Evidence from Surveys and Case Studies: What We Know and What We Do Not Know About Industrial Innovation in South Africa

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Abstract—Innovation, and particularly technological innovation, has come to be recognised as the primary force driving economic growth and prosperity. In the last decade a number of national innovation surveys were conducted in South Africa to measure innovation with the aim of utilising the findings for policymaking. National surveys of innovation in South Africa were conducted in 1996, 2001, 2005 and 2008. These national innovation surveys were supplemented by more detailed sub-sector surveys that focused on particular sectors of interest, such as the defence related industries and the automotive component manufacturing sector. Survey research is a positivistic research methodology that provides a broad overview of the national system of innovation, but it does not provide a clear picture of innovative behaviour at the individual firm level. Case study research, being a phenomenological research methodology, has to augment our understanding of industrial innovation at the firm level. This paper is an overview of past surveys and case studies of industrial innovation in South Africa and highlights the main findings as well as the major questions that still remain unanswered.

I. INTRODUCTION

This paper provides an overview and analysis of innovation surveys and case studies conducted over the last decade with the aim of utilising the findings for policymaking. The goal of this paper is an attempt to answer the question: What do we know and what do we not know about industrial innovation in South Africa?

Innovation - the introduction of new and/or improvement of products, services and production processes - is the driving force of a nation's economic development and the improvement of competitiveness of its firms. Innovation, and particularly technological innovation, has come to be recognised as the primary force driving economic growth and prosperity. Despite its importance, not much is known about the innovative behaviour of South African firms. In the last decade a number of national innovation surveys were conducted in South Africa to measure innovation with the aim of utilising the findings for policymaking.

II. SOUTH AFRICAN NATIONAL INNOVATION SURVEYS

National surveys of industrial innovation in South African were conducted in 1996, 2001, 2005 and 2008. Table 1 show the time periods surveyed as well as the organisations that conducted the surveys, the size of the sampling frames (number of firms selected for surveying) and the sample sizes (number of firms that responded). Although the response rates were disappointingly low, the sample sizes were generally adequate for obtaining significant results when analysed statistically.

The first two national innovation surveys did not cover all the industrial sectors as shown in Table 2.


The first national Survey of Innovation in South African Manufacturing Firms (SISAMF-1996) was a joint undertaking by the Directorate for Science and Technology Policy of the Foundation for Research Development and the Industrial Strategy Project based at the Development Policy Research Unit of the University of Cape Town [1]. The SISAMF-1996 found that only a handful of South African firms see innovation as the key and critical component of the life of a firm [1]. The survey sample was a judgemental sample of innovative firms and the results could therefore not be generalised to all South African manufacturing firms.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Period</th>
<th>Conducted by</th>
<th>Sampling frame</th>
<th>Sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>SISAMF-1996</td>
<td>1994-95</td>
<td>FRD &amp; ISP</td>
<td>2732</td>
<td>244</td>
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<tr>
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<td>UP &amp; ECIS</td>
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<td>617</td>
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<tr>
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<td>2002-04</td>
<td>CeSTII</td>
<td>2627</td>
<td>980</td>
</tr>
<tr>
<td>SAIS2008</td>
<td>2005-07</td>
<td>CeSTII</td>
<td>2836</td>
<td>754</td>
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TABLE 2: INDUSTRIAL SECTORS COVERED IN THE SOUTH AFRICAN NATIONAL INNOVATION SURVEYS

<table>
<thead>
<tr>
<th>Survey</th>
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<th>Services</th>
<th>Mining</th>
<th>Other industrial</th>
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<td>SISAMF-1996</td>
<td>X</td>
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<td>SAIS2001</td>
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<td>SAIS2005</td>
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<td>SAIS2008</td>
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2001 South African Innovation Survey (SAIS2001)

The South African Innovation Survey 2001 (SAIS2001) was the first comprehensive innovation survey conducted in South Africa. It was conducted during 2001/2002 by the University of Pretoria, in cooperation with the Eindhoven University of Technology in the Netherlands. The purpose of the survey was twofold; firstly, to get a representative, nationwide picture of the innovative behaviour and performance of South African firms in manufacturing and services, and secondly, to compare the South African situation on innovation to the European one. The survey therefore used the European Community Innovation Survey (CIS) questionnaire, modified to suit the South African environment [15].

