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**Government R&D impact on the South African macro-economy**
**Radhika Perrot, David Mosaka, Lefentse Nokaneng and Rita Sikhondze**

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# Government R&D Impact on the South African Macro-economy[1]

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*This paper analyses the impact of government R&D on the macro-economy of South Africa. The empirical estimates of the impact of R&D are based on the backward and forward linkages of a macro-economy, within a national innovation system (NIS). There are structural implications of the study, namely how R&D investments can result in the creation of new industries, job creation and improved national productivity. The largest indirect impact of R&D expenditure by public institutions and agencies is on community services, financial and businesses and manufacturing, in terms of employment and contribution to the country's GDP. Community services are impacted through the backward linkages derived from the expenditure by various research institutions on intermediate inputs such as water, electricity and health. Describing and quantifying the linkages between research, development and innovation and economic impacts provides a basis for a greater understanding of the value the economy and its sectors derive from R&D. The results of the analysis indicates that the real economic significance of R&D lies not in spending, but in the results achieved and is measured in terms of contribution to innovation as a key determinant of economic and social wellbeing, productivity, and growth and development.*

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## 1. Introduction

Governments have sought to create knowledge-based economies by increasing the rate of transfer of academic and public research advances to industry since the 1970s, as part of broader efforts to improve national economic performance (Mowery and Sampat, 2005) and for nations to catch up in the global market of high-tech products (Gannon, 2003). In South Africa, core projections for the year 2018 were summarized in South Africa's "grand challenges" where innovation, science and technology were considered key in creating a knowledge-based economy, while solving its fundamental and pressing socioeconomic challenges to improve national economic performance and reduce unemployment.

Outlined in the New Growth Path (NGP) plan, 2011, South Africa plans to create 5 million jobs[6] in the next 10 years by enhancing national competitiveness and economic performance. However, there are fundamental bottlenecks and imbalances lurking the macro-economy. For instance, bottlenecks and backlogs in logistics, energy infrastructure and skills-availability were responsible for raising costs across the economy. If not corrected, these bottlenecks and imbalances may dampen efforts to achieve its desired employment, and with it, efforts in transforming to a knowledge-based economy. As a long-term structural change to remove bottlenecks and imbalances, the state is expected to increasingly support a knowledge-economy[7] (NGP, 2011).

To achieve these objectives, there is a need to focus on aligning the supply-side factors of innovation such as research and development (R&D) activities with the demand-side factors of innovation such as R&D commercialization, namely activities that transfer science and technology from the labs to the industry. R&D is linked to innovation indicators through the knowledge production function (Mairesse and Mohnen, 2004). R&D as a knowledge economy indicator (KEI) provides a measure of the relative state of the knowledge economy in a country (Gault, 2007; Blankey and Booyens, 2011). These KEI indicators such as R&D offer a bigger picture of a country's performance in the modern knowledge economy (Gault, 2007) and play a crucial role in national policy debates regarding science, technology and innovation (Freeman and Soete, 2009).

In recent years, there has been a growing interest in the measurement as well as the monitoring of the economic impact of knowledge-based indicators such as R&D (Gault, 2007). An economic impact of R&D will refer to its contribution in relation to economic growth, redistribution of resources at

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[6] The South African government is expecting to reduce current unemployment from 25.2% to 15% within the next 10 years.

[7] In addition, a Ten-Year Innovation Plan (2008-2018) proposes to drive South Africa's transformation towards a knowledge-based economy, in which economic growth is led by the production and dissemination of knowledge.

individual, local, regional, national and global levels and the development of human capital. The impact of these KEIs can be measured by their contribution to economic growth (GDP) at regional and national levels, contribution to employment and income earning at the household level, among others. R&D has been considered a principal knowledge indicator and standardized by OCED (OCED, 2011). Several studies have shown that R&D is a reliable indicator of innovative capacity (Boskhin and Lau, 1992; Blankey and Booyens, 2011) and it impacts economic growth (Fagerberg, 1994; Ho and Wong, 2009) and productivity (Griliches (198, 1994 &1998) and Griliches and Lichtenberg (1984).

