The South African national system of innovation: potential and constraint

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ABSTRACT

South Africa displays considerable economic potential, with significant constraints imposed by the legacy of the past. Path dependent features, the legacy of the apartheid system and the system of racial segregation that preceded it, lead to misalignment and may undermine attempts to build a national system of innovation.

Most fundamental is the stark inequality resulting from an economic and social divide that has taken shape over centuries. The legacy is the dualism in national policy goals, of promoting equality and economic development, aimed to meet national developmental needs and address poverty at the same time as achieving global competitiveness and technological advancement. A related 'binding constraint' is directly linked to the levels of human resources to achieve policy goals and change in South Africa. Historically low levels of education for the majority of the population are a fetter on economic growth, and on scientific and technological progress. Another 'binding constraint' is a lack of maturity in the new systems of governance. The result of these trends is problems in implementation and limitations in the ability to realize policy vision.

Keywords: national system of innovation, South Africa, higher education, developmental university, sub-Saharan Africa.

CREATING A NATIONAL SYSTEM OF INNOVATION: POTENTIAL AND CONSTRAINT

GLOBAL POTENTIAL AND REGIONAL DRIVER OF GROWTH

South Africa is regarded as one of the strongest economies in Africa and key to the economic and political development of sub-Saharan Africa. In general, African economies have been growing steadily over the past four years, driven by internal and external factors:
On the external front were strong global recovery, higher commodity prices, higher oil production and prices, continued donor support in the form of aid and debt relief, growth in the tourism sector and rising FDI...The internal factors driving high growth were good macro-economic management, better performance in agriculture across the continent, expansion in the industrial sector, particularly in construction and mining, and the improved political situation in many countries (The Presidency 2007: 68).

In this context, a recent World Bank strategy document argued that South Africa is a major driver of regional growth, accounting for 33% of sub-Saharan Africa's GDP (ppp), and approximately 30% of expansion in the region between 1980 and 2003 (World Bank 2007). South Africa has been a driving regional political force, promoting and supporting NEPAD and the African Union, as well as the Southern African Development Community.

In relation to the global arena, South Africa has been variously categorized, but the central thrust is one of considerable economic potential, with significant constraints imposed by the legacy of the past. It is classified as a middle income (NACI 2006) or a late-developing economy. In terms of competitiveness, it is classified as an 'efficiency driven economy', mid-way between 'factor-driven economies' and 'innovation-driven economies', given constraints such as the lack of a skilled labour force and an inefficient bureaucracy (WEF 2007 cited in The Economist Intelligence Unit 2007a: 32). In terms of technology development, it is classified as a 'dynamic adaptor' (UNDP 2001) in that it has important high technology industries, but the diffusion of 'old' inventions is slow and incomplete across the population. It has generally been grouped alongside countries like Brazil and India in terms of its strong but highly uneven capacity to participate in global technological innovation in the era of a 'knowledge economy'. For instance, Albuquerque (2001) has categorized these countries as being behind of "catching-up", or representing the "non-mature" national systems of innovation.

The general thrust of these analyses is to emphasise the potential of the South African national system of innovation to compete in the global knowledge economy, but that socio-economic developmental demands require critical efforts for long term sustainability, and may be a 'binding constraint'.

Since 1994, with the transition to a democratic government in South Africa, there have been dramatic changes in governance, in the economy and in science and technology policy. Unlike many other countries where change has been more gradual or piecemeal, the transition was an opportunity for a dramatic rupture of the fragmented system of the

past, towards a systematic attempt to put in place policy, structures and mechanisms to build a national system of innovation to meet democratic goals.

However, critical path dependent features, the legacy of the apartheid system and the system of racial segregation that preceded it, may lead to misalignment and constrain attempts to build a national system of innovation.

THE MACRO-ECONOMIC POLICY CHALLENGE

First, is the stark inequality resulting from an economic and social divide that has taken shape in South Africa since the period of colonial conquest in the seventeenth century. The apartheid system that dominated from 1948 to 1990 systematised the racially defined division of labour that had evolved. The 'grand' apartheid policy attempted to create independent, self-governing 'homelands' within which ethnic groups would be confined. Inequality was reinforced through the segregated provision of education, health, justice, social services along racial and ethnic lines, and legislated racially discriminatory inter-personal relations.

The legacy is the dualism in national policy goals, of promoting equality and economic development, of meeting national developmental needs and addressing poverty at the same time as achieving global competitiveness and technological advancement in a knowledge economy. In this regard, there is similarity with policy trends in the countries of the European Union, to balance innovation with concerns for social cohesion.