The survey found that about 44% of all South African firms, and 52% of firms in the manufacturing sector, had technological innovations in the period 1998-2000 [16]. This figure was surprisingly high - it was the same as the European average and higher than that of many developed countries in Europe such as Italy, Norway and France. It was found that about 30% of total sales in 2000 could be attributed to innovated products and services [16]. A Dutch innovation survey (Centraal Plan Bureau, 2002) showed comparable figures for Dutch innovating firms. South African innovators reported that about 13% of sales in 2000 was realised with products and services that can be labelled as “new to the market” [16]. The share of innovative sales realised with innovation new to the market of Dutch innovation firms was 14% (Centraal Plan Bureau, 2002). Similar to industries in other countries, the majority of innovations of South African firms were incremental and larger firms had higher innovation rates than smaller firms [16]. South African innovating firms are able to produce innovation outcomes which are comparable to European levels [16].

South African firms achieved this outcome with relatively few resources. The Research and Development (R&D) effort by firms in South Africa was generally low. About 51% of firms had no R&D effort. Only 1.8% of personnel and 1.55% of total sales were allocated on R&D related innovation activities. Firms spent about 1% of total sales on non-R&D innovation activities. The innovation expenditure in South Africa as a percentage of sales in manufacturing in 2000 was 2.6%, which is low in comparison to the European mean of 3.7%.

An unexpected finding was that South African innovating firms are able to produce innovation outcomes that are comparable to European levels with innovation efforts that are much lower than those of their counterparts. South African innovators were found to be unique in many respects, providing some preliminary and partial explanations for this ‘input-output paradox’. For example, the sources of information for innovations as well as types of partners used by firms indicate a tendency to imitate rather than invent. One in every four innovating firms (26%) participated in innovative partnerships with organisations outside South Africa, whereas only 18% of innovating firms worked together with South African partners on innovation. It was observed that there existed a strong tendency to cooperate with partners located in Europe [16].

It was suggested that South African firms can be characterised as being predominantly engaged in the improvement of products and processes using foreign technology, and the primary mode of innovation seems to be imitation rather than invention [16]. It was suggested that South Africa can therefore be characterised as a ‘technological colony’. Technological colonies were first defined by De Wet [12] as countries whose industries are dependent on foreign technology for the improvement of its products and processes (see Fig. 1).
Rooks, Pretorius, Oerlemans and Buys [18] examined the innovative performance of South African firms by comparing the innovation output and expenditures on innovation with that of European Union firms using the SAIS2001 data. The researchers found that the innovation output of South African firms was comparable to that of their European Union counterparts, but the average South African firm spends much less on innovation than the average European Union firm. The researchers did not find an unequivocal explanation for this phenomenon, and hence concluded that more research into the innovative behaviour of South African firms was needed [18].

South Africa’s dependence on foreign technology was further investigated by the author [4]. He found that South Africa’s industries, like those of many other developing countries, are largely dependent on foreign technology because the National Systems of Innovation (NSI) is deficient and poorly developed. In this study [4] different processes for the development of innovative capabilities were considered. The first is Forward Integration and is based on the entrepreneurship paradigm of innovation. The process is triggered by a scientific discovery, followed by sequential development of the downstream processes such as technology development, new product and/or process development or improvement, production and manufacturing, distribution, marketing, sales and after-sales services.

The second process is Concurrent Development and is based on the technology-economics paradigm of innovation. Inventions are the result of investment in R&D projects by established industries while developing new and improved products and services for the markets they are serving. It is also characterised by strategic management of market-oriented innovations (e.g. differentiation) in a global competitive market where the ability of the NSI to network with the Global System of Innovation is of strategic importance.

The third process of innovative capability development is Backwards Integration of the system of innovation and is typical for developing countries. A six-stage process of backwards integration was proposed as shown in Fig. 2 [4].

The process of backwards integration of the South African NSI was explored in some detail. It was shown that the backwards integration innovative capability development processes is an appropriate strategy for the ‘decolonisation’ of technological colonies such as South Africa [4].

The author used the SAIS2001 data to characterize the South African NSI [5]. It was shown that the South African industry can generally be characterized as being in Stage III of the backwards integration process, namely the improvement of products and processes using foreign technology (see Fig. 3).

