African Journal of Biotechnology Vol. 7 (4), pp. 342-348, 19 February, 2008
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2008 Academic Journals

Review

Great expectations: The state of biotechnology research and development in South Africa

Michael Gastrow

Centre for Science, Technology and Innovation Indicators, Human Sciences Research Council, Private Bag X9182, Cape Town 8000, South Africa. E-mail: mgastrow@hsrc.ac.za.

Accepted 21 January, 2008

As biotechnology industries are knowledge-intensive, Research and Experimental Development (R and D) are key drivers of growth. Governments and businesses have an interest in creating an environment that stimulates R and D and the commercialisation thereof. Discourse relating to the best means to support biotechnology R and D is extensive. However, there has to date a paucity of quantitative data describing biotechnology R and D in South Africa. This paper therefore offers a brief quantitative profile of South Africa's biotechnology R and D. These findings provide key indicators of scale, scope, ownership, sectorial division, geographical distribution and collaborative structure. Bibliometric and patent data are used, as well as data sourced from the National Survey of Research and Experimental Development Inputs. It is found that South Africa's biotechnology R and D investment is small by international standards, but a leader in the African context. There are moreover certain collaborative networks, geographical clusters, and industry applications that demonstrate a high concentration of R and D, which may indicate a path towards achieving critical mass in these areas. Finally, the 2005/6 data used here may be used as baseline data to monitor and evaluate the national 2008 National Biotechnology strategy.

Key words: Biotechnology, research, development.

INTRODUCTION

In line with the great expectations that biotechnology is destined to be a revolutionary technology and a major growth industry, interest in biotechnology research and development (R and D) (The term 'Research and experimental development' (R and D) refers, within the findings of this paper, to the definitions provided in the OECD Frascati Manual (Bisseker, 2003). This definition includes most activities that provide new knowledge, and excludes routine activities such as quality assurance and market research. It also excludes many of the activities defined as innovative, particularly the commercialisation of existing knowledge gained through previous R and D. R and D therefore defines the core knowledge generation capacity of the industry) which is currently high. Biotechnology is knowledge intensive, and two of the major drivers of growth are R and D and innovation. For example, in the USA alone, private sector investment in biotechnology R and D in 2006 amounted to over $14.2 billion (O E C D, 2007). Governments are also actively supporting biotechnology R and D: the Korean government, for example, spent $727 million (PPP adjusted) on publicly funded biotechnology R and D (O E C D, 2007) in 2003. The South African government has also offered some support for R and D in the sector. The South African Biotechnology Strategy (Department of Science and Technology, 2001) of 2001 set aside R450 million over three years to support the establishment of Biotechnology Regional Innovation Centres and business incubators, as well as an array of regulatory and legal support mechanisms. The aim of this strategy was to stimulate the development of biotechnology skills, capacities and tools in South Africa (Campbell, 2007).

However, the strategy was formed in the context of a paucity of quantitative data regarding biotechnology R and D in South Africa. After the formation of the strategy a National Biotechnology Audit was undertaken by the Department of Science and Technology and the eGoli Bio Life Sciences Incubator, measuring 2002-03 data (Department of Science and Technology and eGoli Bio, 2004). This survey achieved a 72% response rate and offers tentative data with respect to the number of firms' active in biotechnology, employment in the sector, research fields, and products in the market. However not all biotechnology firms necessarily perform biotechnology R and D. For example, South Africa has a substantial biosimilars (generics) testing and manufacturing industry. Product development in this industry, according to the Frascati definition, would fall mostly under innovation activity rather than R and D: in other words is characterised by commercialisation of existing knowledge, rather than the development of new knowledge. Thus to date no studies have been conducted that could report on national survey data for biotechnology R and D expenditure, collaboration, ownership and research fields.

The need for such data is apparent within the industry, where discourse with respect to R and D is vibrant but lacking in sound data. For example, the annual Bio2Biz conferences bring together all the major stakeholders in the South African biotechnology arena, as well as many emerging start-up firms. At the 2007 conference much was said about the importance of encouraging venture capital to enter the sector by funding R and D, the importance of streamlining government legislation (including improving Medical Control Council approval lead times and patenting legislation), and forming an industry body that could provide unification and a voice for the currently fragmented group of biotechnology start-ups. Critical debates ensued over what directions should be taken to best support a sustainable biotechnology Industry in South Africa. One element that was lacking in these debates was a concrete and commonly accepted profile of R and D in the sector. The following questions do not currently have quantitative answers: how much is spent on biotechnology R and D in South Africa? In what geographical locations? How is this divided between the private sector, government, science councils and higher education? What are the main industrial sectors? Who owns South African biotechnology firms? What collaboration structures are in place?

