R&D as a source of innovation in South Africa

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Abstract

In investigating the link between R&D and innovation, data was used from the South African Innovation Survey of 2001 (SAIS2001). The SAIS2001 results showed that South African enterprises had a relatively high level of innovation with a low level of R&D related innovation costs. A cross tabulation was performed and a statistically significant link between innovation and R&D was found. The group of firms who innovated had a higher tendency to conduct R&D. Universities or Public Research Organisations (PROs) – the 'conventional' sources of R&D - was rated mostly as unimportant external sources of innovation. This is ascribed to the fact that most R&D that is conducted internally is at the experimental development level and requires little basic or applied research. Sectors also differ in their use of R&D as a source of innovation.

Based on the abovementioned data, a positive correlation between R&D and innovation was found in the SAIS2001 data. However, the majority of R&D reported in SAIS2001 is in-house R&D. In contrast, national R&D programmes focus on science intensive industries where R&D (basic and applied) is an important source of innovation. These can be easily quantified by the annual R&D surveys. However, at the national industry level, the link between R&D and innovation requires more frequent quantification as an input into STI policy. It is therefore recommended that in a developing country such as South Africa, R&D should be closer aligned to enable innovation at industry level.

I. Introduction

South Africa had a strong centrally planned, mission-oriented approach to industrial development during the pre-1994 era. The missions approach was aimed at ensuring self-reliance in specific sectors such as defence, energy and food supply. In terms of innovation policy, the approach could be described as 'mission-oriented' rather than 'diffusion-oriented' [1]. Between 1990 and 1994 the government dropped the mission oriented approach and as a result the R&D spending as a % of GDP dropped from 1.1% to 0.7% [2]. Post 1994, Science and Technology was seen as an instrument to help address the socio-economic needs in South Africa. The first formal step towards mobilising S&T towards these goals was the White paper on Science and Technology of 1996, which amongst others broadened the scope from S&T to innovation and recognised *R&D as crucial to economic growth* and improvement of quality of life. The framework for Science and Technology was based on the concept of a 'National System of Innovation', which was embedded in the S&T policy.

The National R&D Strategy of 2002 [2] is specifically focussed towards increasing innovation; investing in the science base (human capital development and transformation) and creating an effective government S&T system .

The objectives of the paper are to focus on the knowledge creating mechanisms within the SA NSI, specifically the link between R&D and innovation. The following hypothesis will be investigated:

> *H1*: Firms who conduct R&D have a higher innovation rate than those who do not conduct R&D.

II. Innovation theory and hypotheses

Innovation theory develops as the understanding of the innovation process increases. The different innovation models were grouped into generations [3], as follows:

- First and second generation – dubbed ***linear innovation models*** - which emphasises need/market pull and technology push.
- Third generation – dubbed the ***coupling model*** - that emphasises the interaction between different elements and feedback loops between them.
- Fourth generation – dubbed the parallel lines model – which emphasises **linkages and alliances.** It considers linkages and alliances within the firm, upstream with key suppliers and downstream with demanding and active customers.
- Fifth generation – dubbed s***ystems integration and extensive networking*** – which emphasises flexible and customized response, continuous innovation.

The article will focus on the linear innovation model as that model is based on the premise that there is a strong causal link between R&D and innovation.

Linear model

The linear innovation model has been described [4] as the Science Technology and Innovation (STI) approach which is based on the use of codified scientific and technical knowledge. The linear innovation model is viewed as a sequence of linear, discrete stages. Research (or science) comes first, then development, and finally production and marketing. Since research comes first, it is easy to think of this as the critical element [5] and innovation is assumed to be applied science. Technology push occurs when new opportunities arise out of research and gives rise to applications and refinements that end up in the marketplace. Technology/need pull occurs when the market signals for something new and this is then drawn from the research – necessity then becomes the mother of invention [3].

Some of the problems with the linear model are [5]:

- A chain of causation is generalised, however, it only holds for a minority of innovations.
- The feedback loops, which occur between the stages in the innovation process, are ignored.

The linear innovation model has been surpassed by complex systems models, as mentioned in the previous section, which have entrepreneurship and knowledge generation as core concepts [6] and which focus on the an interactive process between firms, customers and suppliers [4]. However, in the EU innovation policy environment, the R&D based indicators are used rather than the innovation survey indicators due to the continuing power of the linear innovation model, the structure of the innovation support programmes [7] and the fact that the R&D link to innovation holds mostly for the science based industries [4].

