth and development over and above the traditional role of producing qualified graduates and publications" (Sibanda 2009).

[17]Broad-Based Black Economic Empowerment (BBBEE or B-BBEE) is a form of economic empowerment initiated by the South African government in response to criticism against narrow-based empowerment instituted in the country during the 2003/2004 timeframe. Narrow-based black economic empowerment was considered to have led the enrichment of just a few previously disadvantaged individuals (Black African, Coloured or Indian). In contrast, the goal of broad-based empowerment is to distribute wealth across as broad a spectrum of previously disadvantaged South African society as possible.

The IPR Act provides for the mandatory IP management of publicly funded research outputs, and requires special benefit-sharing arrangements for IP creators at PROs. It further establishes the NIPMO and the associated IP Fund to cover the cost of securing and maintaining IP protection for public research outputs. In addition, the legislation requires the establishment of TTOs to ensure the IP management and technology transfer needs of all institutions in South Africa are addressed. Accompanying regulations for the IPR Act's implementation provide guidance as to timeframes for actions (some of which also appear in the text of the IPR Act), decision-making regarding licensing, and dispute settlement.[18]

Under the IPR Act, "intellectual property" comprises any creation of the mind that is capable of protection by any law and includes rights to an invention, circuit topography, new plant varieties, new designs, trade marks and copyrights.[19]

The IPR Act applies to all recipients of public funds from any government entity – whether at the national, provincial or local level – that uses these for R&D activities.[20] According to the law, a "recipient" is any legal entity, including a company, a trust, a non-profit organization, or a PRO, that receives money from a South African funding agency to undertake R&D. Pursuant to the IPR Act, all recipients are owners, or co-owners if the requirements as set out in section 15(2) are met, of the IP arising from such research, which entails significant obligations, such as assessing, recording, and reporting the benefits of such R&D outputs for society. The legislation creates uniform conditions for disclosing the IP creations at issue, and for the use of IP tools to support their commercialization. Recipients are *inter alia* required to account for their decisions as to ownership and statutory protection of the knowledge-based assets and to notify NIPMO accordingly. A recipient choosing to retain ownership has two choices: commercialize the R&D outcomes, or place them in the public domain subject to NIPMO approval.

NIPMO has the role to oversee the implementation of the IPR Act and, in particular, the activities of TTOs at individual PROs, to support decision-making regarding IP management and commercialization of publicly funded research outcomes, to provide guidelines for IP transactions involving local and foreign entities, to monitor and review execution of the IPR Act, and to manage all relevant information. NIPMO is empowered to take ownership of IP derived from publicly funded research on behalf of the government in order to advance its commercialization under specific circumstances, and it has certain access rights.

The IPR Act establishes a range of principles to guide NIPMO's work, including the following: (i) non-exclusive licensing must be preferred; (ii) SMEs

[18] Regulation No. R.675 of 2010 of the Intellectual Property Rights from Publicly Financed Research and Development Act 2008.

[19] Although the legislation does not specifically mention trade secrets, these implicitly fall under the IPR Act as they are capable of protection. It explicitly excludes copyright in publications, theses, dissertations, journal articles, and other traditional academic works.

[20] The Act does not apply to inventions derived from R&D that has been fully funded by outside partners, even if they arise from work performed at public research institutions.

and BBBEE entities must have preferential access to publicly funded IP; and (iii) preference in licensing and other IP transactions must be given to entities that seek to use the IP in ways that provide optimal benefits to the people of South Africa. Under the IPR Act, exclusive licensing is subject to a range of conditions, *e.g.* the holder of an exclusive license must commit to manufacture, process, and otherwise commercialize the technology in South Africa. The IP Fund complements and supports the work of NIPMO, in particular by providing resources to cover the costs associated with the registration and maintenance of IP rights emanating from publicly funded R&D. It subsidizes up to 50 per cent of IP protection and maintenance costs, whether these are incurred to secure domestic or international IP rights.

Overall, the IPR Act has introduced a number of important changes in how publicly funded research outcomes are managed and commercialized in South Africa (Table 1).

To evaluate progress over time, NIPMO required information about the state of intellectual property and technology transfer activities by recipients of public research funds. To this end, NIPMO and the DST collaborated with the Southern African Research and Innovation Management Association (SARIMA)[21] to generate the South African National Survey of Intellectual Property and Technology Transfer at Publicly Funded Research Institutions (Baseline Survey), addressing technology transfer activities during the period 2008-2014.

Table 1 Key changes pertaining to IP management under the IPR Act

	Before 2010	***IPR Act***
Ownership of IP derived from publicly funded research	Each institution determined its own approach. There were no restrictions on ownership of IP derived from public research, including for foreign entities. Thus, in some cases, the government was subsidising the development of IP without assurances that its commercialization would benefit South Africans.	There are three clearly defined ownership scenarios: a) ownership of IP derived from public research accrues to the recipient of public R&D funding, which may choose not to retain ownership; b) in this case, NIPMO may decide to acquire ownership and secure protection for the IP; c) should it not do so, the IP creator (*e.g.* the individual researcher) may acquire ownership and/or ownership may be offered to a third party (*e.g.* a firm that contributed to R&D funding).
Use of such IP by recipients	No obligation to use IP. Most public research outcomes were published in scientific journals. In some cases, the researchers commercialized the IP for their own benefit.	Recipients have an obligation to deploy the IP for the benefit of society, for instance, by commercializing it. Publication must be delayed in order to allow for patenting of research outcomes with commercial potential. Publishing and commercializing research outcomes are expressly deemed compatible.