In 2008, South African R&D expenditure as a percentage of GDP was 0.93% (World Bank Statistics, 2012). South Africa shows strong investment in R&D intensive industries, including pharmaceuticals, electronics, aerospace, biotechnology, nanotechnology and open source software, and R&D in these industries accounted for about 22.9% of GERD in 2008  (R&D Survey, 2010). However, despite a good level of R&D expenditure on high-tech and R&D intensive industries, the innovative or knowledge-generation performance of the country has remained low (Blankey and Booyens, 2011). There is an inherent 'systemic' inability to increase the rate of transfer of academic research advances to industry, and thus provide a stimulus to its competitiveness, resulting in increased economic activities in various sectors and employment.

Against this background, a macro-economic impact study of South Africa's R&D is considered timely, as this study assesses the relationship between macro-economic factors and R&D. There are few studies measuring the impact of R&D in developing countries (Ho and Wong, 2009) because of the difficulty of collecting measuring R&D and innovation, and non-consideration as an important policy tool. This study will measure how R&D expenditure has impacted macro-economic factors such as employment, capital formation, and income, among others. In this study, the impact of public or government R&D is assessed, and not R&D expenditure by businesses[8]. This study has highlighted sectoral-impacts, indicating the economic sectors which will have the most beneficial and/or negative impact of government R&D expenditure. The impact is assessed in terms of its contribution, for example, to the national GDP, job creation and productivity, as they are key policy debates in South Africa.

This paper is structured as follows. Section 2 following the above introductory section is on the role of R&D expenditure within a NIS. Section 3 briefly discusses government R&D expenditure trend in South Africa. Section 4 discusses the Social Accounting Matrix (SAM) Input Output (IO) model and its limitations, and variables of the model. Section 5 discusses the results of the model and Section 6 is the conclusion with implications for future research.

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[8] Defined as per the terms of reference defined by research study commissioned by DST

## 2. R&D Expenditure and NIS

Innovation, technology and economic development are considered the result of a complex set of relationships among actors and institutions within a national system (Freeman, 1987; Lundvall, 1992; Freeman, 1995) and within sectors of an economy (Malerba, 1999). Such a systemic approach is lending new insight into the innovative and economic performance of OECD countries, and more recently, in developing countries. The NIS approach posits that economic improvement in a country is largely a result of the application of knowledge in productive activities and the associated adjustments in social institutions. Lundvall and colleagues speculate that NIS thinking gained ground, in part, due to the fact that "mainstream macroeconomic theory and policy have failed to deliver an understanding and control of the factors behind international competitiveness and economic development" (Lundvall, 2002: 214).

For decades, technological change and innovation, driven by research and development (R&D) within a NIS have been the most important sources of productivity, growth and increased welfare (Edquist, 2000). As a result, there is a high correlation between those countries that have shown significant economic improvement in the past and those countries that have made substantial investment in R&D. A growing number of studies are proving the value of innovation as an outcome of R&D to the economy, and which drives socio-economic transformation and rapid progress to development. R&D and innovation has a strong link within the processes of countries, regions and firms (Schumpeter, 1934; Rosenberg, 1982; Freeman, 1987; Fagerberg, 1988; Perez and Soete, 1988). Current theoretical debates recognize R&D and innovation as the engine for growth and as offering substantial potential for achieving developmental effects (Cassiolato et al., 2003; Rosenberg, 2004; Fagerberg et al., 2004; Metcalfe and Ramlogan, 2008).

However, it must be understood that the relation between innovation and economic development is complex (Kraemer-Mbula and Wamae, 2010) and develops in each country with its own dynamics and processes leading from investments in R&D and innovation (supply-side factors) up to the stage of commercialization (demand-side factors). South Africa's transformation towards a knowledge-based economy implies that economic growth will be led by the way in which the NIS produces and disseminates knowledge. The performance of an NIS is measured by the degree to which science and technology plays a driving role in enhancing productivity, economic growth and socioeconomic development.