Figure 2: Stage III of the Backwards Integration Process of Innovative Capacity Development [4]
It was concluded that South Africa was therefore a type of technological colony whose industries are dependent on foreign technology for the improvement of its products and processes. The implications this had for industrial development and policymaking were discussed and some guidelines for policymaking were presented. It was proposed that backwards integration of the NSI should be adopted as a national industrial strategy for South Africa and that the emphasis should be on policies to support local design and technology absorption and diffusion [5].

The author further noted that South African firms are benefiting from networking extensively with foreign innovation partners [6]. As technology followers and imitators, South African firms seem to be more cost-efficient innovators than that of many of their foreign counterparts. Although this is not always the case, the ability of technology followers to be more successful than technology leaders has been reported at firm level, and at national level, particularly for developing or "catch-up" countries [6]. There are however also many follower disadvantages (or leader advantages). Many of these leader advantages such as setting standards, establishing brand names and monopoly power are not available to followers. There are indications, such as the fact that only 12% of firms transfer or sell technology, and only 30% of firms were able to export more than 10% of their sales volume, that South Africa may already be suffering from the negative competitive consequences of its status as a technology follower/imitator. Imitation is therefore unlikely to be a sustainable competitive advantage [6].

The development of a complete NSI (Stage VI) should be a national priority. In the short term, the proven ability of South African firms to improve products and processes using foreign technology should be encouraged, supported and strengthened. Furthermore, the transfer, assimilation and diffusion of technology should receive high priority. It was also argued that 'design & product development' should be a higher national priority than 'research & technology development', with the emphasis on policies to support local development of new products and processes using foreign and locally developed technology. The primary challenge will be for the national education system to supply sufficient technically trained personnel [6].

2005 South African Innovation Survey (SAIS2005)

The Centre for Science, Technology and Innovation Indicators (CeSTII) was commissioned by the Department of Science and Technology to undertake the South African Innovation Survey 2005 (SAIS2005), covering the period 2002–2004.

As previously found in the SAIS2001, the results of the SAIS 2005 showed that South African enterprises have much in common with enterprises in many European Union (EU) countries. For example, the factors hampering innovation and the most important outcomes of innovation for enterprises were very similar [2].

Again it was found that South African firms were able to produce innovation outcomes which were comparable to European levels. The survey found that 51.7% of South African enterprises were engaged in innovation activities between 2002 and 2004 [2]. This was higher than the EU average of 40% for the same period. About 80% of innovative South African enterprises introduced new or
improved products to the market [2]. This was higher than for any European country.

In South Africa, 10.1% of firms’ turnover was generated by the sale of new or significantly improved products (new to the market and not just new to the enterprise) compared with the EU average of 8.6% [2]. Many (39.9%) innovating enterprises had innovation activities with other enterprises and institutions. By comparison, an average 26% of innovative enterprises in the EU had collaborative partnerships.

The previous finding that South African innovating firms are able to produce innovation outcomes that are comparable to European levels with innovation efforts, and particularly R&D efforts, that are much lower than those of their counterparts, were observed again. Walwyn [20] showed that South Africa’s Business Expenditure on R&D (BERD) of R6.77 billion (0.49% of GDP) [10] is considerably below the international norm, especially when compared with those countries against which South Africa compete in international markets. He proposed that manufacturing BERD should be increased to R12.5 billion (an 85% increase on the 2004 values), thereby raising the important ratio of BERD/GDP to 0.9%.

2008 South African Innovation Survey (SAIS2008)

CeSTII also conducted the South African Innovation Survey 2008 (SAIS2008), covering the period 2005–2007. The results of the SAIS2008 indicated that 65.4% of South African enterprises were engaged in innovation activities, an increase (13.7%) when compared with the results of the SAIS2005 (51.7%) [14]. The South African rate of technological innovation was not only much higher than the EU average of 39%, it was higher than that of Germany, the most innovative country in Europe who had a rate of 63% for the same period [14]. This was a remarkable finding: South African firms are able to produce innovation outcomes which are higher than European levels as shown in Fig. 4.

In South Africa, 10.1% of the turnover of industrial enterprises was from new or significantly improved products (new to the market and not just new to the enterprise), whereas the average share of turnover from products that were new to the market was 8.6% for the EU-27. South Africa’s 10.1% was higher than the percentages for countries such as Italy (9.7%), Greece (9.6%) and France (9.0%) [3].