[21] SARIMA is a membership organization of research and innovation managers that operates at an institutional, national, and international level, and across the value chain, from research through to commercialization. Its stated purpose is to promote research and innovation management for the benefit of southern Africa.

IP management and record-keeping	IP emanating from publicly funded R&D could be freely assigned to private entities and inventors.	Transparent and clear rules now exist. NIPMO must review and approve any assignment of IP, and an offshore exclusive license. In the case of foreign entities, a recipient must demonstrate to NIPMO that a) there is insufficient capacity in South Africa to further develop the IP locally and b) that South Africa will benefit from the transaction in question. In relation to IP, recipients are required to report to NIPMO biannually about the status of the IP and commercial developments in this regard. NIPMO must keep records related to all the above.
Government use rights	The government's right to access patented inventions could be exercized through compulsory licensing under the Patent Act. Innovation Fund contracts included clauses providing for government march-in rights.	If a recipient does not commercialize or otherwise make use of the IP, the government can intervene, *e.g.* through NIPMO reclaiming title.
Investments in technology transfer capacity	Some research institutions were actively engaged in technology commercialization. However, approaches differed across organizations.	Each institution must (a) execute the same IP management policies and (b) develop adequate technology transfer capacity, which comprises the ability to perform functions such as: • provide procedures for invention disclosures and analyze them; • set up a framework for the identification, protection, development, and management of IP; • manage revenues from IP transactions; • negotiate and enter into IP transactions; • ensure adequate capacity to manage technology transfer and commercialization; and • fulfill reporting obligations under the IPR Act.
Distribution of revenues from IP commercialization	Most publicly funded research institutions had technology transfer policies that were institution-focused in terms of revenue distribution. Therefore most of the revenue from successful inventions accrued to the institution rather than to the individual researcher(s). There also were no common, minimum benefit-sharing arrangements for inventors.	The "creators" of IP – as distinct from the recipient institutions – benefit directly from their ingenuity, thus having an incentive to engage in applied research and commercialization. Specifically they receive at least 20 per cent of the first one million of the revenues generated by the IP they develop and 30 per cent of the net thereafter. [22] The recipient institutions must apportion part of the IP revenues for more R&D, TTO operations, or to cover part of the costs of securing

[22] The IP Act also provides for the IP creators to receive a minimum of 20 per cent of the first ZAR 1m of gross revenues, before any deductions can be made, as an incentive to ensure that the creators receive benefits as early as possible from commercialization of the relevant IP.

		statutory protection of IP.

Sources: Chart developed based on IPR Act 2008, Faul 2016.

ASSESSING THE CURRENT FRAMEWORK, INCLUDING THE IMPACT OF THE IPR ACT AND NIPMO

Two new data sets published in 2017 allow for the evaluation of progress in building the NSI in South Africa. They provide evidence about trends in IP management, the use of IP tools to commercialize publicly funded research outputs, technology transfer involving PROs. At the same time, the two studies elucidate the role that the adoption of the IPR Act and establishment of NIPMO have played in this regard. The first assessment is the "Baseline Survey", which was developed through a multi-stakeholder process. It covers the 2008-2016 period, and is meant to support measurement of NIPMO's impact over time. The second is a forthcoming doctoral study by McLean Sibanda (co-author of the present paper). It analyses a new data set regarding IP management and commercialization during the 2006-2015 period, thus supplementing the 2007 Innovation Fund study regarding patenting during the 1995-2005 period ("Sibanda 2017").

Sibanda 2017

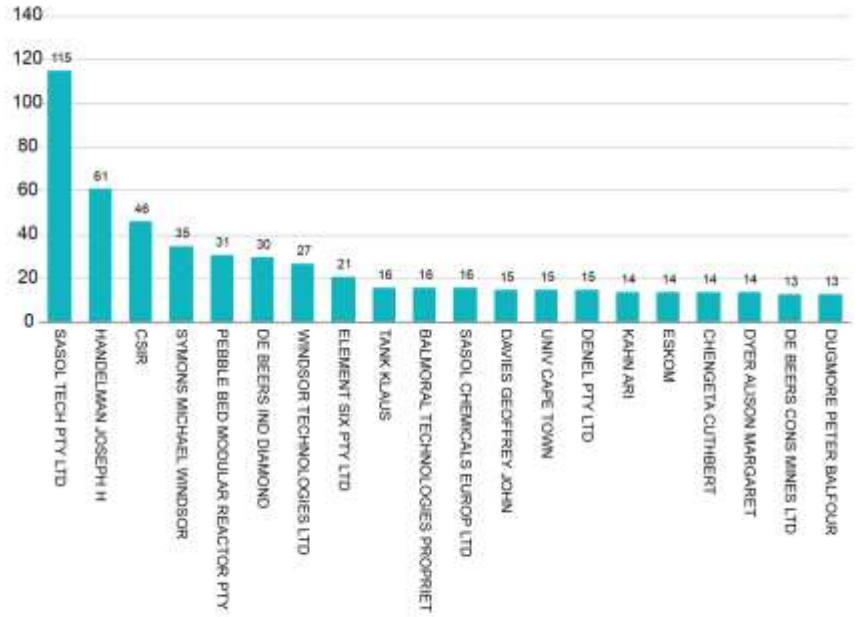
This forthcoming study extends the 2007 Innovation Fund analysis of patenting by South African inventors by a decade, to cover the time period 1996-2015. It analyses the results of a survey of all PROs that filed international patent applications through the Patent Cooperation Treaty (PCT) system during the period 1996-2015.[23] In addition to IP management among South African inventors, the study examines recent trends in commercialization by South African PROs. It also identifies lessons learned from the initial years of NIPMO's operation, using data from the PRO survey as well as from the Baseline Survey. Not all the trends identified in the analysis are driven by, or related to, the IPR Act.