And therefore, to achieve its objectives of a knowledge economy, South Africa has to focus on aligning the supply side factors of innovation (i.e. the stimulation and support of research, development and innovation (RD&I) with the demand side factors of innovation (i.e. commercial

activities of RD&I as well as increasing its market intelligence capabilities). Such a view is based on the framework of a national innovation system, which assists policy-makers in aligning the supply-side (or technology push) factors with the demand-side (or technology push) factors.

Critical changes will be required to transform South Africa into a knowledge-intensive economy – namely an effective NIS which continuously supports knowledge generation and dissemination (Blankey and Booyens (2011). Although there have been significant changes and achievements in the South African NIS, "what is missing, however, is across the board efforts to enlarge the national system of innovation." (Pouris 2010: 224). R&D expenditure is increasingly viewed as a process through which a nation's knowledge base and inputs are enlarged and the NIS is within whose parameters the search for knowledge and expansion happens.

## 3. Impact of Government R&D in the South African Economy

Total R&D expenditure includes a mix of business, and government funding for R&D in sectors such as defense, health, water, electricity and space. Government R&D provides insights into government R&D priorities, having indirect impact on the South African economy. The indirect impact consists of backward and forward linkages. The backward linkages includes the impact derived from R&D expenditure by the various research institutions on intermediate inputs such as water, electricity, business services, as well as consumption expenditure derived from the payment of salaries and wages to scientists and other researchers.

The forward linkages originate from spending by industries and institutions that form part of the research and development cluster. According to the South African National Treasury, the budget of the various public institutions and agencies involved in research, development and innovation was R9.017 billion for the 2011/12 financial year. The R&D expenditure of public institutions and agencies has significant multiplier effects on the South African economy as illustrated in the model results of Table 2 below.
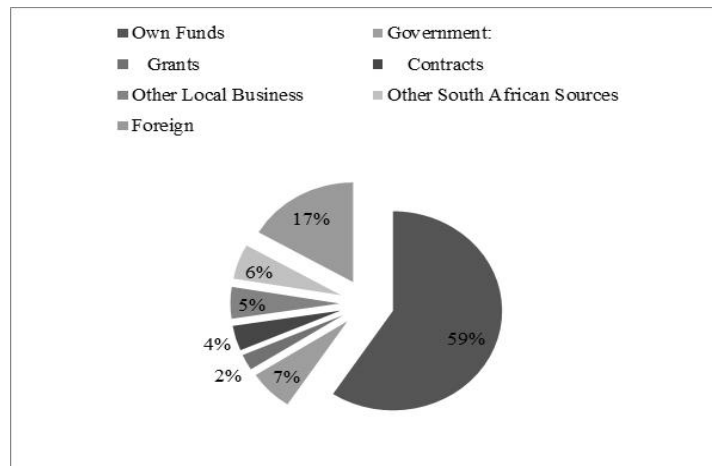
Figure 1: Sources of total R&D funds in South Africa

Source: R&D Survey, 2010

As illustrated in Figure1 above, approx. 60% of all R&D expenditure by business enterprises is solicited from their own sources of funding, followed by foreign sources at 7%. The government of South Africa funded 17% of the R&D projects in 2008/2009. In South Africa, the combined funding offered by the Innovation Fund, THRIP and the Support Programme for Industrial Innovation (SPII) is less than R500 million, not all of which goes to the business sector. Considering that the 2008 innovation survey showed that enterprises spent about R56.9 billion on innovation activities, the public funding available for innovation in industry represents less than 1% of business expenditure on innovation activities. Public funding for R&D activities in the business sector appears to be far better supported, and the 2007/08 R&D Survey reported that 21.7% of business R&D expenditure was supported by government sources.