III. R&D in South Africa

South Africa has a relatively broad research base for a developing country. The University of Cape Town, founded in 1829, is the oldest university in the country. The Council for Scientific and Industrial Research (CSIR), the largest PRO, was formally established in 1946.

The current science policy framework for South Africa is that of a National System of Innovation [2]. Government has committed itself to achieving an investment of 1% of GDP on R&D by 2008. In order to focus the R&D efforts in South Africa and to align R&D activities with national imperatives, a number of Sector specific initiatives were undertaken [8]. They include, amongst others, R&D programmes to address:

- Space sciences and astronomy,
- The disease burden in South Africa,
- ICT,
- Biofuels research and innovation, and
- Specific proposals from South Africa's public entities to extend national capabilities, for example in cyber-security research.

It should be noted that the abovementioned R&D programmes are intentionally science intensive. This implies that the linear innovation model can be considered appropriate in this context.

In order to investigate R&D in South Africa, a number of R&D surveys have been completed, namely for the periods 1991-92 [9]; 2001-02 [10]; 2003-04 [11] and 2004-05 [12]. The 2004/05 R&D survey results show R&D spending to be 0.87% of GDP [8]. The R&D survey for 2005-06 is currently underway. In an effort to stimulate the use and investment of the private sector in R&D, a tax rebate for R&D expenditure was increased from 100% to 150%, and a more favourable regime was created for the depreciation of R&D capital expenditure (50:30:20), [8]. The drive to increase private sector investment in R&D is based on the belief that most innovation originates from the private sector and that a 'lean state' is beneficial [13].

The R&D surveys focuses on quantifying and characterising the R&D activity within South Africa; however, there is little attempt made to investigate the link between R&D and innovation. The only reference to "innovation" found in these documents is that R&D forms part of the National System of Innovation (NSI).

Two national innovation surveys were also conducted, the innovation survey in 2001 [14] (performed by the University of Pretoria and Eindhoven) and the 2005 innovation survey performed by the Human Sciences Resource Council (HSRC). Only the highlights of the SAIS 2005 [15] have been released to date.

Apart from the official R&D surveys, a number of papers have been written on the topic of R&D in South Africa. Most of the papers focus on the structure and strength of the R&D base – stating that once again that R&D forms part of the South African NSI. There are only a few papers, for example [16], [17] which investigates the link between R&D and innovation. They also use the SAIS2001 data.

IV. Empirical analysis

The SAIS2001 survey data was the primary source used in this research for investigating the link between R&D and innovation in South Africa. The results presented in the Innovation Survey 2001 report [14] were weighted in order to be representative of the complete population of South African firms. Direct comparison between the two reports is therefore not possible. The SAIS2001 data sampling, description and validity is given in [14] and will not be repeated again in this paper.

Methodology

The questions in the SAIS 2001 survey that related to R&D were:

- Q3a1: "Define the estimated R&D effort in your firm in 2000 (in persons, man-years and Rand) in South Africa." This response is used as an indicator of internal R&D activity and quantification (question q3a1) of the man-year effort of internal R&D performed by the firm. The monetary value of R&D is captured in q3a3.
- Q3b3: "Outsourced research: All creative, systematic research conducted to develop technological innovation … by third parties by order of your firm…" This response was used as an indicator of external R&D and quantification (question q3b4) of the amount of external R&D conducted in 2000.

Results

In order to investigate this hypothesis that companies who conduct R&D have a higher innovation rate than those who do not conduct R&D, various approaches were followed. The analysis was based on innovation performance (SAIS2001 population; innovators and non-innovators) and R&D conductance.

The questions regarding R&D activity in the questionnaire related to four R&D categories, namely:

- Only internal R&D conducted (user defined category 1)
- Internal and outsourced R&D conducted (user defined category 2)
- Only outsourced R&D conducted (user defined category 3)
- No R&D (internally or externally) conducted (user defined category 4)

The variables and the basis of their measurement in SAIS2001 are given in Table 1.