The complete data set reveals interesting trends relating to PCT applications by South African inventors, whether privately or publicly funded, during the period 1996-2015. The figures rose by 24 per cent, from 2,959 during the 1996-2005 period, to 3,349 during the 2006-2015 period. At the same time, there appears to have been a decline in patenting by private firms and state-owned enterprises (SOEs) (Figures 3 and 4). This trend can be inferred from differences in the list of top 20 assignees during the 1996-2005 and 2006-2015 timeframes. In fact, a number of private sector assignees that were on the list during the initial period were no longer present during the latter period.[24]

[23] In total, there are eighteen such PROs, comprising five science councils and thirteen HEIs. There was a 94 per cent response rate to the survey. Domestic patenting by South African PROs is not analyzed. In addition to survey results, the study integrates data from current datasets from Thomson Innovation databases.

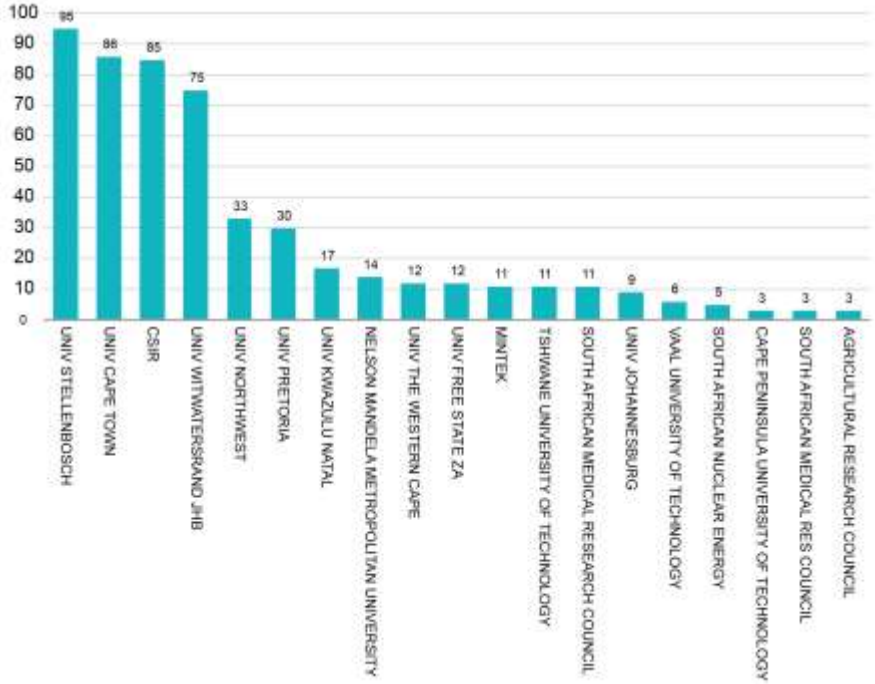
[24] These companies include: De Beers Industrial Diamonds (this appears to be due to name change to Element Six), Handelman Joseph, Pebble Bed Modular Reactor (SOE), Symons Michael Windsor, Windsor Technologies, Balmoral Technologies, De Beers Consolidated Mines, AECI, Denel (SOE), and Eskom (SOE).

Figure 3 PCT applications in the period 1996-2005 (South African inventor address) by top assignee/applicant



Source: Sibanda 2017.

Figure 4 PCT applications in the period 2006-2015 (South Africa inventor address) by top assignee/applicant



Source: Sibanda 2017.

In contrast, with regard to PROs, the study reveals an overall increase in patenting. The CSIR and the University of Cape Town, which were among the top 20 assignees for both periods, increased their pace of filing during the

period 2006-2015. Both remained in the group of top five assignees during the entire timeframe studied. There was an increase in the share of patenting by universities, which increased their representation in the top 20 assignees list from two during the 1996-2005 period to six during the 2006-2015 period. At least half of South Africa's universities filed on average at least one PCT application per year, with the University of Stellenbosch filing almost 10 PCT applications per year (Figure 4)**.** Higher rates of patenting may be attributed to broader adoption of strategic IP management, possibly the result of new requirements set forth in the IPR Act.