The results of the 2008 innovation survey also suggest that the majority of innovative enterprises in South Africa still have limited, if any, access to public funding to support their innovation activities. An analysis of these findings indicates that in order to provide public funding to 20% of innovative enterprises, the South African government would have to fund a total of 2 986 enterprises – 251 enterprises from the largest size group, 660 medium-sized enterprises, 1 022 small enterprises and 1 053 very small enterprises. Currently, about 11.4% of enterprises in the large enterprise group, 13.5% medium-sized enterprises, 0.3% small enterprises and 0.1% very small enterprises are funded from public sources. Slightly higher percentages of innovative enterprises received funds from South African government sources than reported in the 2005 innovation survey.
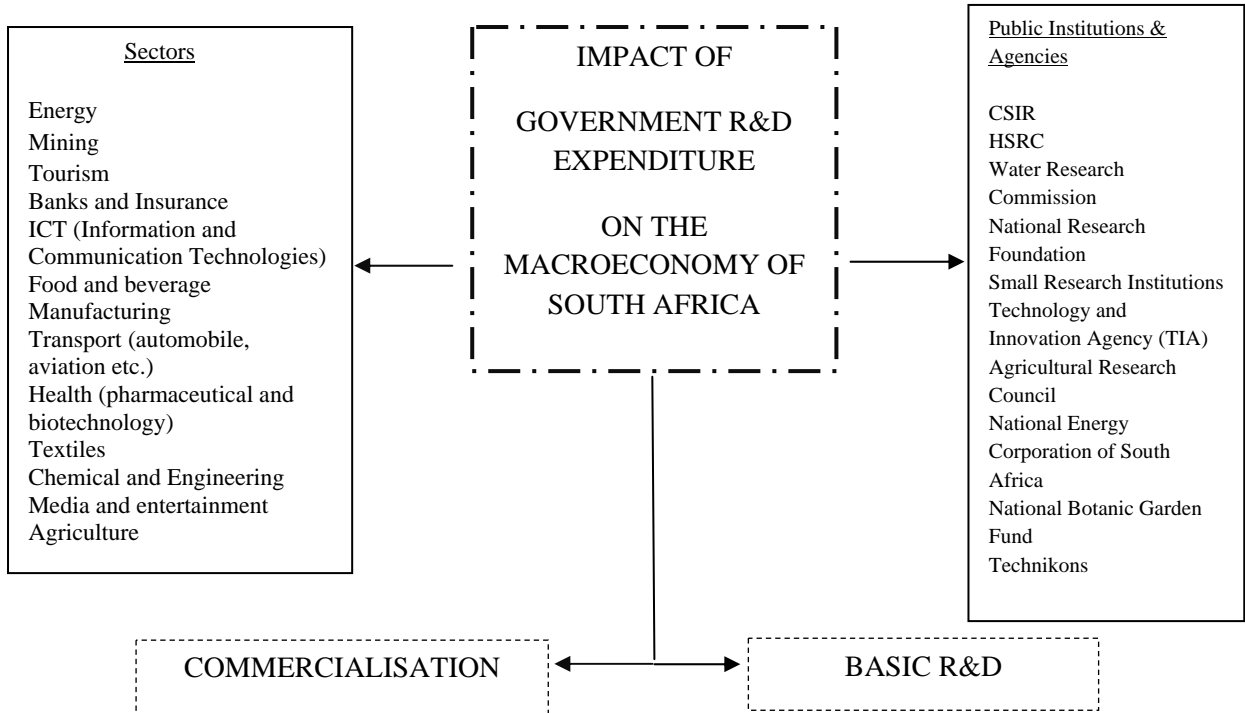
BACKWARD LINKAGES ← IMPACT → FORWARD LINKAGES

Sectors

Energy
Mining
Tourism
Banks and Insurance
ICT (Information and Communication Technologies)
Food and beverage
Manufacturing
Transport (automobile, aviation etc.)
Health (pharmaceutical and biotechnology)
Textiles
Chemical and Engineering
Media and entertainment
Agriculture

IMPACT OF GOVERNMENT R&D EXPENDITURE ON THE MACROECONOMY OF SOUTH AFRICA

Public Institutions & Agencies

CSIR
HSRC
Water Research Commission
National Research Foundation
Small Research Institutions
Technology and Innovation Agency (TIA)
Agricultural Research Council
National Energy Corporation of South Africa
National Botanic Garden Fund
Technikons

COMMERCIALISATION ← → BASIC R&D

Figure 2: Framework analysing the impact of government R&D on the South African macro-economy

Source: Authors' Own

From a national or NIS perspective, the economic impact of research and development is much more important than measures of direct financial return. This is because in the case of government funded research and development, any financial return to the government is indirect, acquired through the tax system (flowing from increased employment, competitiveness, domestic sales and exports) or from reduced expenditure that results from increases in the efficiency and effectiveness of government service delivery. In most cases these are not easily attributable to any particular project.