Table 1: Variables and the measurements from the SAIS2001 data

Variable	Description / measurement in questionnaire
Innovator (Y/N)	Did your firm have technological innovations in the period 1998-2000? (Y / N).
Internal R&D	An estimate of R&D effort in your firm in 2000 in persons in South Africa (q3a1).
External R&D	All creative, systematic research conducted to develop technological innovations, including corresponding research and software development conducted by third parties by order of your firm (q3b3).
Joint R&D	True if both internal and external R&D is conducted, based on the abovementioned criteria (user defined).
Internal innovation costs	The innovation costs of your firm in 2000, incl. personnel costs and related investment expenditures (q3a4).

Variable	Description / measurement in questionnaire
External R&D costs	All creative, systematic research conducted to develop technological innovations, including corresponding research and software development performed by third parties by order of your firm. Include costs of specialists that were temporarily employed by your firm to work on innovation (q3b4).

The first investigation was to calculate the descriptive statistics for the level of R&D conducted and the category of R&D. The results for the R&D activities per category for the SAIS2001 sample, the innovators and the non-innovators are depicted in Table 2. The percentages reported in the table are the number of firms who indicated that they conduct R&D as defined in Table 1. The results show a similar trend in the R&D efforts, namely, when R&D activities took place, it was mostly conducted internally, or jointly or only outsourced. There is however a large difference in the total level of R&D activities of innovators (88.5%) compared to that of non-innovators (39.7%).

Table 2: R&D activities (% firms) from SAIS 2001.

Category	Internal R&D alone	Internal & Outsourced R&D	Only outsourced R&D	Total all R&D	No R&D
SAIS 2001 all firms	**38.9%**	18.6%	3.7%	61.2%	37.3%
Innovators	**55.2%**	29.5%	3.8%	**88.5%**	10.5%
Non-innovators	20.2%	**6.1%**	3.6%	**39.7%**	**57.9%**

Note: The fact that the rows do not add up to 100% are due to missing data values.

Within the group that conducted no R&D at all, 10.5% of the firms still had innovations, compared to 57.9% who did not innovate. The percentage outsourced R&D seems equal in Table 2. However, when the R&D Rand values as a percentage of sales are analysed (Table 3) it is clear that there is a substantial difference in the level of effort in R&D. Furthermore, small firms were found to spend higher proportions of their sales on innovations than larger firms [14]. The high level of skewness in the data should be noted.

Table 3: Only Internal and External R&D cost as a percentage of sales in 2000

Category	Mean internal R&D cost (% of sales)	Mean External R&D cost (% of sales)	Comment
SAIS 2001 sample	**2.05** (Std error 0.29)	**0.25** (Std error 0.07)	Very skewed distribution. 40% and 81% of firms were at 0% of sales for internal and external R&D costs respectively.
Innovators	**3.36** (Std error 0.49)	**0.45** (Std error 0.14)	Very skewed distribution. 10% and 70% of firms were at 0% of sales for internal and external R&D costs respectively.
Non-innovators	**0.744** (Std error 0.28)	**0.04** (Std error 0.013)	Very skewed distribution. 72% and 92% of firms were at 0% of sales for internal and external R&D costs respectively.

The R&D continuity per category of R&D conducted is depicted in Table 4. Based on the percentages, the firms who conduct R&D do it more or less continuously, whether it is only internal, joint or only external R&D. Of interest is the low level of only external R&D that is conducted occasionally. This is contrary to the expectation that a firm will only conduct external R&D when the need arise. Instead, the results indicate that the firms who only conduct external R&D do it also on a more or less continuous basis. The fact that 62% of firms who conducts joint R&D (Internal and external) do it on a more or less continuous basis is a good indicator for internal capacity and ability absorb external knowledge.

The values in the last column in Table 4 seem contradicting, and therefore the following explanation is offered. The question stated ‘Our firm is…” with three options to choose from, namely – “Engaged more or less continuously in R&D”; “Engaged occasionally in R&D” and “Not conducting any research and/or development”. Firms who only conduct external R&D could have interpreted the question as a) the firm is not itself conducting R&D and therefore they do not conduct R&D, or b) the firm conducts R&D, despite the fact that it is outsourced, they still pay for it and own the results. The results for only external R&D should therefore be used with care.