This paper therefore offers a brief quantitative profile of South Africa's biotechnology R and D, with the aim of providing key indicators of national biotechnology R and D to inform current discourse in the sector, inform policy formation, and assess government strategies. The little data that are available indicate that South Africa performs a substantial proportion of Africa's biotechnology R and D. An understanding of the country's biotechnology R and D profile is therefore important in understanding biotechnology R and D in Africa as a whole.

Measuring biotechnology research and development

Numbers of scientific publications are commonly accepted as indicators of scientific performance in a particular scientific sphere. In South Africa such analysis in the field of biotechnology has been undertaken by Molutadi and Pouris (2006). Table 1 highlights that global publication output is dominated by the USA, EU and the Asia Pacific region. Developing economies in Africa and Latin America account for only a small fraction of global output. The total African publication output of 1,802 scientific papers equals only 3.4% of the output of the USA alone. Even by comparison with other developing regions, such as Latin America, African output is low. South Africa, however, is prominent in Africa, producing 38% of the continents biotechnology-related publications.

Table 1. International comparison of publication outputs in the fields of microbiology, molecular biology and genetics, 1996 – 2000*.

Region	Publication output
USA	53,723
EU	58,410
Asia Pacific	24,454
Australia	4,451
Latin America	4,766
South Korea	1,698
Africa	1,121
South Africa	681

* Molatudi and Pouris, 2006.

However, production of journal publications is not a perfect measure of research activity. This is particularly true in the business sector, where R and D may be largely directed at applied research and product development, and may moreover be closely guarded by firms not wanting to jeopardise their competitive edge, choosing to file patents rather than publish papers.

Patents then provide another measure of R and D output. According to the statistics of the US Patents and Trademark Office (http://www.uspto.gov/, 2007], between 1976 and 2004 there were 58 biotechnology-related patents awarded to South African inventors. This level falls behind both developed and many developing country comparators (Quach et al., 2006). In 2002 alone more than 5,800 biotechnology patents were registered at the European Patent Office (EPO) (Khan and Dernis, 2006). These patents originated mostly from the USA (39.9%), the EU (34.5%) and Japan (13.8%). Developing economies accounted for less than 5% of the world total. Even among developing countries South Africa has a comparatively low patent output: in a survey measuring biotechnology patent output of seven developing countries between 1991 and 2003, South Africa was ranked second lowest in terms of biotechnology patents and the ownership of these patents (Quach et al., 2006).

There is an extensive discourse addressing the reasons for this low output, which falls outside the ambit of this paper. It is worth noting, however, that the recent increase in support for biotechnology has resulted in the

Table 2. Total expenditures on biotechnology R and D by biotechnology-active firms, Million PPP$, 2003*.

USA	14,232
Germany	1,347
France	1,342
Canada	1,194
Korea	699
Israel	251
Australia	201
Spain	199
New Zealand	95
Poland	5
South Africa**	54

* Source: OECD Biotechnology Statistics 2006,
** Source: National R and D survey data, PPP adjusted.

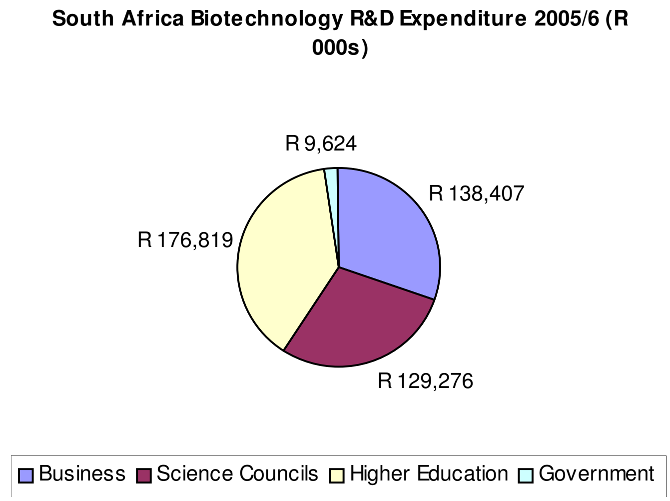

Figure 1. National expenditure on biotechnology R and D 2005/6 (R 000s).

generation of an intellectual property (IP) pipeline that may not as yet have produced protectable IP, but may do so in future. Patent numbers therefore do not reflect the full extent of IP generated in the country (Cloete et al., 2006).