## 4. The R&D Impact Model: Methodology

### a. The Input Output (IO) Model (Social Accounting Matrix)

A SAM macroeconomic model assesses flows of all economic transactions that take place within an economy - at the regional or national levels (Stone and Brown, 1962; Pyatt and Round, 1988; and Vanoli, 2005). However, it has been extended to include non-national accounting flows. The tool has found wide application in measuring the impacts of policy decisions and government expenditure on an economy-wide basis. For instance, it helps in assessing economy-wide changes in the cost of importing new technology or understanding the impact of R&D on the economy. SAM is also referred

to as a Leontief's Input Output[9] (IO) model which is a partial general equilibrium model and can be used, to quantify the direct, indirect and induced impacts resulting from government research and development.

An I-O framework (measuring the impact of government R&D expenditure in this case) and equations can be thought of as a simple model of the economy that captures the way in which economic sectors interact, both in terms of the flow of goods and services, and in terms of prices. The flows across the macro-economy are represented as *backward* and *forward* linkages. An Input Output model equation is represented as follows:

$$q = (I-A)^{\wedge}(-1) \times f$$

Where,

| | | |
|---|---|---|
| q | = | Sectoral production |
| (I-A)-1 | = | Inverted input/output coefficients matrix |
| f | = | Final Demand per sector |

Using these basic mathematical relationships, also known as technical/economic coefficients, the impact multipliers[10] can be calculated. The nature and extent of the impact of an autonomous change in a specific economic quantity such as, for example, R&D expenditure, on another economic quantity or quantities, for instance production or employment, will be defined in terms of the multiplier concept.

The IO Model is used here as an econometric model to calculate *backward* as well as *forward* linkages. Backward linkages explain the government R&D efforts directly and indirectly associated with a specific's industry final demand (consumption, investment or exports). Forward linkages, on the other hand, explain by what proportion the output value of an industry should increase as a consequence of a unitary increase of another industry's costs (R&D). The multiplier effect also takes into account the direct, indirect and induced impacts of R&D expenditure. The model allows for the calculation of the impact of R&D expenditures on several sectors of the economy.

There are number limitations when analysing innovation using this approach. The degree to which technological knowledge spreads through the economy depends on the level of economic and technological interdependence among sectors. The structure of production and its linkages is usually

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[9] An input-output model is a quantitative economic technique that represents the interdependencies between different sectors of the national economy or between sectors of different, even competing economies. An I/O-table is nothing more than an extension of the national accounts of a country, i.e. disaggregating it into the various sectors of the economy.

[10] A multiplier is a factor of proportionality that measures how much an endogenous variable changes in response to a change in some exogenous variable.

used as a point of departure when analysing R & D spillovers. The input-output process is a linear model but there are "changes" to an output which takes place, thus overcoming a major IO criticism. A fundamental assumption of the IO-model, as well as its use for analytical purposes is, firstly, that it production activities are grouped into homogeneous sectors. Secondly, it is necessary that the mutual inter-dependence of sectors which features in the model can be expressed in input functions.

Using this approach it is possible to establish business linkages that create links from research outputs to societal value. Thus the Input – Output model allows for a possible analysis of the effect of R & D expenditure by other sectors. This could have interesting policy implications, because it can for instance show which sectoral R & D expenditure can induce larger direct and indirect effects.