After democratic transition in 1994, government adopted the Reconstruction and Development Programme (RDP). From 1996, there was an abrupt shift to a macro-economic policy known as GEAR – the Growth, Employment and Redistribution strategy – which aimed to create a competitive economy, create jobs and ensure redistribution of opportunity and of access to social services. The core elements of this strategy reflect a commitment to fiscal restraint and 'structural adjustment-like' measures:

- a renewed focus on budget reform to strengthen the redistributive thrust of expenditure;
- a faster fiscal deficit reduction programme to contain debt service obligations, counter inflation and free resources for investment;
- an exchange rate policy to keep the real effective rate stable at a competitive level;
- consistent monetary policy to prevent a resurgence of inflation;
- a further step in the gradual relaxation of exchange controls;
- a reduction in tariffs to contain input prices and facilitate industrial restructuring, compensating partially for the exchange rate depreciation;
- tax incentives to stimulate new investment in competitive and labour absorbing projects;
- speeding up the restructuring of state assets to optimise investment resources;
- an expansionary infrastructure programme to address service deficiencies and backlogs;
- an appropriately structured flexibility within the collective bargaining system;
- a strengthened levy system to fund training on a scale commensurate with needs;
- an expansion of trade and investment flows in Southern Africa; and
- a commitment to the implementation of stable and coordinated policies (GEAR 1996: 2).

Government has claimed that the macro-economic policy has paid dividends, evident in the fact that real GDP growth was 3.2 in 1994, went down to 0.5 in 1998 and rose steadily to 5.0% in 2006 (Presidency 2007). GDP stood at R1 727.5bn in 2006, equivalent to US$ 255 361 million (The Economist Intelligence Unit 2007a). An IMF report noted the strong economic growth over the past five years:

> The economy is undergoing its longest expansion on record, and in recent years has experienced elevated growth in an environment of rapid credit expansion, booming asset prices, strengthening public finances and rising international reserves financed by large capital inflows (IMF 2007: 5).

Following the early 'sluggish' growth, the benefits of the macro-economic policy and structural reforms were reflected in more expansionary budgets that prioritised social spending and redistribution. The benefit of macroeconomic stabilization is reported as creating space to triple social grant expenditure, and improve social development by pro-poor spending (World Bank 2007).

However, there has been ongoing national debate around whether growth will lead to job creation and hence to redistribution, or whether redistribution should come first and would lead to economic growth. Critical questions were raised as to whether sufficient jobs are created (Bhorat 2004, PCAS 2003, Altman 2005), to the persistence of structural unemployment (Banerjee et al 2006) and to the extent of social redistribution of the benefits of economic growth. Government itself has noted that even 5% growth is 'insufficient given the scale of the challenges our country faces, including high levels of unemployment and the degree of poverty' (Report of the Presidency 2007: 16).

From 2003, the president introduced a discourse of 'two economies' and 'two nations', emphasizing that until that point, most interventions had focused on the 'first world economy' but that this has made it possible to focus increasingly on the 'second economy' which requires targeted interventions to address poverty and unemployment (Mbeki 2003, Mbeki 2004, Mbeki 2005). In early 2006, government launched a new strategy, the Accelerated and Shared Growth Initiative for South Africa (AsgiSA), which reflects the persistence of the central policy tension, in that it:

> ...originated from a commitment made by the ANC in its 2004 election manifesto to halve unemployment and poverty by 2014. Accomplishing this depends on achieving 6% growth per year by 2010. By 2004, economic growth had exceeded the average 3% growth per year of the first 10 years of democracy. Yet the challenge remained to increase and sustain growth at levels sufficient to meet social targets (AsgiSA 2006: 3).

AsgiSA aimed to raise the growth rate at the same time as halving poverty and unemployment. The intention was to have a dedicated strategy to address the 'binding constraints' on economic growth, job creation and decreasing poverty, under the direct leadership of the deputy president. Six main constraints identified for intervention relate to macro-economic policy, improving infrastructure, developing specific Sector and Industrial strategies, improving skills and education, growing the Second Economy and strengthening public administration (AsgiSA 2006).

Thus, contemporary South Africa remains a highly unequal society. A government report on development indicators identified the main trend in relation to poverty and inequality:

Since 2002, strong overall income growth, including the expansion of social grants, resulted in the rise of the income of the poorest 10 and 20 per cent of the population. However, the rate of improvement of income for the poor has not matched that of the rich, and thus, while income poverty is declining, inequality has not been reduced (Presidency 2007: 23).