![Figure 4: International comparison of share of innovative enterprises as a percentage of all enterprises, 2005 – 2007 (Source: [14])](image-url)
The South African industry also outperformed their European counterparts on other measures of innovation output. For example, Fig. 5 shows the percentage of innovative enterprises that introduced organisational and/or marketing innovations, 2005 – 2007.

Figure 6 shows that when ranked alongside 23 selected European countries, South Africa was sixth with respect to the proportion of firms that introduced products that were new to the market [14]. Most of their innovations could therefore not have been imitations as was suspected before.

The previously reported low expenditure on innovation activities by South African firms was observed again for this time period. Fig. 7 shows an international comparison of the innovation expenditure as % of turnover of innovative enterprises for 2006-2008 [13]. Not only was expenditure on innovation low, but South Africa’s Gross Expenditure on R&D (GERD) as a percentage of GDP was even lower in comparison to other countries as shown in Fig. 8 [11]. With such a low GERD and innovation expenditure, it is not surprising that South Africa has a very low patenting rate as shown in Fig. 9 [14]. Figure 10 shows an international comparison of percentage of innovative enterprises that received public funds [14]. South Africa has the lowest rate of all the countries in this comparison.

Figure 5: International comparison of percentage of innovative enterprises that introduced organisational and/or marketing innovations, 2005 – 2007 (Source: [14]).
Figure 6: International\(^1\) comparison of percentage of innovative enterprises that introduced products that were new to the market, 2005 – 2007. (Source: [14])

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\(^1\) Acronyms: AR Argentina, AT Austria, AU Australia, BE Belgium, BG Bulgaria, CH China, CR Croatia, CY Cyprus, CZ Czech Republic, DE Germany, DK Denmark, EE Estonia, ES Spain, EU-27 European Union average (27 countries), FI Finland, FR France, GR Greece, HU Hungary, IE Ireland, IN India, IS Iceland, IT Italy, JP Japan, KO Korea, LT Lithuania, LU Luxembourg, LV Latvia, MT Malta, NL Netherlands, NO Norway, OECD OECD average, PL Poland, PT Portugal, RF Russian Federation, RO Romania, SA South Africa, SE Sweden, SI Slovenia, SK Slovakia, TU Turkey, UK United Kingdom, US United States.
Figure 7: International comparison of innovation expenditure as % of turnover of innovative enterprises, 2006-2008 (Source: [13]).

Figure 8: International comparison of Gross Expenditure on R&D as a percentage of GDP 2007. (Source: [11])
Figure 9: International comparison of percentage of innovating companies that applied for a patent (Source: [14])

Figure 10: International comparison of percentage of innovative enterprises that received public funds, 2005-2007 (Source: [14])
The innovation input-output paradox of the South African Industry

The finding, now substantiated by successive innovation surveys, that South African innovating firms are able to produce innovation outcomes that are comparable or better than European levels, with innovation efforts that are lower than those of their counterparts, remains an ‘input-output paradox’. Efforts by researchers to understand and explain this phenomenon has only been partially successful. Oerlemans and Pretorius [17] attempted to identify the major determinants of innovation outcomes of South African firms using the SAIS2001 data. They found some evidence that innovative outcomes were influenced by the extent to which firms had internal knowledge resources and used internal and external knowledge and information sources. This could, however, still not explain the input-output paradox as such.

There also appears to be no significant correlation between innovation inputs and outputs in the South African system of innovation. It seems logical to expect that the more effort (expenditure and human resources) is put into innovation activities, the more innovation output in the form of new and improved products will be realised. This proposition was investigated with the SAIS2001 data. Two input variables, IEX (Innovation expenditure, including R&D expenditure, as a percentage of sales) and RDE (R&D personnel as a percentage of all employees of the firm) were used as operational variables for the conceptual variable IIN (innovation input). Based on the concept of the Cobb-Douglas production function, IIN was calculated as the product of IEX and RDE. IPR (Innovated products as percentage of sales) was used as operational variable for the conceptual variable ‘innovation output’. The following hypotheses were tested with the empirical data:

h1 There is a positive correlation between innovation expenditure and innovated products as percentages of sales.

h2 There is a positive correlation between R&D personnel as a percentage of all employees of the firm and innovated products as percentage of sales.

h3 There is a positive correlation between innovation inputs, expressed as the product of innovation expenditure as a percentage of sales and R&D personnel as a percentage of all employees of the firm, and innovated products as percentage of sales.