### b. Data Sources and the Variables

To measure the impact of R&D expenditure on the structure or the macro-economy of South Africa, a number of indicators and measures were used. The independent impact variables fall under two categories - backward and forward linkages. The various indicators of a knowledge economy, is described briefly, and as defined by OCED (2011) include:

(i)    Macroeconomic Aggregates: Impact on Gross Domestic Product; Impact on capital formation; Impact on Household Income; Fiscal Impact; and Impact on the Balance of Payments (BoP)

(ii)    Sectoral Impacts: Impact on the sectors of the economy

### Government R&D

This study uses government R&D expenditure to analyse its impact on the macro-economy, namely the variables used above. Government R&D budgets provide an indication of the relative importance of various socioeconomic objectives, such as defence, health and the environment, in public R&D spending. It measures the funds committed by the national government for R&D to be carried out in one of the four sectors of performance – business enterprise, government, universities, public research organizations, private non-profit – at home or abroad (including by international organizations). The government R&D expenditure data are based on South African budgetary sources.

### Employment

The employment indicator was informed by Human Resource Science and Technology Data, where the chosen category of workers is considered major actors in innovation. The chosen category of workers corresponds to professionals and technicians as defined in the International Standard

Classification of Occupations (ISCO-88) major groups 2 and 3. Details of this group of professionals and technicians are provided in the Appendix section.

*Capital Stock*

Capital stock as an outcome indicator of R&D is one of the main inputs of production. Capital goods range from fixed assets such as buildings, roads, and machinery, to intangible items such as software and exploration rights. Measures of capital stock provide a snapshot of capital assets available for use in production at a point in time, as well as a forward-looking measure of the economy's potential performance. In recent years, the fixed capital stocks of countries have occupied an important place in economic policy and economic growth debates. Measures of a country's stock of capital provides the basis for measuring national wealth, and understanding factors that underpin growth, such as advances in productivity, technical progress, and efficiency.

*Technology BoP*

Technology balance of payments (BoP) measures international technology transfers such as licence fees, patents, purchases and royalties paid, know-how, research and technical assistance. These are payments for production- ready technologies. Although the balance reflects a country's ability to sell its technology abroad and its use of foreign technologies, a deficit does not necessarily indicate low competitiveness. In some cases, it results from increased imports of foreign technology; in others, it is due to declining receipts. Likewise, if the balance is in surplus, this may be due to a high degree of technological autonomy, a low level of technology imports or a lack of capacity to assimilate foreign technologies.

## 5. Results

According to National Treasury (2011), the budget of the various public institutions and agencies involved in research, development and innovation in South Africa was R9.017 billion for the 2011/12 year as shown in Table 1 below.

Table 1: R&D Expenditure by various South African research centres, in Rand million

| South African Researc | 2007/2008 | 2008/2009 | 2009/2010 | 20010/2011 | 2011/2012 |
|---|---|---|---|---|---|
| CSIR | R 517 | R 555 | R 599 | R 686 | R 687 |
| MRC | R 485 | R 494 | R 501 | R 575 | R 580 |
| ARC | R 718 | R 778 | R 773 | R 827 | R 892 |
| DST | R 2 929 | R 3 403 | R 3 821 | R 4 207 | R 4 407 |
| DST-DA | R 529 | R 853 | R 1 141 | R 827 | R 855 |
| ASA | R 3 | R 6 | R 10 | R 11 | R 11 |
| AISA | R 27 | R 30 | R 29 | R 31 | R 32 |
| HSRC | R 156 | R 164 | R 166 | R 194 | R 206 |
| NRF | R 658 | R 683 | R 692 | R 749 | R 1 089 |
| SANER | R 42.00 | R 44.27 | R 0.00 | R 0.00 | R 0.00 |
| SANSA | R 0.00 | R 0.00 | R 0.00 | R 0.00 | R 93.58 |
| Tshumisano Trust | R 49.50 | R 36.60 | R 36.44 | R 0.00 | R 0.00 |
| WRC | | | | | R 164.10 |
| TOTAL | R 6 113 | R 7 046 | R 7 769 | R 8 106 | R 9 017 |