As an illustration, in 2006, the richest 10% earned 55.9% of total income, while the poorest 10% earned 0.6% (Presidency 2007). And although the proportion is declining, 43.2% of the population still live below the poverty line of R3 000 per annum. Some 12 million South Africans rely on social grants for their income, with some 3.2% of GDP disbursed as old age or disability pensions and child support as the main forms of assistance. The high national rate of HIV prevalence exacerbates the living conditions of those in the poorest percentiles.

The GINI coefficient has increased over the past ten years, to a current level of 0.685. The population total stands at 47.9 million in mid-2007, 79.7% of whom are classified as African, 9.1% as White, 8.8% as Coloured, and 2.1% as Indian/Asian (Statistics SA 2007). The distribution of richest and poorest remains defined along these racial lines, but there is also evidence to suggest that there is widening inequality within race groups and a decline of inequality between race groups, reflecting the growth of the middle classes (Presidency 2007: 24). Inequality leads to and is evident in unequal access to quality public education and health services, and thus to inequality of outcomes in education and health.

Employment has increased in concert with increased growth rates, but concern about the rate of labour absorption, particularly of youth, remains. The goal of AsgiSA is to cut unemployment by half between 2004 and 2014 to reach a maximum of 14%. Unemployment fell from 2003 to the point where the official unemployment rate stood at 25.5% in March 2007 (Reserve Bank Economic and Financial Data for SA 2007). This is commonly known as a 'narrow' definition, in that it does not include those who have given up job-seeking. Using the broad definition, unemployment remains at 37.3% in 2006, down from a high of 42.5% in March 2003 (Presidency 2007). Trends in employment reflect a growing share of high- skilled workers with real wage increases as industries and the economy as a whole respond to technological change. Banerjee et al (2006:4) conclude that 'the unemployed are becoming on average, less skilled and the gap is widening between their skill level and the skill level of the employed'.

Inequality is also spatially concentrated, with stark inequalities between the nine provinces. Economic wealth, research and innovation activity are concentrated in the Gauteng province, with the Western Cape and the Kwa-Zulu Natal provinces following (DST 2005, Lorentzen 2006).

This inequality is critical in interpreting the development of a national system of innovation, and the notion of a developmental university. The legacy of deep-seated cultural, ideological and social divisions, coupled with a profound lack of capacity and expertise on the part of a large proportion of the population, continue to impact in complex ways on what is possible.

HUMAN RESOURCES AND SKILLS

There is widespread agreement that a major 'binding constraint' is directly linked to the levels of human resources required to achieve policy goals and change in South Africa. For instance, a recent survey of companies found that skills shortages cause operational difficulties, in that many firms pay inflated salaries to obtain the necessary human resources, or tolerate inadequate staff, and experience poaching of skilled staff (CDE 2007).

Historically low levels of education for the majority of the population are proving to be a fetter on economic growth, and on the development of a national system of innovation. For instance, the schooling system does not produce sufficient mathematics and science graduates to enroll in higher education science, technology and engineering programmes (HSRC 2003, DuToit 2008). In turn, this means that the intermediate and high level engineering skills required to work on expanded infrastructure development projects or on innovation in firms are not available on a sufficient scale, becoming a constraint on economic growth.

MATURITY IN NEW GOVERNANCE AND ADMINISTRATION SYSTEMS

A further 'binding constraint' commonly identified is a lack of maturity in the new systems of governance and in administration. Thus, the presidency is committed to building a system of state steering and regulation that recognizes the need for 'joined up' solutions to economic and social problems. This is evident in cabinet clusters that cut across government line departments, to develop coordinated multi-sectoral strategic responses. Building a national system of innovation requires 'joined up' solutions between the policies of multiple government departments, but driving and coordinating a NIS was the primary responsibility of the newly created Department of Arts, Culture, Science and Technology, now a dedicated Department of Science and Technology.

However, such systems are not yet mature, and the extent to which they have permeated beyond the senior departmental levels and down to the administrative level is highly uneven. The Economist Intelligence Unit (2007b: 5), for example, remarked in relation to increased infrastructure and social development spending, that a key challenge is 'to raise institutional capacity by a sufficient degree to ensure that earmarked funds are spent productively'. The exception is tax collection, in which regard efficiency and effectiveness has underpinned a rise in government revenue.