Table 4: R&D continuity per type of R&D conducted

R&D Category	R&D conducted more or less continuously	Conduct occasional R&D	Do not conduct R&D
Only internal R&D	**48.9%**	44.5%	-
Joint Internal & external R&D	**62.7%**	30.1%	-
Only external R&D	27.3%	9.1%	**45.5%**

The continuity of the R&D effort between innovators and non-innovators are depicted in Table 5. The results indicate clearly that the innovators are inherently accustomed to conducting R&D (whether it is continuously or only occasionally). In response to this question, only 8.8% of the innovators do not conduct R&D at all. The non-innovators have a high tendency (53.8%) not to conduct R&D.

Table 5: R&D continuity vs. innovation

Category	R&D conducted more or less continuously	Conduct occasional R&D	Do not conduct R&D
All sample	**32.4%**	25.9%	30.2%
Innovators	**53.6%**	31%	8.8%
Non-innovators	9.0%	20.2%	**53.8%**

In order to test the correlation between R&D and innovation, a cross tabulation was performed. The results of the data counts are given in Table 6. The results of the Chi-squared correlation are given in Table 7. The results indicate a statistically significant relationship between R&D and innovation.

Table 6: Innovations and R&D conducted

		RD activity		Total
		R&D conducted	No R&D conducted	
q5a Technological innovations in 1998-2000?	Yes	271	32	303
	No	83	188	271
	Total	354	220	574

Table 7: Chi-Square Tests for Innovation and R&D

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	209.327(b)	1	.000
Likelihood Ratio	225.875	1	.000
Linear-by-Linear Association	208.962	1	.000
N of Valid Cases	574		

a Computed only for a 2x2 table
b 0 cells (.0%) have expected count less than 5. The minimum expected count is 103.87.

A relationship between R&D category (internal, joint, external, no R&D) and innovation was found to exist, as is reflected in the Chi-square test results in Table 9, the base data is given in Table 8.

Table 8: R&D category and innovation (data count table)

		RD Conducted Category				Total
		Internal R&D only	Int & ext R&D	Ext R&D only	No R&D	
q5a Technological innovations in 1998-2000?	Yes	173	86	12	32	303
	No	56	17	10	188	271
	Total	229	103	22	220	574

Table 9: Result of Chi-Square Tests for R&D Type and innovation

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	215.687(a)	3	.000
Likelihood Ratio	234.101	3	.000
Linear-by-Linear Association	187.044	1	.000
N of Valid Cases	574		

a 0 cells (.0%) have expected count less than 5. The minimum expected count is 10.39.

Similarly, a positive relationship was found between R&D continuity and innovation, as depicted in Table 10. (The base data is given in Table 5).

Table 10: Result of Chi-square tests for R&D continuity and innovation

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	193.065(a)	2	.000
Likelihood Ratio	211.556	2	.000
Linear-by-Linear Association	186.626	1	.000
N of Valid Cases	516		

a 0 cells (.0%) have expected count less than 5. The minimum expected count is 67.31.

From the above results that the hypothesis is true – that there is a positive link between R&D and innovation. Further investigation of the relationship between R&D as an external source of innovation, is only possible for the innovator group, as non-innovators were not required to complete the full questionnaire.

The firms which rated R&D (Public research organisations or universities) as an important and very important external source of innovation; and which conducts internal and external research were grouped and analysed. The group of eight firms consists mainly of four firms from the manufacturing sector; one is a service provider, and the remainder consist of wholesale firms. The mean of the level of specialisation was determined - 29% of the personnel in these firms are considered to be specialised and 35% of the personnel in these firms have been educated at a tertiary level.

Table 11 depicts the data counts of PRO as an external source of innovation and R&D category. Table 12 depicts the same information for universities as an external source of innovation.

Table 11: External sources of innovation: PROs and R&D category

		RD Conducted Category				**Total**
		Internal R&D	**Int & Ext R&D**	**Only Ext R&D**	**No R&D**	
q8a7 External source: Public research labs	Source not used	117	43	4	25	189
	Of little importance	21	17	2	1	41
	Important	**11**	**15**	**0**	0	26
	Very important	**3**	**5**	**1**	2	11
	Total	152	80	7	28	267

Table 12: Data count: External sources of innovation: Universities and R&D category

		RD Conducted Category				**Total**
		Internal R&D	**Int & Ext R&D**	**Only Ext R&D**	**No R&D**	
q8a8 External source: Universities	Source not used	116	40	5	22	183
	Of little importance	23	15	0	2	40
	Important	**10**	**20**	**2**	2	34
	Very important	**2**	**3**	**1**	1	7
	Total	151	78	8	27	264

It is clear that most firms reported the R&D source (Universities and PROs) is not used. A very small number of firms rated these sources as very important for innovation.