It is therefore constructive to consider a third indicator of R and D activity in the form of aggregate expenditure. Both research and experimental product development require the allocation of financial resources. Expenditure is therefore in many respects both a broader and a more precise indicator of actual R and D activity. Table 2, drawn from 2006 OECD statistics, again highlights the dominance of the developed countries. South Africa's total business sector expenditure on biotechnology (Figure 1) is R138 million, or approximately $53.5 million after purchasing power parity (PPP) adjustment. This is very small in comparison to the USA (PPP$14.2 billion), Germany or France (each approximately PPP$1.3 billion). However it compares favourably to Poland (PPP$5 million), another developing economy. Unfortunately no comparable data are available for other African countries.

Biotechnology R and D policy in South Africa

During South Africa's period of political and economic isolation, domestic scientific and technological capacities were developed in strategic sectors such as arms, mining and energy. However at this stage biotechnology was still in its early stages of development, characterised by first and second phase biotechnologies, as was not commonly seen as a strategically important industry or a critical industry for future growth. Biotechnology during the apartheid years therefore received little state support (Cloete et al., 2006). Government's interest in biotechnology began to develop during the late 1980s, but only gained substantial momentum after 1994. Firstly, biotechnology was seen by the new government as having the potential to grow the economy by creating more efficient industrial processes and innovative new products (Bisseker, 2003). Biotechnology was also seen as a tool to help address development challenges, for example improved food security through the development of genetically engineered crops, and improved health care through improved vaccines, diagnostics and treatments (Cloete et al., 2006).

Increased support for biotechnology R and D led to the adoption of the 2001 National Biotechnology Strategy (Department of Science and Technology, 2001). The strategy addressed human resources development, funding, regulatory and legal issues, and assistance with closing the gap between R and D and commercialisation. This resulted in the establishment in 2002 of Biotechnology Regional Innovation Centres (BRICs). Four BRICs were established: the Cape Biotechnology Initiative (Cape Biotech), the East Coast Biotechnology Consortium (EcoBio, operating under the trade name of LIFElab), the National Innovation Centre for Plant Biotechnology (PlantBio), and Biotechnology Partnerships and Development (BioPAD). The BRICs have difference focus areas: Cape Biotech and LIFElab focus on human health biotechnology R and D, PlantBio on plant biotechnology, and BioPAD on several areas, including biotechnology R and D in agriculture, mining, and environmental applications (Cloete et al., 2006).. In addition to the BRICs, a National Bioinformatics Network was established to assist in the development of human resources in this key area. Government allocated R450 million to the BRICS over three years. Also, through the government's Godisa trust, two technology incubators for biotechnology were established in 2002, namely eGoli Bio Life Sciences and Acorn Technologies. The aim of these is to facilitate the commercialisation of life sciences R and D by supplying business infrastructure and advice, particularly by helping biotechnology firms to survive the start-up phase, when they are at their most vulnerable (O'Donnell, 2007).

The above institutions have played an important role in stimulating biotechnology R and D. The scale and scope of this role cannot be quantified with current survey data, and is certainly a question that begs further research. The success of these institutions is a contentious question: a number of start-ups have been initiated under the protection of the BRICs and incubators; however, the National Biotechnology Strategy, which includes the BRICs, has also encountered several criticisms (Jordaan, 2007). Firstly, the strategy has been accused of neglecting small businesses. Secondly, while the strategy promised a comprehensive review of biotechnology legislation, this has not yet taken place. Finally, the strategy is perceived to lack a clear vision for South African biotechnology.