Some analysts and commentators have also noticed a degree of over-optimism in policy-making, and a lack of realism in analyzing what it is possible to achieve. With regard to science and innovation policy for example, questions have been raised that South Africa has tended to 'let enthusiasm override rational, long-term planning' (Van Renssen 2006). A recent review of the national system of innovation by the OECD (2007) found that there has not been sufficient prioritization, and given the pool of available resources, one unintended consequence is that the scale of activity has in many cases been too small to achieve policy goals or impact effectively. The same report also noted a mismatch between stated policy goals and the programmes that have been implemented in practice. For instance, some priority programmes were not implemented (most notably, Technology for Poverty Reduction), and other programmes that were not identified as strategic priorities have been implemented and supported with extensive funding.

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Then, many government departments have not yet developed solid capacity to implement new systems. Unintended consequences that emerge sometimes contradict the original intent of a new structure or funding mechanism. The deputy president has identified this as a general 'binding constraint' on achieving government's goals. The result of these trends is problems in implementation and difficulties to realize policy visions and mandates. Immediately after 1994 the task was to merge multiple racially defined government departments, to achieve a single unified system. For example, in education, there were 19 racially defined departments dealing with schooling in different areas of the country for distinct racial groups. Concomitantly, there was contestation within government departments between technically experienced officials from the old order, and politically experienced new officials, who generally lacked technical and managerial experience. Currently, there remains a high turnover and high vacancy rate in key posts in some key departments, leading to inefficiencies, loss of institutional memory and inaction.

The lack of continuity and lack of interactive capability (Von Tunzelmann 2007) on the part of key government actors translates into systemic lack of coordination within and between government departments, and a potential mismatch of priorities, leading to network misalignment across the national system of innovation.

The following section will describe the ambitious new science and technology policy framework, and provide an outline of new structures and mechanisms intended to implement the strategy and to address these constraints.

At the most general level, there has been progress towards achieving the National Research and Development Strategy (2002) target to achieve a Gross Expenditure on R&D (GERD) ratio to GDP of 1% by 2008. From a significant drop in the early 1990s during the period of transition, the ratio is steadily rising, from 0.76 in 2001/2 to 0.87 in 2004/5 (DST 2004 and 2006). Gross domestic expenditure on R&D has likewise increased from R7 499,6 million in 2001/2 to R12 010 million in 2004/5. However, South Africa remains significantly below the OECD average of 2.26% of GDP, in the company of European countries like Hungary (0.88) and Portugal (0.78 in 2003), and of Brazil (0.95 for 2003) and India (0.84 for 2003) (IMD 2005).

These positive trends are commendable, and indicate a shift towards knowledge intensification, but they only tell part of the story. They do not reflect the state of alignment within and between sectors of the NSI nor the state of absorptive capacity in firms, or interactive capability in government and higher education. The extent to which implementation depends on the conditions of a well educated population, of a large pool of intermediate and high level technological and scientific skills, and on the interactive capability of government, firms and universities, will become evident.

A COHERENT NEW POLICY FRAMEWORK DEVELOPED AFTER 1994

South Africa now has an ambitious comprehensive science and technology policy framework with clear direction and a formal commitment to coordination across government departments, as well as a series of funding incentives and strategic mechanisms, such as national incubator schemes, centres of excellence and investment programmes. Policy aims to promote the transition from a resource to a knowledge based economy, through building a national system of innovation, which in turn requires innovation instruments, funding and human resources (Mjwara, DST Ten year strategic plan for 2008-2018).

The primary aim articulated in the White Paper on Science and Technology (1996) was to set up a national system of innovation based on the core principles of partnerships, coordination, problem-solving, multi-disciplinary knowledge production, and a societal culture which privileges the advancement of knowledge and information in all its forms (DACST 1996: 3). The national system of innovation was explicitly adopted as the guiding conceptual framework, defined as 'the means through which a country seeks to create, acquire, diffuse and put into practice new knowledge that will help that country and its people achieve their individual and collective goals' (DACST 1996: 15). The SET policy making process was supported and informed by foreign donor agencies, such as the IDRC, it drew heavily on policy models of the developed economies, and it was directly influenced by theoretical trends such as the 'mode 2' knowledge debate initiated by Gibbons et al. This policy framework aimed to bring about structural change in the existing patterns of linkages and interactions between institutions, sectors and firms.

The White Paper explicitly promoted linkages and interaction between universities and industry as a driver of innovation. Government departments such as Science and Technology (DST), Trade and Industry (DTI) and Education (DoE) have designed a range of meso- and micro-level mechanisms and incentivisation programmes that aim to promote linkages and interaction. For universities, science councils and firms, there is considerable government initiated impetus to form linkages to harness research and technology development aimed at enhancing productive capability and competitiveness, and to contribute to the quality of life for all citizens.