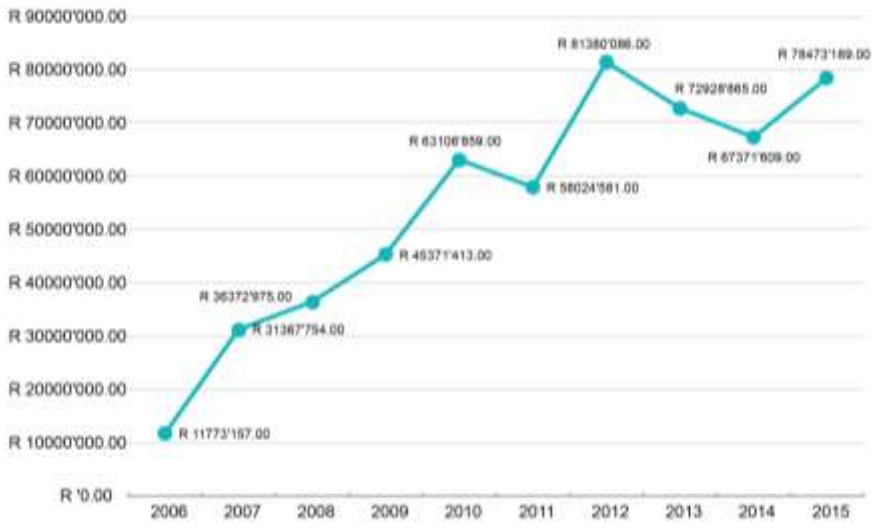
Data from the PRO survey reveal that the highest levels of patenting among universities were associated with the traditionally strong research HEIs, in particular the University of Stellenbosch, the University of the Witwatersrand (Wits University), the University of Cape Town, the University of Pretoria, and North-West University.[25] The data show a correlation between patenting and number of publications (Figures 7 and 8), which is unsurprising given that a higher publication rate likely indicates a stronger research base.

Figures 3 and 4 identify the number of international patent applications filed by PROs during the time period analyzed. While the figures may appear to be relatively low, they are significant when compared to the total number of filings by South African inventors. It is anticipated that the rate of PRO patenting will continue to grow in line with the increase in publication output (Figures 7 and 8). The rate should also rise as the DST pursues its stated goal of increasing public investments in R&D to hit an "investment target of 1 per cent of gross expenditure on R&D as a percentage of gross domestic product (GERD/GDP)" (Wild 2016). To reach this target, DST will need to finance a major expansion of human capital needed to carry out the research. The data confirm that South Africa has been growing its R&D capacity albeit at a slow pace (Figures 1 and 2).

In addition to trends in patenting, Sibanda considers IP commercialization by PROs during the period 1996-2015. The data indicate a link between the conversion of PROs' IP to patents and licenses, along with the formation of start-ups, on the one hand, with levels of TTO capacity, on the other hand. The data also show that commercialization revenues accruing to the PROs increased during this period (Figure 5). Although most of the revenues were earned by the science councils – namely the Nuclear Energy Corporation of South Africa (NECSA), the Council for Scientific and Industrial Research (CSIR), and the Agricultural Research Council (ARC) – the commercialization revenues from HEIs' IP portfolios have been increasing year-on-year (Figure 6).

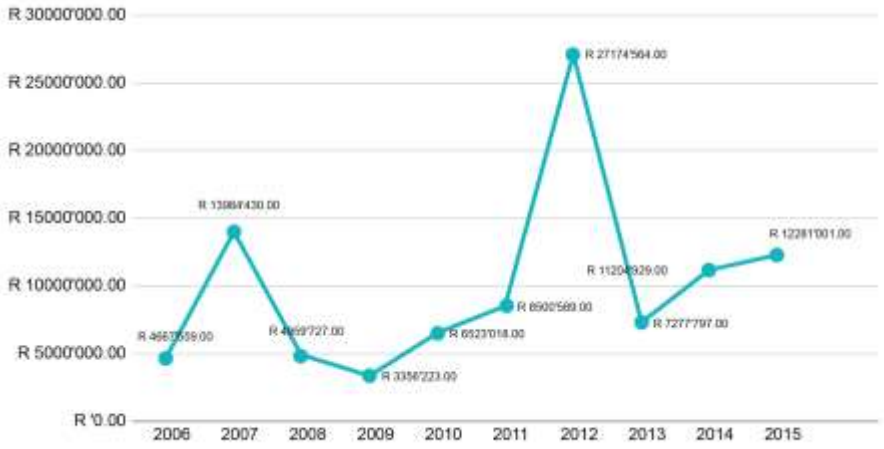
[25] The survey was sent to all PROs that had filed at least one PCT application during the period 1996–2005.

Figure 5 Commercialization Revenues Earned by PROs (2006-2015)