Data from the SAIS2001 database were extracted for the variables and checked for face validity by removing records that contained apparently erroneous entries and outlier values. The frequency distributions for all the variables were found to be sharply left-skewed (high predominance of small values). They were therefore transformed using the power function X^p to obtain symmetrical distributions such that linear regression (a parametric statistical test) can be applied. The correlations between the untransformed variables as well as for the transformed variables are shown in Table 3.

The coefficients in Table 3 indicate that none of the variables are strongly correlated. There is therefore no empirical support for any of the hypotheses. This finding was further checked by linear regression analysis using the transformed variables. Multiple linear regression using RDE^{0.1} and IEX^{0.2} as independent variables (they are only weakly correlated, see Table 3) showed no significant correlation between the dependent and independent variables (R Square = 0.18) and simple linear regression using only IIN^{0.07} as independent variable showed exactly the same result. This apparent disconnect between innovation inputs and outputs must be seen as a provisional finding pending the search for possible extraneous, moderating or intervening variables. This finding does however deepen the enigma of the input-output paradox.

III. SOUTH AFRICAN SUB-SECTOR INNOVATION SURVEYS

The national innovation surveys discussed above were supplemented by more detailed sub-sector surveys that focused on particular sectors, such as the automotive component manufacturing sector and the defence related industries. The methodology used for the sub-sector surveys was a combination of both survey & case study research designs. The survey questionnaires were fixed format questionnaires but were completed during interviews with senior management of the firms. The survey data was supplemented with other data obtained through unstructured & focus group interviews, observations during site visits and other relevant documentation and records.

2007 South African Automotive Component Manufacturing Industry Innovation Survey

The 2007 South African Automotive Component Manufacturing Industry Innovation Survey was undertaken as part of an international comparative study of the National Innovation Systems of Brazil, Russia, India, China and South Africa. Some of the key issues that this survey investigated were the resources utilised for innovation, the type and importance of innovation, the strategies employed to access local and foreign markets and innovation linkages and channels.

TABLE 3: SAIS2001 PEARSON CORRELATION COEFFICIENTS

<table>
<thead>
<tr>
<th></th>
<th>RDE</th>
<th>IEX</th>
<th>IIN</th>
<th>RDE^{0.1}</th>
<th>IEX^{0.2}</th>
<th>IIN^{0.07}</th>
</tr>
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<td>IEX</td>
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<tr>
<td>IPR</td>
<td>0.21</td>
<td>0.39</td>
<td>0.31</td>
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</table>
The author [7] reported that this subsector consisted primarily of subsidiaries of foreign enterprise groups. Most firms (61.5%) were foreign owned firms. The majority manufactured products according to design specifications provided by external buyers (Original Equipment Manufacturing). The results of the survey indicated that this is a highly innovative subsector with 78.6% of firms engaged in innovation activities [19]. Most innovations were new or improved methods of manufacturing and internal management practices and the innovation activity that had the largest domestic and international impact was the acquisition of new and improved machinery and equipment. Nonetheless, 44.6% of firms introduced new or significantly improved goods or services during 2007. Significant differences existed in productivity and innovative behaviour of foreign and domestic owned firms. On all indicators the foreign owned firms outperformed the domestic firms [8]. A significant finding was that the National Government’s Incentive Schemes have stimulated foreign direct investment rather than upgraded the domestic industry.

The South African Defence Related Industries Survey


Defence industries are often viewed as constituting the most innovative sector of the manufacturing industry of a country. This industrial sector usually scores high on R&D effort, but the research question is whether this translates into a correspondingly high output of new or improved products and services.

Some of the variables that were investigated were R&D effort, innovation expenditure, innovated products and services; export performance, innovation partners and information sources for innovation. The objective of this study was to highlight the main differences and similarities between the innovative behaviours of the SADRI and other industries.