The main thrusts are described here. The wide range of multiple priorities will become evident, as will the priority accorded to promoting 'big science', high technology capability, and research at the 'technological frontier'. A continuous process of progressively adapting and refining policy frameworks and strategic mechanisms, since 1994, in itself may lead to a degree of instability and hence misalignment in the fledgling national system of innovation.

ENHANCING TECHNOLOGY MISSIONS.

South Africa followed an international trend in the early 1990s with a national technology foresight exercise that identified three emerging technological bands requiring prioritisation: biotechnology, information and communication technologies (ICT), and new materials development. More recently, the DST (2007a and b) developed a Ten Year Plan that identifies five priority 'big science' technology platforms, such as space science and earth sciences, both with strong orientations to development applications,

as well as a 'human capital' strategy aimed to address the skills constraints described above. These were not all areas of historically strong technological expertise and innovation capability. A range of programmes targeting funding and development of capacity in the strategic scientific research areas on which these technologies depend, were initiated to stimulate development of SET and of the industrial sectors.

One example will suffice here, to illustrate the inter-locking range of meso-and micro-level mechanisms proposed to change structures, institutions and capabilities. Strategic interventions in relation to growing a Biotechnology technology platform are most coherent to date. The goals of the National Research and Development Strategy (2002) informed the development of a substantive National Biotechnology Strategy (2002), manifest in the establishment and funding of three Biotechnology Regional Innovation Centres (BRICs) to promote R&D, to provide entrepreneurial services, technology platforms, intellectual property management, and business incubation. These consortia aim to facilitate collaboration between universities and companies in the mature biotechnology sector and the bioeconomy, Support structures, such as a National Bioinformatics Network and a Biotechnology Advisory Committee, were initiated by DST and the National Advisory Council on Innovation (NACI). The Department of Trade and Industry (DTI) established a national biotechnology incubator, EgoliBio, to support small companies and develop capacity. There is evidence to suggest that while research capacity has developed, the industrial sector remains small.

RENEWING THE R&D AND ACADEMIC LABOUR FORCES

The need to reproduce the scientific, R&D and academic workforce is a key focus, particularly to ensure that the distribution of scientists and technologists reflects national demographic patterns in South Africa. A National Research Foundation (NRF) was established from the former funding organisations, to coordinate financing and capacity building of research in the higher education system, and to administer the national research facilities (DACST 1996). It is intended to provide economies of scale in agency grant funding and to facilitate multidisciplinary work. In its most recent strategic plan, the NRF proposed to increase the scale and quality of the PhD degree as a key vehicle for enhancing the national system of innovation (2005). The 'seamless approach' adopted aims to coordinate programmes from school level to the point of commercialisation of knowledge. Doctorates are recognised as the 'platform upon which transformation of our knowledge system can commence, so that it can make a real difference to the lives of ordinary South Africans' (2005:6). Funding and capacity development programmes have been initiated to intervene at a number of levels, from student bursaries to incentive systems for academics, and to fostering international scientific collaboration. The extent to which the doctorate can be a driver of innovation depends on a large enough pool of SET university graduates, which in turn depends on a large enough pool of school leavers matriculating with mathematics and science. Constraints in this regard will be discussed below.

ENHANCING THE R&D INSTITUTIONAL INFRASTRUCTURE

South Africa has a number of science councils, most notably the Council for Scientific and Industrial Research (CSIR), and the NRF hosts and manages National Research Facilities aligned with priority missions. As publicly funded research institutions, they are subject to greater public accountability in setting strategic research directions than universities. Science councils are charged with expanding their international activities in

areas of strategic importance, and to create internationally visible centres of excellence to open opportunities for international collaboration. A National Equipment Programme aims to provide funding to renew the equipment infrastructure for research and technology development, informed by a National Research and Technology Infrastructure Strategy (2004). There is currently little research that can illuminate the extent to which these strategies have been effective.

ENHANCING TECHNOLOGY TRANSFER AND INNOVATION

Government's role in technology diffusion – of both domestic and imported technologies – is identified as critical, particularly for stimulating diffusion among SMMEs. Central to technology diffusion is the presence in firms of a workforce that is able to absorb new technologies, to optimise transfer of technological capacity to firms, and the creation of locally-based expertise, or 'doing, using and learning' modes of innovation. DST has tended to focus on promoting 'big science' rather than these other more tacit modes of innovation that relate to firms rather than research institutions. DTI's response has been to support direct state intervention through a coordinated package of investment and export incentives as well as measures which aim to exploit externalities, supply chain linkages and agglomeration economies to create labour absorbing industrial growth. These incentives foreground government intervention in technology promotion and innovation support, through enhancing technology transfer capacities within local firms. A new Industrial Policy was developed in 2007, but this raises questions about the extent of policy coherence between government departments, in the lack of synergy between the strategic priorities proposed in the industrial strategy and the new SET strategy proposed by DST.