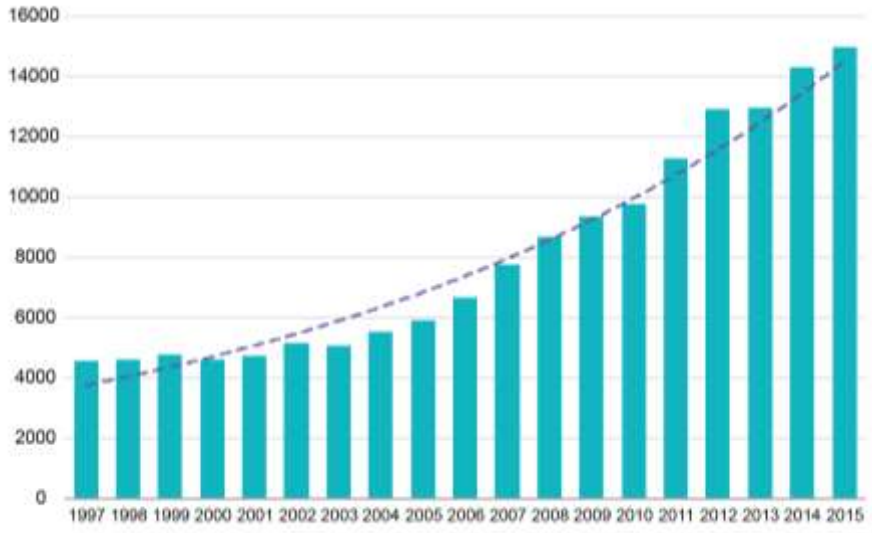
Source: Sibanda 2017.

Figure 6 Commercialization Revenues Earned by HEIs (2006-2015)



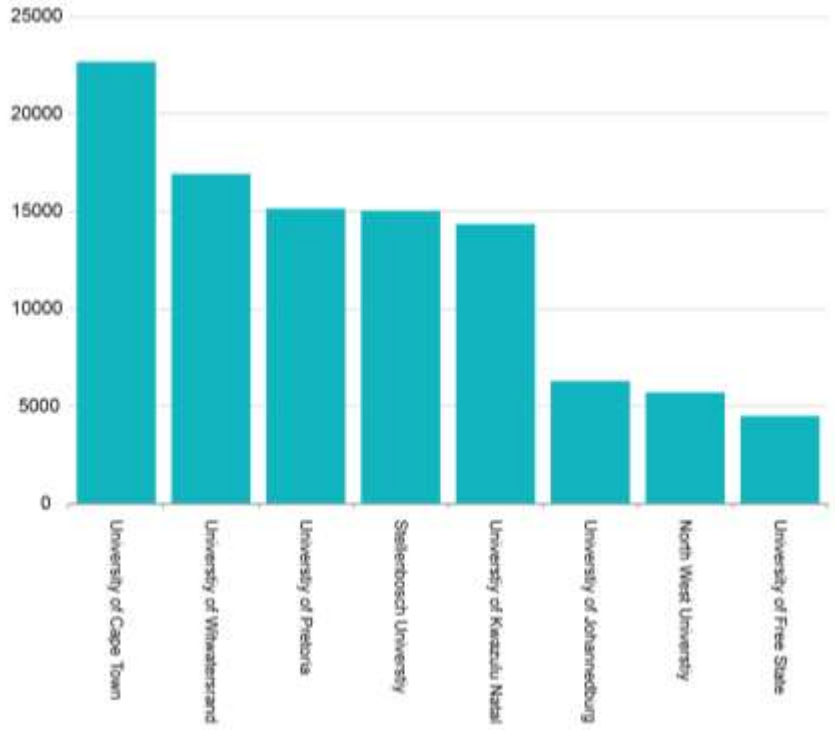
Source: Sibanda 2017.

Figure 7 *Web of Science* Publications with at least one South African resident author (1997-2015)



Source: Sibanda 2017, based on Thomson Innovation Web of Science publications database.

Figure 8 Top South African HEIs according to publications in *Web of Science* Core Collection (2006-2015)



Source: Dudhia et al. 2017.

Baseline Survey 2017

The survey data show that most university technology transfer capacity is still located at those HEIs that have traditionally been strongest in research, with the average TTO team composed of between three and six people. The survey results show a correlation between technology transfer capacity, patenting activity, and startup formation, with those HEIs with higher levels of established TTO capacity accounting for the highest number of startups launched during the period 2006-2015.

The PRO survey reveals that, since the IPR Act's entry into force, numerous benefits have accrued to South African PROs (regardless of whether they had TTO capacity prior to 2008):

- Support from NIPMO for establishing and/or strengthening TTO functions as well as for funding expansion of their patent portfolios;
- Increased awareness of and appreciation for the value of IP management as a tool for commercialization, particularly among researchers and senior management at the institutions;
- Increased IP protection, resulting from better awareness by the researchers and availability of financial support from NIPMO; and
- More ease and certainty when contracting with third parties, attributable to assistance from NIPMO with commercialization activities.

Prepared jointly by DST, NIPMO, and SARIMA, the Baseline Survey provides another noteworthy measurement of IP management, TTO capacity, and technology transfer and commercialization activities.[26] At the same time, it is meant to enable NIPMO to measure its impact and progress over time. The Baseline Survey identified achievements and challenges during the initial years of NIPMO's operations (2008-2014) that were similar to those identified in the Sibanda 2017 study. The Baseline Survey compares performance during NIPMO's initial period of operations (post-2010) to patenting and other trends during the preceding two-year period (2008-2010). Unlike Sibanda 2017, it only analyses the activities of PROs.

Based on available evidence, NIPMO's notable achievements so far have been to support the development of technology transfer capacity in nearly all of South Africa's 33 PROs, by end-2016, and to set and enforce a unified national framework requiring the use of IP tools to translate publicly funded research outcomes to market. Thus NIPMO has secured a foundation for strategic IP management and commercialization across the public research network in the future. At the same time, TTO teams remain small (Sibanda 2017), while the staff often have less than four years of experience. Across South Africa, there are less than 100 FTEs engaged in technology transfer of publicly funded research outcomes (Baseline Survey).