The engagement of government with the above criticism falls outside the scope of this paper. However, government is set to continue its support of biotechnology R and D. The details of this support will be outlined in the anticipated 2008 National Biotechnology Strategy. In the Department of Science and Technology's Ten Year Plan (Department of Science and Technology, 2007), the biotechnology sector, titled 'farmer to pharma', is identified as one of five 'grand challenges' that will take a high priority over the next decade. Also to have an effect on R and D (although more directly on innovation rather than R and D), will be the establishment of the Technology Innovation Agency (Department of Science and Technology, 2007) (TIA), which is to be targeted at improving the rate at which R and D is commercialised through innovation.

Research approach

South Africa's official national annual Survey of Research and Experimental Development Inputs is carried out by the Human Science Research Council's Centre for Science, Technology and Innovation Indicators (CeSTII), on behalf of the Department of Science and Technology, and forms part of official statistics for the National Statistics System. Specialised questionnaires are directed at government, science councils, higher education institutions and non-profit organisations (NPOs). Through a purposive methodology, all firms that could potentially be involved in R and D in South Africa are targeted in the business sector survey. The statutory survey requires that all organisations performing research or experimental development return a survey questionnaire containing basic economic data and extensive R and D data.

The 2005/06 R and D survey asked respondents to estimate the percentage of R and D expenditure allocated to biotechnology R and D. The firms that answered positively to this formed the sample for this paper. This sample represents the majority of biotechnology R and D in South Africa; however, these data must be seen as a lower bound. R and D surveys are inherently imperfect, as they must rely on the co-operation of respondents. This is particularly difficult in the business sector, where firms do not have a strong incentive to disclose sensitive information. With these caveats in mind, one can use these data to tentatively describe the scale, scope and structure of South African biotechnology R and D.

Findings

The sampling frame consisted of 727 positive respondents to the national R and D survey. This number excludes those that responded but reported no R and D, and excludes the non-profit sector. This was done primarily because there was only a single respondent reporting biotechnology R and D in that sector, and confidentiality therefore needed to be protected. However the amount reported was insignificant, being less than 0.1% of the national expenditure on biotechnology R and D. The final sample therefore consisted of organisations from the business sector, higher education, government research institutions, and the science councils. It must be noted that, in line with conventional R and D survey methodologies, in several cases multiple institutions were reported under a single unit of measure. For example, in the science council sector several research units may report to a single council, in higher education many research units may fall under a single institution, and in the business sector many individual firms may be reported under the results of a conglomerate or group.

Expenditure

The survey reported a total expenditure of R454 million on biotechnology R and D in South Africa in the 2005/6 financial year. This formed only a minor part (3.2%) of South Africa's overall expenditure on R and D. Since the 2004/5 survey was the first year in which national biotechnology R and D was measured, future surveys will tell whether this proportion expands or contracts.

Of the four sectors, higher education was the largest performer of R and D, spending approximately 39% of the total, followed by business sector (31%) and the science councils (28%) and government research institutes (2%). It is, however, important to note that the survey questionnaire requests data about R and D performed *in-house*, and therefore excludes outsourced R and D. For example, private-sector funded R and D performed at Higher Education Institutions would be included in the data reported by these institutions. The data therefore reflect the actual performance of biotechnology R and D, rather than funding or the control of the resultant IP.

Table 3. Profile of sample frame and sample.

	No of organisations performing R&D in the sampling frame	No of organisations performing biotechnology R&D in the sample
Business	606	22
Science Councils	9	6
Higher Education	24	18
Government	88	4
TOTAL	**727**	**50**

In the context of the above profile, more concrete questions may be asked of the data.

In keeping with the confidentiality requirements of the survey, individual respondent details may not be released. There is however a wealth of information regarding performers of biotechnology R and D available in the public domain (Campbell, 2007). In the higher education sector there are a number of key performers, mostly drawn from the life sciences faculties of the major universities. Among the science councils, key performers are the Agricultural Research Council, the South African Institute for Medical Research, the Council for Scientific and Industrial Research, and Mintek. In some technologies science councils are among the world leaders. For example, Mintek developed a bioleaching process used in mineral beneficiation that is used for more than 95% of the gold contained in refractory pyrite-arsenopyrite in Chinese and Australian gold mines.