ENHANCING COLLABORATION AND NETWORKS

Linkages between higher education, business and science councils were identified as critical to address issues such as; diffusion of best practice technology, making full use of ICT and the social sciences, and avoiding problems such as duplication, fragmentation and lack of coordination within the national system of innovation. DST has identified a critical enabling role for government in encouraging innovation within the private sector. It has established the Innovation Fund, aiming to provide financial incentives for longer-term, large innovation research projects with cross-sectoral collaborative consortia composed of researchers from the higher education sector, government science councils, private sector, or civil society.

The main focus of the DTI's new policy framework has been to attempt to overcome a range of weaknesses in past trade and industry performance. One mechanism was the introduction of the 'Technology and Human Resources for Industry Programme' (THRIP), which aims to facilitate the increased participation of higher education and science council researchers and students in industrial innovation, technological adaptation and commercialisation. THRIP operates by matching funds that are invested in innovation research by private companies. The Support Programme for Industrial Innovation (SPII) supports innovation of product or process in private sector firms, providing incentives by matching grants.

Together, these funding initiatives have been important in creating awareness in firms and government of the benefits of interaction, and in fostering a number of UILs that

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have yielded post-graduate students, publications, patents, new processes and artefacts (HSRC 2003, Letseka 2004).

INTELLECTUAL PROPERTY RIGHTS FRAMEWORK

A key condition for enhancing collaboration, technology transfer and diffusion is an adequate Intellectual Property Rights framework. Currently, the national legislative framework is influenced by British and European legislation, and for the most part, in compliance with international treaties and conventions. Wolson (2003) argued that a problem lies in the understanding and management of intellectual property rights on the part of those in the scientific and R&D labour force. There was a lack of clarity and different practices prevail in relation to the ownership of research funded by higher education institutions, government and the private sector, which created a degree of confusion and disadvantage to institutions and ultimately, to the national system of innovation in general. A proposed new consolidated national IPR framework that aimed to address this (2007) has, however, elicited considerable criticism that it will in effect act as a constraint (Woolson 2007).

THE EDUCATION AND UNIVERSITY SYSTEMS

The political will, strategic policy goals and intended mechanisms to build a national system of innovation are strongly present in South Africa, unlike many other sub-Saharan African countries. However, binding constraints operate to shape the extent and ways in which implementation takes place, and the national system of innovation is indeed developing in practice. This section will illustrate the complex constraints further by examining the education and university systems, and the ways in which they are in alignment with the goals of building a national system of innovation.

A POTENTIALLY SOUND SCHOOLING SYSTEM WITH MAJOR QUALITY PROBLEMS

Relative to many other sub-Saharan African countries, South Africa has achieved almost universal access and enrolment in primary education, with a total combined learner:educator ratio of 32 (with a norm of 40:1 in primary school and 35:1 in secondary school). However, the Gross Enrolment Ratios provide evidence of high repetition rates, particularly among boys at primary school level, and there is evidence of higher drop out rates on the part of boys at the secondary school level (Presidency 2007).

There has been an increase in the pass rate of the final school leaving examination (matriculation) to almost 70% by 2005, but the data indicates a sharp attrition and 'drop out' from schooling at Grade 10. That is, only a proportion of the cohort that begins schooling remains in the system and are eligible for exiting with a Grade 12 qualification, which is essential for access to higher education. More significantly in terms of the national system of innovation, the number of passes with 'exemption', which allows access to university, remains low, as does the proportion of candidates who pass with mathematics and science, allowing access to SET fields. The proportion of SET graduates is fairly stable between 25% and 28%, and growing this proportion is a key policy goal (Presidency 2007). A great deal of funding and a number of special programmes were established in the past five years to deal with this critical constraint on the development of high level skills, but have yet to show results.

The quality of schooling, and the resultant low throughput rates of the schooling system, is a major blockage of the 'skills pipeline' (Bloch 2007). While the infrastructure and foundation for a sound schooling system exists, there are many historical patterns of uneven resourcing, inadequate quality of teachers, unequal and inadequate curricula, and cultural and political impediments that constrain against the strong national will to improve the quality of schooling. A constantly shifting policy environment since 1994 and contestation around the introduction of a new outcomes based national curriculum are further constraints. Inequality within schooling and of education outcomes remains a cause of misalignment in the national system of innovation.