Source: National Treasury, 2011

It is evident in Figure 3 below that expenditure on research and development by public institutions and organizations that undertake scientific and technological activities has grown significantly over the past five years.
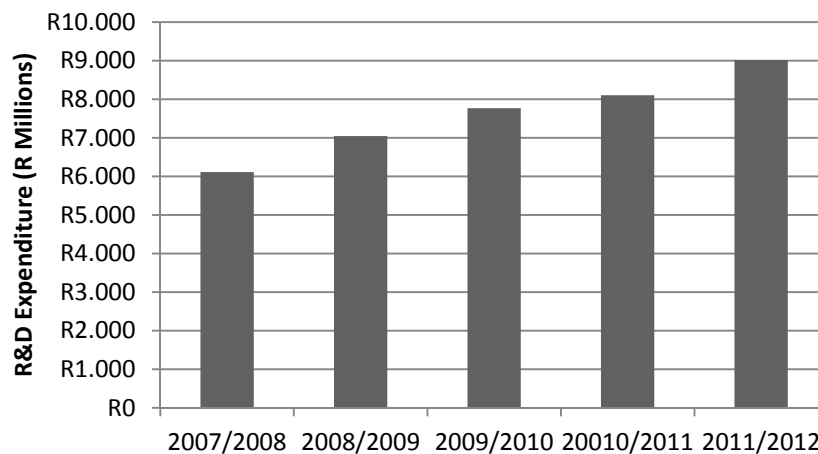


Figure 3: Expenditure on R & D by public institutions and organizations, R Millions

Source: Authors' Own Data
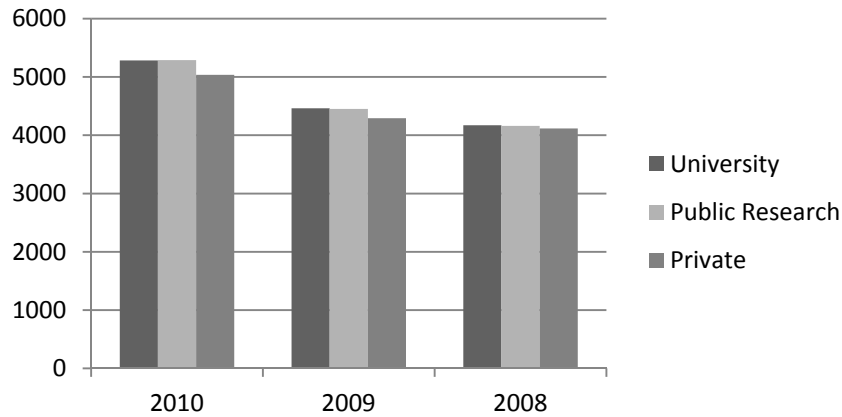
Figure 4: Share of research output measured in scientific publications or bibliometric data of South African universities, public research organizations and private enterprises in 2008 to 2010

Source: Web of Science (2011)

Universities, public research organizations and private enterprises have contributed almost equally to the scientific output of South African research as indicated in Figure 4. The number of contributions has increased each year between 2008 and 2010. It is interesting to note that although private firms contribute a significant 59% of the total R&D expenditure in South Africa (HSRC, 2010) its engagement in scientific and research output is equivalent to the research contributions of public research organizations and universities. This is mainly attributed to the experimental development type of R&D activity undertaken by firms in South Africa, which often does not warrant publications.
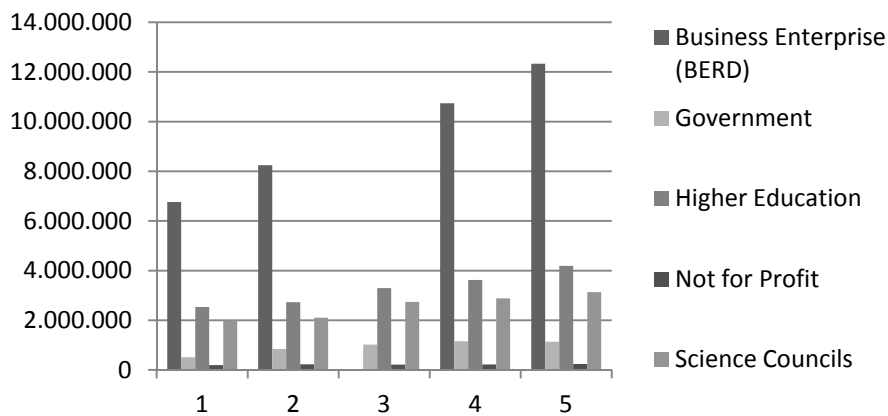


Figure 4: Sector-wise R&D expenditure (in Rand) in South Africa HSRC R&D Survey, 2010

Figure 4 above illustrates the sector-wise R&D expenditure in South Africa, where the business sector exceeds the combined spending by the government, universities and science councils in the country.