The Baseline Survey indicates that the policy framework that was harmonized nationwide under the IPR Act and managed by NIPMO rapidly began

[26] The survey was sent to all 23 HEIs and 10 publicly funded research institutions in South Africa, of which 24 responded. The team conducting the survey followed up with additional interviews.

delivering results. This finding is confirmed by data maintained within NIPMO as well as by Sibanda 2017. For instance, from August 2010 through October 2016, there were 1057 invention disclosures derived from publicly funded research. Of these, 88 per cent were deemed “actionable” and thus taken forward by NIPMO, and 18 per cent of these were ultimately protected using IPRs. NIPMO’s conversion rate is slightly higher than 7 per cent (Faul 2016). Commercialization successes during this brief timeframe include a number of solutions targeting critical public policy challenges (Box 5). Moreover, 24 per cent of the licenses granted during the six-year period were for SMEs and BBEEE entities, advancing one of the key objectives of the IPR Act (Faul 2016).

Box 5 Commercialization success stories Lumkani and SmartSpot

Samuel Ginsberg and Francis Petousis of the University of Cape Town (UCT) developed the innovative *Lumkani* fire detection system for use in informal settlements where access to traditional emergency service responses is generally quite limited.

More than 3 million South Africans live in shacks made of highly flammable materials and arranged in dense settlements. The candles and paraffin stoves typically used for cooking, lighting, and heat pose a serious threat to residents of such settlements, in particular as fires can spread quickly. Fire detectors that measure smoke levels are not suitable under such conditions because smoke generated by paraffin stoves can generate false alarms.

The innovative Lumkani fire detection system device measures the rate at which temperatures rise as opposed to detecting smoke. Low-cost and durable, it can be set up as a smart network of detectors located within a 40-meter radius of one another. If one device rings, the entire network can sound an alarm, thus enabling the community to rapidly respond to the fire. The connected devices monitor the health of the network and, in the event of a fire, send GPS coordinates to emergency service providers.

Lumkani Traders, a spin-off, was created to commercialize the technology. It protected the invention with the aid of a patent and a copyright. Lumkani has 10 permanent employees and, since November 2014, has manufactured and distributed more than 10,000 devices in South Africa. This case study underscores the potential value, for diverse stakeholders including employees, customers, and the government, of using IP tools to advance commercialization of public research outcomes.

The *SmartSpot* technology is a specially designed paper card that is used to examined the accuracy of machines used to detect tuberculosis (TB). It was developed by scientists at Wits University and the National Health Laboratory Service (NHLS). Wits Enterprise, which is the University's unit responsible for IP commercialization, worked with the research team to develop a plan to commercialize this patented technology. In 2015, a spin-out company called SmartSpot Quality (Pty) was created. To date, SmartSpot has been shipped to 22 countries globally, with many more countries in the pipeline. In South Africa, SmartSpot has been used on all 289 GeneXpert instruments in the National TB program since 2011. SmartSpot has saved an estimated 78,000 test results of the 3 million tests performed from being inaccurate.

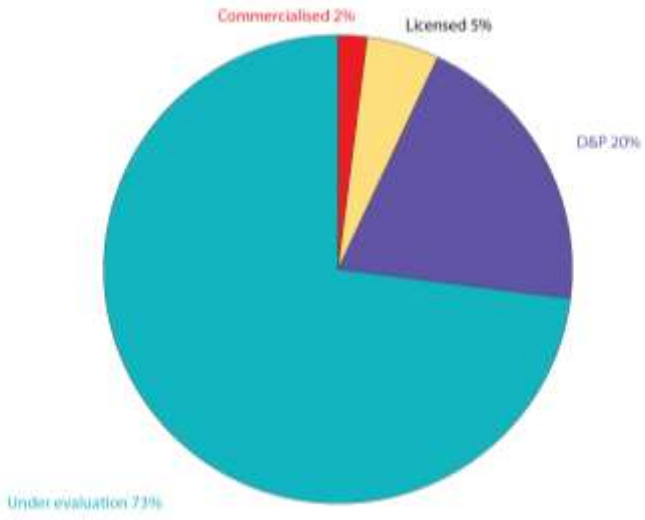
Sources: Baseline Survey 2017; Minors 2016.

NIPMO's efforts since 2010 have been critical to scaling the TTO capacity, IP management, and commercialization activities that existed in the public research network prior to the IPR Act. As of 2016, the system was described as having "pockets of excellence" in knowledge and technology transfer, namely, the National Research Foundation, CSIR, the Medical Research Council, the Agricultural Research Council, the Council for Geoscience, and MINTEK, along with Stellenbosch University (Schraudner *et al.* 2106). The characteristics of these particular institutions, for instance the availability of industry funding for the national research councils, and Stellenbosch University's proximity to innovation ecosystems, may make it difficult for other

PROs to emulate their technology transfer activities.[27] A crucial challenge for NIPMO will be to maintain momentum in order to continue to expand capacity across TTOs, particularly those with lower levels of knowledge and expertise. This will help to ensure the objectives of the IPR Act are fulfilled.