PATH DEPENDENT DIFFERENTIATION AND SEGMENTATION IN THE HIGHER EDUCATION SYSTEM

The differential capacity of universities in the national system is a salient feature of path dependency in South Africa, and one that is potentially a constraint on the extent to which universities can be a resource for the future development of a national system of innovation.

The South African higher education landscape in 2007 consists of 22 universities and universities of technology, which are emerging from a process of government mandated mergers and restructuring initiated since 2004, aimed to create new organisational forms that can potentially transform the system inherited from the past (Ministry of Education 2002, Council on Higher Education 2004). Universities and technikons were established in South Africa in distinct periods to meet distinct purposes, and these origins continue to shape their differential and unequal nature.

Research universities in the national system

Some of the strong research universities, based in the major metropolitan areas and most developed geographical regions, have their origins in private post-secondary institutions set up in the late nineteenth century. At the turn of the nineteenth century, a second set of colleges were established to meet the demands for technical and vocational education that emerged with the growth in the mining and manufacturing industries, and were granted university status alongside those established in the earlier period. Over the course of the twentieth century, these early 'English' and 'Afrikaans' South African universities established themselves and developed their three-fold mission of teaching, research and community service. In general, these universities enjoyed a relatively high degree of scientific autonomy, research was science driven and primarily fundamental, and the 'linear model' of science predominated (Mouton 2001, IDRC 1993, Kaplan 1996). The English speaking universities - with a strong commitment to the principles of academic autonomy - tended to develop stronger flexibility and pluralism in research agendas than the Afrikaans speaking universities, which were more isolated and more strongly tied to an authoritarian, ethnic and cultural nationalist tradition associated with the apartheid state - that shaped and limited research programmes - as well as security-related scientific research. Afrikaans universities were also more limited in their participation in international networks by their language restriction, tending to build stronger links with Dutch and Flemish universities.

From the 1980s, the academic and cultural boycotts of South Africa intensified the international isolation of all universities, cutting them off from global scientific networks to an extent that remains to be researched. Nonetheless, a small group of universities have

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succeeded in building internationally comparable reputations in specific disciplines and research fields. In a strongly politicized society such as South Africa, a strong culture of conformism developed, whether in support of or opposition to dominant authority. Strongly polarized intellectual traditions are promoted in different universities, evident in separate academic associations for different research traditions in the same discipline, for example. This militates against collaboration between research groups across different universities.

Historically disadvantaged universities in the national system

In the 1960s, a set of what have come to be known as 'historically black' or 'historically disadvantaged' ethnically defined universities were established as part of the apartheid political strategy. Located for the most part in isolated and peripheral rural locations, these new universities focused primarily on teaching in a limited range of disciplines (education, administration, health, law and religion), to preparing bureaucrats for local government. This trajectory largely precluded the development of a strong academic research tradition, although it gave rise to a strong alternative political tradition centred on community development and insertion in local developmental networks (Nkomo et al 2006). Many of these universities were plagued by decades of student revolt, administrative and managerial incompetence, political conflict, and debt and infrastructural under funding, which further weakened them as research organisations.

The legacy for the system as a whole was a set of universities with very little research infrastructure, little scientific research capacity, few post-graduate programmes and a relatively undeveloped research culture on which to build in the present (Subotzky 1999). In 2003, this set of organizations represented 10 of the 21 universities, virtually half the universities as they then existed. The government-driven restructuring of the higher education landscape from 2004 was in part motivated by an attempt to address the historical 'lock-in' represented by this set of universities.

Technikons in the national university system

A third set of specifically South African higher education organisations is the technikons, whose historical role was to teach applied technology fields and conduct no research, while universities were responsible for basic science and research. Created in the 1970s, they aimed to prepare skilled, high level, occupationally oriented graduates to meet the needs of commerce and industry, focusing on applied engineering, biological, chemical and physical sciences and commerce. This 'binary divide' has shaped the trajectory of technikon growth until the present. In 1993, technikons were accorded degree-granting status and initiated a stronger applied research focus, together with post-graduate programmes, with the focus on developing applied research capacity and potential areas of strength. The dangers of 'mission drift', of organizations losing their technological specialization as they aspired to be more like the universities with their reputational competition and greater status, increasingly became a concern (Winberg 2005). 'Mission drift' impacted negatively on their critical role in preparing technicians and in technological education and training at intermediate and high skills levels in general, to enhance the absorptive capacity of firms. Their aim of becoming a 'university of technology' was realised with higher education restructuring (from 2004), but for the most part, these universities of technology are yet to develop strong applied research capacity, although there are some significant instances of applications research and design and prototyping capabilities to support technology development.