SAIS 2005

The data for the SAIS2005 is not available for academic use outside the body that conducted the survey. However, highlights from South Africa's innovation survey 2005 [15] state that ~52% (44% in SAIS2001) of South African enterprises had technological innovations in the period 2002-2004. In terms of innovation expenditure ~2.4% of sales (2.6% for SAIS2001) was spent on innovation activities. The R&D portion of the innovation investment is ~27.8% (1.55% of total sales in SAIS2001). In SAIS2005, 5% (2% in SAIS2001) of the enterprises rated Universities and Technicons (Universities of Technology) as highly important and 3% (3% in SAIS2001) rated public research institutes and science councils as highly important. From the above cursory comparison, the innovation outcomes are relatively similar, although a large increase in innovative behaviour is reported in SAIS2005.

V. Discussion

Based on the earlier results, R&D is a familiar activity for innovators as 88% of innovators conducted R&D. R&D was conducted mostly internal, then jointly and only then externally or outsourced. This is a desirable distribution as internal capacity and capability are firstly required before firms can enter into joint R&D activities, or even fully outsource R&D.

The definition of R&D is described in [18]. The Frascati manual defines three types of R&D are defined, namely Type A – basic research; Type B – applied research and Type C – experimental development. Type A and B research are predominantly conducted by universities and PROs. This type of activity, especially in a developing country is normally small and often difficult to transfer or to integrate with the needs of local industry. The SA R&D survey of 2003/04 [11] states the R&D type distribution in South Africa in 2001 as 27% basic research; 40% applied research and 33% experimental development. The relatively large percentage of basic research could be attributed to the national R&D initiatives (as discussed earlier) which are science intensive.

In considering R&D in SAIS2001, a bias could be generated by the fact that R&D is defined in the broad sense in the questions relating to internal and external R&D. However, in the question on the use and importance of external innovation sources and R&D, it is difficult to derive the complete R&D effort. Universities and PROs conduct mostly basic and applied research, and one can easily consider this as the only form of R&D. However, other forms of R&D might for example be conducted by consultants, new personnel in the group, innovation centres, sector institutes, etc. As mentioned above, the basic research activity is normally small and therefore it could lead to the underestimation of the importance of R&D as an external source for innovation.

Secondly, in context of the linear innovation model, where R&D is considered one of the main inputs to innovation, [19] states that "Except in such industries (pharmaceuticals, organic and food chemistry, biotechnology and semiconductors), scientific knowledge stemming from basic research is rarely a direct input into technological innovation." Such science intensive firms/industries are not prevalent in South Africa.

The findings in this research seemingly contradict the findings in [16] which found that R&D does not have the expected positive outcome on innovation. One possible explanation for the difference in results is that this research was conducted along the delineation of innovators and non-innovators and the analysis in [16] was based on incremental and radical innovations.

VI. Conclusion

R&D is considered important in South Africa and its conductance is measured continuously through annual R&D surveys. The South African STI policy focuses its R&D programmes in science intensive sectors. In these sectors, R&D is an important source of innovation. Part of the motivation for the R&D investment and emphasis within the South African STI framework is based on the fact that R&D forms part of the South African National System of Innovation. In view of this background, the link between R&D and innovation was investigated.

Descriptive data analysis revealed a strong link between R&D and innovation in the SAIS2001 data, specifically if innovators and non-innovators are compared on their level and continuity of R&D activity. The relationship between R&D and innovation was confirmed through a Chi-square test. The low importance attributed by innovators to the classical R&D organisations (Universities and PROs) as an external source of innovation, confirms the existence of the ‘innovation chasm’ and also indicates that a lot of the activities defined as R&D could actually be experimental development required for incremental innovations.

The national R&D surveys are therefore more suited to quantify the type of R&D that is conducted in the national R&D programmes. However, the quantification of the link between R&D and innovation, at national industry level, should be conducted more frequently. Furthermore, additional instruments and initiatives are required to help apply/implement the new knowledge created by R&D into the industry as innovations.

Innovation grows the economy and if the purpose of R&D is to be part of the South African NSI, an improved causal link between R&D and innovation will greatly improve the efficiency of the South African national system of innovation.

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