Based on data maintained by NIPMO, 2 per cent of the intellectual property derived from publicly funded research since October 2010 has been successfully commercialized to date, with an additional 5 per cent under license (Figure 9). Other research outcomes have been designated and protected (D&P) using IP tools (20 per cent), or are under evaluation. A range of IPRs have been leveraged to commercialize public IP since October 2010, with emphasis on patents (Figure 10). The data point to a nascent commercialization system with significant potential in the coming years.

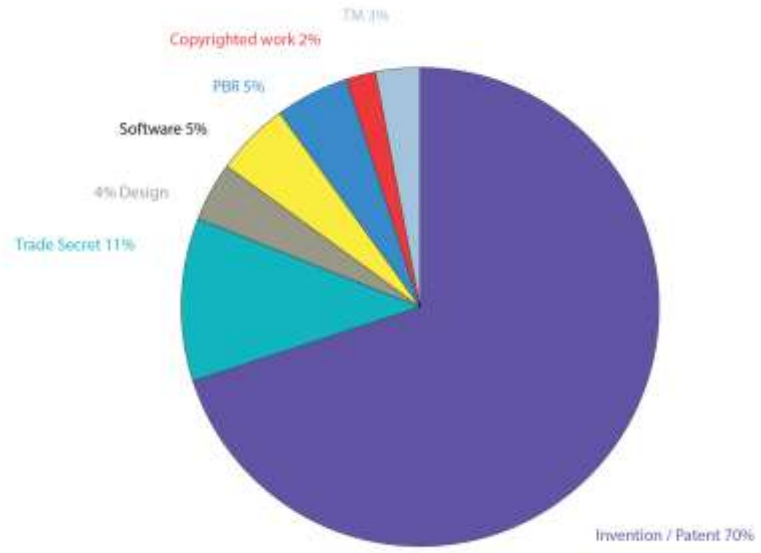
Figure 9 State of Commercialization of Publicly Funded IP Created in South Africa after 2 August 2010



Source: Internal NIPMO data.

[27] In addition to marked differences in TTO capacity across the network of PROs, this same study noted two additional challenges: certain universities have reverted to their former, purely educational role, putting research and innovation on the back burner, and relatively few universities actively support academic entrepreneurship (Schraudner *et al.* 2016).

Figure 10 NIPMO Management of Publicly Funded IP Created in South Africa after 2 August 2010



Source: Internal NIPMO data.

The Baseline Survey uncovered the following positive results:

Government resources were successfully enabling institutions to secure IP rights where needed;

- The portfolio of managed technologies grew over time. Overall, invention disclosures rose from 2010 to 2014, and, in 2014, 86 per cent of them derived from publicly funded R&D;
- The number of patent families managed by PROs almost doubled during the 2010-2014 period, as did the number of registered trademarks;
- There was an increase in both exclusive and non-exclusive licensing of publicly funded IP and, during the period 2010-2014, licensing revenue increased fourfold; and
- The number of startups established by PROs and based on publicly funded IP grew from 29 to 45. From 2011 onward, 73 per cent of startups were based on publicly funded IP (a percentage that almost doubled during the time period analyzed in the Baseline Survey).

At the same time, the study revealed the following key challenges:

- Experience in IP management and commercialization experience among staff remains insufficient; for instance, most actions related to IP registration and maintenance must be outsourced to law firms;[28]

[28] In particular the lack of commercialization experience was highlighted in a 2016 Report about knowledge and technology transfer in Southern Africa: "Most [TTO staff at South African universities] are lawyers or come from a variety of other transfer-unrelated disciplines; very few are certified "KTT professionals" or have experience in industry and/or entrepreneurship. Most regard providing legal support to aspiring patent and license holders as their primary responsibility, which they typically fulfil by providing training or, occasionally, IP scouting. Combined with typically poor funding, such narrow specialization of transfer offices poses a particular problem" (Schraudner *et al.*

- There is a low conversion rate of patents to commercialized products, which could be attributed to the combination of under-resourced TTOs and low levels of IP awareness, which in turn lead to lower number of invention disclosures and patenting rates.[29]
- The turnover of staff dealing with technology transfer is high, especially at universities, where short-term contracts or internships prevail. At the same time, most of these staff tend to move from one PRO to another (Sibanda 2009);
- In the research community, the cultural shift to embrace IP and commercialization has been slow – although the trend is in the right direction;
- IP commercialization revenues were low, unevenly distributed, and subject to fluctuations. At the same time, the new data set from Sibanda shows that there has been modest growth in commercialization revenues by PROs during the period 2006-2015 (Sibanda 2017); and
- Licensing activities and startup formation remain concentrated in certain PROs, and 50 per cent of the research institutions have not engaged in IP licensing. Startups emanated mostly from a handful of institutions, with a single institution accounting for 47 per cent of all startups formed in 2014. Sibanda found that startup creation, while somewhat concentrated, was happening across a broader range of institutions if analyzed over a longer time period (Sibanda 2017).