The current national university system

The global shifts to a knowledge-based society from the 1980s, and the imperatives for new kinds of interaction between universities and firms experienced in the advanced economies, began to impact more strongly in South African higher education only from the period of transition in 1990. Given these diverse historical origins, missions and priorities, which determined their location in regions with uneven economic and social conditions, the 22 universities in the national system currently have differential capacity to interact with industry. This is a major source of misalignment within the university system, and between the university system and other components of the national system of innovation. For instance, while the NRF may propose the PhD as driver of innovation and provide funding, there may not be sufficient capacity across the university system to produce SET doctoral graduates in greater numbers. There are extremely low levels of research and technology development capacity at some of the new comprehensive universities created from formerly historically disadvantaged universities and at some of the new universities of technology, particularly those located in isolated rural areas in the provinces with the lowest levels of development in South Africa. There are considerable national efforts to promote research capacity, such as, targeted funding programmes for researchers and post-graduate students. However, in general, these have yet to have significant effects, if indicators such as accredited publications and post-graduate enrolment and graduations are used as measures.

Whitley (2003) proposed that a high degree of segmentation between organizations in the national university system can discourage researchers from undertaking a wide variety of types of research and from moving between different kinds of university, without loss of reputation. This can slow down the rate of knowledge and skills transfer between the different types of universities in South Africa, and lead to the separation of technological development and radical intellectual innovations. In situations with low segmentation, knowledge and skills flow more easily between different types of universities, and the development of joint projects, collaboration and adaptation to new knowledge is facilitated. Clearly, the South African higher education system is characterized by a high degree of segmentation between organizations in the system. There are generally low levels of academic and scientific collaboration between universities, whether of the same or different types, even those in close regional proximity to one another (Gibbon and Parekh 2001). That is not to say such knowledge intensive collaboration does not exist at all, or that there are not mechanisms that attempt to foster it, such as regional associations of universities. However, interlocking complementarities are not sufficiently present between the organizations within the university system.

This path dependent process of developing a highly differentiated and segmented national university system has led to the situation - as described in the recent OECD (2007) study - of a set of established universities with core areas of strength and experience considered as a major asset, alongside a larger set of universities with little research and science and technology capacity. In order for innovative activity to expand throughout the economy, the OECD report argues, an expansion of the university research system is required, particularly in relation to producing research-capable human resources. However, there are indications that it may not be possible to sustain current levels of university R&D, let alone expand the system significantly (OECD 2007). The OECD report attributes this primarily to constraints in the human resources pipeline described above, in turn shaped by the legacy of apartheid schooling, and secondly, in

relation to constraints on the reproduction of the academic labour force itself - issues that have received considerable research attention over the last few years (HRD Review 2003, COHORT 2004, Koen 2006 and 2007).

These phenomena are outcomes of the historical processes of development of the university system – and they establish conditions of possibility for university-industry interaction. The highly segmented higher education system means that there is misalignment within the university system that has considerable impact on building the national system of innovation, and on conditions for university-industry interaction.

CONCLUSION

The policy to build a national system of innovation in South Africa has drawn heavily from the cutting edge of theory and practice in developed economies. A policy framework and set of structures and mechanisms has been progressively developed, shifting from very broad statements of symbolic aspiration towards more implementable targeted strategic plans. There is a great deal that can be debated about the adequacy and efficacy of the policy-making processes over the past fifteen years, and the substantive content of policy. For instance, the primary focus of government support on 'big science', and the lack of prioritization have been criticized (OECD 2007). Leaving that debate aside for the moment, it is evident that an enabling policy environment has been created to meet the stated national goals.

The inherited system is uneven, but there are pockets of potential, expertise and capacity that are globally competitive and provide a foundation for development. The major challenge lies in addressing the constraints that impact on the effectiveness of implementation. The paper has identified key 'binding constraints' - evident in the unevenness of the inherited economic, education and science systems - in the lack of the intermediate and high level skills required, and in the inadequate interactive capability within government departments and between government and other sectors of the national system of innovation, and in the segmentation of the university system that constrains collaboration and knowledge flows.

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[i] The extent to which this may be attributed to improved coverage of the national survey on R&D however, must be considered.