In the business sector South Africa is also a global leader in bioleaching technology. The South African mining company Gencor, now part of BHP Billiton, developed a leading bioleaching process for gold-bearing sulphide and the bio-COP process for copper (Campbell, 2007). However, private firms from a range of industrial sectors are active in biotechnology R and D. The business sector questionnaire requested SIC codes as related to revenue and R and D activity. Of the 22 firms, the largest number of primary revenue SIC codes were in the pharmaceutical sector (8), followed by chemicals (5), manufacture of food and beverages (3), manufacture of wood, paper and pulp (2), and health (2). The remaining data cannot be fully divulged for confidentiality reasons, as only a single firm is active in each remaining sector.

Biotechnology in the business sector

The business sector survey included other business-specific questions not included in the questionnaires directed at other sectors. Firstly, firms were requested to indicate the nationality profile of their ownership. These data indicate that the ownership of biotechnology R and D performing firms is largely South African, as illustrated in Table 3. Table 4 illustrates that the majority of biotechnology R and D performing firms are South African owned. When comparing the size of the firms (in terms of both turnover and total R and D expenditure) to their ownership profile, it becomes clear that start-ups are largely South African owned, while the larger firms involved in the industry are either foreign owned or have joint South African and foreign ownership. Multinationals, although fewer in number than start-ups and domestic firms, account for a substantial proportion of the biotechnology R and D performed in South Africa. For policy makers this may indicate that creating an enabling environment for big business is as important the current focus on start-ups.

Table 4. Ownership of South African biotechnology R and D performing firms.

South African owned	15
South African-originated transnational	4
USA-based multinational	2
EU-based multinational	1

A question on collaboration was also included in the business sector questionnaire. This allows for an analysis of the collaborative propensities of firms performing biotechnology R and D. Table 5 reflects the structure of the question answered by firms, in which types of potential collaboration partners were listed and divided into domestic and international partners. The number of positive responses to each potential collaboration partner is detailed in the right-hand column:

The most common collaboration partner was domestic higher education institutions, with which 15 of the 22 firms collaborated. However there was a high level of collaboration with most sectors: more than a third of firms collaborate with domestic science councils, members of their own company, and other companies. International collaborations are less common, but nonetheless important, particularly with foreign higher education institutions and other companies. These findings are unsurprising given the structure of the biotechnology knowledge economy. Biotechnology is multidisciplinary, and R and D in the sector requires an array of competencies and types of knowledge. Firms therefore rarely develop new technologies without collaborative partnerships (Kruss et al.,

Table 5. Collaboration among firms performing biotechnology R and D.

	Collaboration partner	No. of firms (N = 22)
South African Collaborators	Higher Education	15
	Science Councils	9
	Government	7
	Members of own company	8
	Other companies	10
	Non-profit organisations	2
International Collaborators	Higher Education	7
	Science councils	3
	Government	5
	Members of own company	5
	Other companies	11
	Non-profit organisations	1

Table 6. 2005/6 main geographical location* of organisations performing biotechnology R and D.

	Business	Science councils	Higher education	Government research institutes	Total
Eastern Cape			2		2
Free State			2		2
Gauteng	8		6	2	16
KwaZulu-Natal	1		3		4
Limpopo					
Mpumalanga	1				1
Northern Cape					
North West	1		1		2
Western Cape	4		3	1	8
Split location*	6	6	1	1	14
TOTAL	22	6	18	4	50

* The geographical location is reported where 50% or more of the organisation's R and D is undertaken in a single province. If there is no majority location the organisation is reported as having a 'split location'.

2006). This is also an encouraging finding, as it indicates that the conditions exist in which firms are able to establish a rich network of collaborative R and D partners, both locally and internationally.

Where is it happening?

In light of the above, is there evidence of geographical clustering of biotechnology R and D performing firms? The survey questionnaire requested that respondents indicate the provincial split of their R and D activities, as indicated in Table 6 below.

Biotechnology R and D-performing organisations are concentrated in Gauteng (16/50) and the Western Cape (8/50), which form the only significant clusters of activity. Business sector biotechnology R and D is particularly concentrated in Gauteng, with eight of the 22 sample firms located in this province. The higher education sector illustrates a national spread of activity, but even here six of the 18 sample organisations are in Gauteng. Among the science councils a high degree of geographical spread was a dominant feature. The science councils are centred in Gauteng and the Western Cape, but have peripheral R and D activity in most of the other provinces. These findings may be useful for policy formation: biotechnology clusters based on geographical proximity have been shown to be successful in utilising collaboration networks, infrastructure sharing and focussed funding to substantially bolster R and D and commercialisation thereof. A good example of this is the life science cluster in Pittsburgh, Penn (http://www.plsg.com/index.php, 2007].