Overall appraisal of the NSI

The current state of South Africa's NSI needs to be measured against the three objectives set out in the 2008 IPR Act (see p. 21)

Both analyses discussed in the previous section point to a shift in the South African innovation system towards more strategic management of publicly funded R&D outcomes, albeit slowly and with uneven results across PROs. They attribute this development to an evolution of the culture of innovation among South African PROs, resulting from the DST IPR Framework, the IPR Act, and actions by the Innovation Fund and NIPMO. While a range of IP rights have been used to further develop intellectual property derived from public research in South Africa (*e.g.* patents, copyright, trademarks, trade secrets, design rights, plant variety protection), these analyses focus on patenting given the prominence of patents in the commercialization of public IP to date. The Baseline Survey underscores that, for NIPMO, IP conversion is the ultimate goal, in order to generate a positive impact from public R&D spending for South Africans.

The framework established under the IPR Act is intended by the South African government to deliver the benefits of public research spending to all South Africans. This is in keeping with the broader objective of developing a national system of innovation that is geared towards the needs of, and which invites participation from, more South Africans than did the pre-1994 NSI. Building on

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2016).

[29] This particular outcome was noted by other analysts as well (Sibanda 2017; Alessandrini *et al.* 2013).

the foundation provided by the Innovation Fund, NIPMO appears to have been a decisive building block.

Assessment of NIPMO's performance going forward should center on the IP conversion rate, in addition to IP management indicators such as patenting. It should also account for the impact of public research commercialization on social and economic well-being, and the distribution of benefits, given that the three goals enumerated in the legislation are aspirational as well as practical. Based on available evidence, NIPMO has contributed to shifting the perception and use of IP tools for the commercialization of publicly funded research outputs – vis-à-vis government, the South African research community, and the public – as a means of improving human welfare. NIPMO has ensured better recognition and remuneration for South African inventors engaged in publicly funded research endeavors, through the enforcement of new mandatory benefit-sharing schemes. Further, NIPMO has helped to improve the prospects for bringing publicly funded research outputs to market, to the benefit of South Africans, by building TTO capacity and supporting the use of strategic IP management when moving breakthroughs to market. Its efforts have been supportive of SMEs and BBEEE entities' advancement in particular, as evidenced by licensing data from the Baseline Survey. It has made the case overall for IP management being a tool for development and wealth creation.

In relation to welfare improvement, the benefits to South Africans of commercializing publicly funded research outputs could be seen as direct for those in the innovation value chain, and indirect in relation to the South African population broadly. Benefits for the country as a whole derive from the strengthening of PROs through monetization of their IP, as well as knowledge gained through IP-based collaborative work aimed at commercializing promising research outcomes. Moreover, the inventions thus far successfully commercialized respond to specific needs of South African citizens.

Patenting and commercialization trends suggest that the South African NSI is starting to shift, noticeably and in the right direction (Baseline Survey; Sibanda 2017). Contributing to the rise in commercialization is a growing culture of IP awareness. The new data set from Sibanda reveals a fundamental shift in IP management by PROs since 1996, likely owing to policies driven by the DST, notably the IPR Act and the associated support mechanisms arising from this legislation, administered by NIPMO. The crucial role of NIPMO, as the custodian of the IPR Act, in advancing the commercialization of publicly funded IP is undisputed and will continue to grow.

Overall, evidence indicates that the South African national innovation system has been evolving positively over time – but that progress has been fairly slow and uneven (DST 2006; Baseline Survey 2017; Sibanda 2017; Faul 2016). In relation to the commercialization of publicly funded research outputs, this is likely due to the very different starting points and levels of expertise in technology transfer at the PROs (Sibanda 2017).

SUMMARY AND CONCLUSIONS

This paper has traced the evolution of the South African NSI since the transition to democracy in 1994. The analysis focuses on policies that encourage IP management to support the commercialization of publicly funded research outcomes.

The new evidence demonstrates how technology transfer capacity, including in relation to IP management, has been growing across PROs. It also indicates the gradual emergence, among the country's research community, of a new culture related to the use of IP tools. In fact, the growth in the filing of patent applications by PROs (especially universities) can be attributed to an increased awareness of the strategic importance of these instruments. In this regard, the IPR Act constituted a major step forward, establishing a formal, unified national framework for the commercialization of public research outputs, including the NIPMO, mandatory compliance and a strong government commitment to providing financial support for IP management and TTO training.

The current framework responds to an objective explicitly set out in the IPR Act. It supports delivery of benefits for the South African population as a whole in the coming years and could serve as model for other low- and middle-income countries that intend to build their own systems for using IP tools to commercialize public research outcomes.

ACRONYMS

BBBEE	Broad-Based Black Economic Empowerment
CSIR	Council for Scientific and Industrial Research
DACST	Department of Arts, Culture, Science and Technology
DoE	Department of Education
DST	Department of Science and Technology
DTI	Department of Trade and Industry
EPO	European Patent Office
FTE	full time equivalent
HEI	higher education institutions
IP	intellectual property
NIPMO	National Intellectual Property Management Office
NSI	National System of Innovation
PCT	Patent Cooperation Treaty
PCTI	Portfolio Committee on Trade and Industry
PRO	public research organization
R&D	research and development
SARIMA	Southern African Research and Innovation Management Association
SETI	science, engineering, technology and innovation
SMEs	small and medium-sized enterprises
SPII	Support Programme for Industrial Innovation
TIA	Technology Innovation Agency
TTO	technology transfer office
USPTO	US Patent and Trademark Office
WIPO	World Intellectual Property Organization
VC	venture capital

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