The key innovation indicators for the SADRI in comparison to the other industrial sectors can be summarised as follows [9]:

The SADRI companies reported that they all had innovated and almost all (94%) had innovated products and services. This was the highest of any industrial sector in the SAIS2001 survey. Innovated products & services constituted about 65% of total sales of the SADRI companies. This is much higher than for any other sector. The corresponding figure was 30% for all South African innovating companies.

Technologically new products and services accounted for 23% of total sales of the SADRI. This was again the highest figure of all sectors. The average was 11% for all South African innovating companies.

The SADRI devoted 13.93% of its workforce to R&D. This was almost double that of the next highest sector (Electrical & optical equipment - 7.73%). The SADRI had a high level of R&D related innovation costs (5.47% of sales), but it was less than that of the manufacturers of transport equipment (9.37%) and chemicals, rubber & plastic products (5.77%). The SADRI had total innovation expenditures of 10.45% of sales. This was the second highest ratio after that of the manufacturers of transport equipment (13.3%). The SADRI made more use of the private and public knowledge infrastructure (research labs, universities, innovation centres, and sector institutes) than the rest of the industrial base. Technology transfer through foreign direct investment also played a much more important role in the SADRI than in other sectors. 44% of SADRI companies had local innovation partners, while only 18% of all innovating companies in other sectors worked together with local partners on innovation. 69% of the SADRI companies had cooperative relationships with foreign partners, whereas only about 26% of all South African innovation companies had cooperative relationships with foreign partners.

The 2005 Defence Related Industries Survey showed that the SADRI was the highest scoring sector on almost all the innovation indicators measured.

The proposition that the more effort (expenditure and human resources) is put into innovation activities, the more innovation output in the form of new and improved products will be realised, was also tested with the SADRI2005 data.

The correlations between the variables (as defined before) are shown in Table 4.

| TABLE 4: SADRI2005 PEARSON CORRELATION COEFFICIENTS |
|---------------------------------|-----|-----|
| IEX 0.71 IEX 1 IN 0.04 |
| IPR -0.03 0.22 0.04 |

The coefficients in Table 4 indicate that there is a correlation between Innovation expenditure as a percentage of sales (IEX) and R&D personnel as a percentage of all employees of the firm (RDE) (Pearson = 0.71). However, there is no significant correlation between Innovated products as percentage of sales (IPR) and any of the input variables. 

The apparent disconnect between innovation inputs and outputs are therefore also apparent in the highly innovative SADRI. This finding further deepens the enigma of the input-output paradox.
Survey research is a positivistic research methodology that provides a broad overview of the national system of innovation, but it does not provide a clear picture of innovative behaviour at the individual firm level. For this reason case study research, being a phenomenological research methodology, has to augment our understanding of industrial innovation at the firm level. In Table 5 some of the main differences between positivistic survey research design and phenomenological case study research design are highlighted.

There is a need for firm and project level case studies to complement the survey studies. Survey research has provided us with the ‘big picture’, but it presents us with poorly understood phenomena such as the input-output paradox.

The question whether South Africa can be classified as being in Stage III of the Backwards Integration Process of Innovative Capacity Development was analysed by considering 95 prominent South African technological innovations. They were classified according to the history of the process whereby they came about. It was found that 34% was the result of the Forward Integration process, 49% as the result of Concurrent Innovation, and 17% originated from the Backwards Integration process. Some examples of Forward Integration innovations are the Kreepy Krauly automatic swimming pool cleaner, Cryoprobe, CyberTracker, Gonomela moth silk and the SharkPOD. It was noted that the impact these innovations had on industrial and economic development of the country has been relatively minor. Examples of Backwards Integration innovations are most of the products of the Defence Related Industries, the Automotive Industry and Sasol’s fuel-from-coal plants. These innovations have had a major impact on industrial and economic development. Examples of Concurrent innovations are the Scheffel railway bogie and Sasol’s Synthol plant. These innovations also had a major impact on industrial and economic development. However, most of these industries were established by backward integration. This analysis therefore supports the notion that Backwards Integration is an appropriate model of the South African NSI.

Some tentative project level investigations were done to explore the innovation phenomenon at project level. Examples of such technological innovation case studies are Ansys’s Wheel Profile Monitoring System, Eskom’s prepaid electricity system, the Pebble Bed Modular Reactor and the Joule electric car.