CONCLUSIONS

South Africa's national Survey of Research and Experimental Development Inputs provides a valuable source of data for better understanding the state of biotechnology R and D in South Africa. These data are useful supplement to bibliometric and patent-based means of measuring biotechnology R and D in the country. These data could also be used as a baseline for the monitoring and evaluation of the 2008 National Biotechnology Strategy. However, several research questions remain, including the further investigation of the efficacy of the BRICs and other government initiatives.

The R454 million spent on biotechnology in South Africa in 2005/6 makes it a small player in the global context, but a significant contributor to biotechnology R and D in Africa. Higher education institutions performed the largest proportion of biotechnology R and D, followed by the business sector and the science councils – this is indicative of the early stage of development of biotechnology in South Africa. Within the business sector, biotechnology R and D is a key driver for the future trajectories of several key sectors, particularly in pharmaceuticals, chemicals, food and beverage manufacture, and agriculture. While the majority of the business sector samples were domestic start-up firms, multinationals were found to account for a substantial proportion of total expenditure, highlighting that support for big business should remain on the policy agenda.

The findings also revealed that biotechnology R and D is collaboration-intensive, both domestically and internationally. Here the roles of higher education and science councils were found to be particularly important as collaboration partners with the business sector. Moreover distinct clusters of geographical concentration emerged in Gauteng and the Western Cape. For policy makers these areas of concentration may indicate potential areas for supportive intervention.

ACKNOWLEDGEMENTS

This work is supported by funding provided to the Centre for Science, Technology and Innovation Indicators (CeSTII) by the Department of Science and Technology and the Human Sciences Research Council. The author would also like to thank William Blankley and Professor Michael Kahn for their support.

REFERENCES

Bisseker C (2003). Beaker gets a stir. Financial Mail, 1 August. Johannesburg.

Campbell K (2007). Biotech Billions: SA accelerates development of cutting-edge R&D sector. Martin Creamer's Engineering News. January 19.

Cloete TE, Nel, LH, Theron J (2006). Biotechnology in South Africa. Trends Biotechnol. 24(12): 557-562.

Department of Science and Technology (2001). National Biotechnology Strategy. http://www.dst.gov.za/publications-policies/strategies-reports/reports/dst_biotechnology_strategy.PDF.

Department of Science and Technology (2007). Innovation Towards a Knowledge-Based Economy: Ten-year Plan for South Africa (2008 – 2018).

Department of Science and Technology and eGoli Bio (2004). South African National Biotechnology Audit.

Jordaan D (2007). Time to Review Biotech Strategy. Financial Mail: Innovations, April 6. Johannesburg.

Khan M, Dernis H (2006). Organization for Economic Cooperation and Development, Directorate For Science, Technology And Industry. Global Overview Of Innovative Activities From The Patent Indicators Perspective. Sti Working Paper 2006/3: Statistical Analysis Of Science, Technology And Industry.

Kruss G, Klerck G, Paterson A, Godfrey S (2006). Creating Knowledge Networks - Chapter 2: Biotechnology research and technology networks: the dynamics of competition and cooperation. HSRC Press.

O'Donnell S (2007). Zygote to banknote' is the way to go, says biotech body. Creamer Media's Engineering News. 6 July.

Organization for Economic Cooperation and Development. (2006). Proposed Standard Practice for Surveys on Research and Experimental Development Frascati Manual. Paris: Organization for Economic Cooperation and Development.

Organization for Economic Cooperation and Development. (2007). Biotechnology Statistics 2006. Paris: Organization for Economic Cooperation and Development.

Pittsburgh Life Sciences Greenhouse webpage (2007). (http://www.plsg.com/index.php).

Quach U, Thorsteinsdottir H, Renihan J, Bhatt A, Aesch Z, Singer P, Daar A (2006). Biotechnology patenting takes off in developing countries. Int. J. Biotechnol. 8: 43-59.

United States Patent and Trademark Office webpage (2007). (http://www.uspto.gov/).