Ansys dominates the local market in railway trackside measurement, which comprises both health/condition monitoring systems and automatic vehicle identification systems. The Wheel Profile Monitoring System consists of 14 high speed cameras and lasers that measure and record the dimensions of the wheels of passing rail vehicles and report its status by means of a remote data communication system. This innovation was the result of an international R&D partnership between Ansys and the overseas sensor technology supplier and can be classified as a Concurrent innovation.

In 1988 Eskom developed the "Electricity for All" concept and started the development of a basic prepayment system. The first enquiry for electricity dispensers was issued in 1989 and the South African Bureau of Standards produced the first national prepayment meter specification in 1990. During 1993 Eskom identified the need to standardise the vending systems and development was started in conjunction with Conlog to design and build the Common Vending System. Eskom’s prepaid electricity system is a typical Concurrent innovation.

The Pebble Bed Modular Reactor (PBMR) is a High Temperature Nuclear Reactor with a closed-cycle, gas turbine power conversion system. In 1998 Eskom launched a programme to develop the PBMR and PBMR (Pty) was founded. After the Government had spent R7 billion on the project, it decided in 2010 to no longer invest in the PBMR project and it was cancelled. The Pebble Bed Modular Reactor can be classified as a Forward Integration innovation for the local industry, although the technology originated in Germany and it involved a number of foreign partners. Overall, it can best be classified as a Concurrent innovation by an industry that was established by Backwards Integration. This case illustrates the difficulty of classifying a project as of any particular type.

The Cape Town based company Optimal Energy unveiled a full electric multi-purpose urban passenger vehicle named Joule to the world at the Paris Autoshow in 2008. In April 2009 Optimal Energy announced industrialisation plans to mass produce the vehicle in South Africa from 2012. This announcement came on the back of a further share issue to the Industrial Development Corporation, as well as the Government’s Innovation Fund. Optimal Energy shut down in July 2012 after R300 million was invested to develop the

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<th>Case study research</th>
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<td><strong>Positivistic paradigm</strong></td>
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<tr>
<td>• Static design: categories isolated before study</td>
<td>• Emerging design: categories identified during study</td>
</tr>
<tr>
<td>• Quantitative data</td>
<td>• Qualitative data</td>
</tr>
<tr>
<td>• Hypothesis testing</td>
<td>• Generating theories</td>
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<tr>
<td>• Reliability is high</td>
<td>• Reliability is low</td>
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<tr>
<td>• Validity is low</td>
<td>• Validity is high</td>
</tr>
<tr>
<td>• Generalises from samples to population</td>
<td>• Generalises from one setting to another or to theory</td>
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vehicle. The Joule electric car can be classified as a Forward Integration innovation.

The failure of the PBMR and Joule projects can be ascribed to the global economic recession and small local market for these products.

V. CONCLUSIONS AND RECOMMENDATIONS

National innovation surveys have provided us with a picture of the innovative behaviour of South Africa’s industry. These surveys should be repeated on a regular basis to provide longitudinal data for trend analysis. Sub-sector surveys indicate that there are major differences in innovation behaviour between the different sectors of the industrial base. Many more such surveys are required. Case studies of firms and innovation projects provide insight into the innovation phenomena at grass-roots level. This is important for explanation building and theory development.

In this paper an effort was made to answer the question: “What do we know and what we do not know about industrial innovation in South Africa?” In summary one can conclude that South Africa’s NSI has much in common with those of other countries. Examples are public institutions not being important sources of knowledge for innovations and the low utilisation of public funds for innovation. However, in many respects the South African NSI is uncommon and extraordinary. It is strongly embedded in international technology networks, whereas the level of embeddedness in national technological networks is weak. The ability of South African firms to produce innovation outcomes that are comparable to European levels with innovation efforts that are much lower than those of their counterparts - the input–output paradox - remains an enigma. The lack of empirical evidence for the proposition that the more effort (expenditure and human resources) is put into innovation activities, the more innovation output in the form of new and improved products will be realised, makes the input-output paradox even more puzzling. This proposition should be tested with other countries’ innovation survey data to see if this is a common phenomenon. South Africa’s low R&D expenditure also has implications for the theory of absorptive capacity building by R&D activity (Cohen and Levinthal's model). Answers to these vexing questions will only be found by much more research into the innovation phenomena of the South African NSI.

REFERENCES