**Table 3: Impact of R&D Expenditure using the SAM-IO model (Rand million)**

| | Macroeconomic Impact of government R&D | | | |
| --- | --- | --- | --- | --- |
| | Direct impact | Indirect impact | Induced impact | Total impact |
| Impact on Gross Domestic Product | R 2 228 | R 2 371 | R 3 657 | R 8 255 |
| Impact on capital formation | R 9 000 | R 5 017 | R 8 343 | R 22 360 |
| Total impact on employment [job opportunities] | 7 672 | 12 584 | 19 645 | 39 900 |
| Skilled impact on employment [job opportunities] | 4 910 | 4 286 | 5 412 | 14 608 |
| Semi-skilled impact on employment [job opportunities] | 1 995 | 6 086 | 10 120 | 18 200 |
| Unskilled impact on employment [job opportunities] | 767 | 2 212 | 4 113 | 7 092 |
| Impact on Households | | | | R 6 039 |
| Low Income Households | | | | R 859 |
| Medium Income Households | | | | R 1 203 |
| High Income Households | | | | R 3 977 |
| Fiscal Impact | | | | R 2 482 |
| National Government | | | | R 2 267 |
| Provincial Government | | | | R 29 |
| Local Government | | | | R 185 |
| Impact on Technology Balance of Payments | | | | R 3 602 |

Source: Authors' own

Table 3 above shows that the expenditures on R&D by public institutions and agencies have major multiplier effects on the South African economy. The economic impacts associated with such expenditure are assessed and estimated for the following dimensions (macroeconomic assessment criteria). The impact of government expenditure on the macro-economy of South Africa can be summarized as follows:

- The average annual impact of the R&D expenditure by public institutions and agencies on the GDP of South Africa will amount to R8.2 billion in 2011 prices. Thus, each year, R8.2 billion of GDP will be generated consisting of remuneration of employees and returns on capital

- The impact on capital formation associated with the investment and operation of all activities related to R&D expenditure by public institutions and agencies, was estimated to be R22.36 billion per annum. This implies that R22.36 billion of capital (productive capacity) is required on an annual basis to sustain all activities related to R&D expenditure by public institutions and agencies. However, this is not an additional R22.36 billion each year, but rather the magnitude of productive capital stock that needs to be available on an annual basis

- On an annual basis, R&D expenditure by public institutions and agencies sustains 39 900 job opportunities (direct, indirect and induced).

- The total impact on household income amounts to R6.039 billion of which 14% is earmarked for the lower-income households and 20% for middle-income households. Thus, of the total income generated directly and indirectly through the R&D expenditure by public institutions and agencies, a significant percentage of it will reach the poor communities in South Africa. The impact on the low income households comes through the linkages that the R&D expenditure by public institutions and agencies has on other sectors of the economy

- The annual fiscal impact will amount to approximately R2.48 billion per annum through direct and indirect taxes due to the activities related to R&D expenditure by public institutions and agencies. All these additional taxes provide the government with revenues that can be used to improve the average quality of life of the average citizen in South Africa, in particular, education and health

- The impact on the Balance of Payments is a positive R3.60 billion per annum over the lifespan of the activities related to R&D expenditure by public institutions and agencies

The impact of government R&D has found to have impacts on nine sectors of the South African economy. The results depict that the total effect is more profound in the community services (health, water, sanitation, conservation activities etc.), financial and business services, as well as the manufacturing sectors. It is interesting to note that the financial and business services sector is impacted to a greater extent in terms of GDP than the trade-related sectors. However the reverse is true with regards to employment creation as the trade related sectors are more labour intensive than the financial and business services sector.
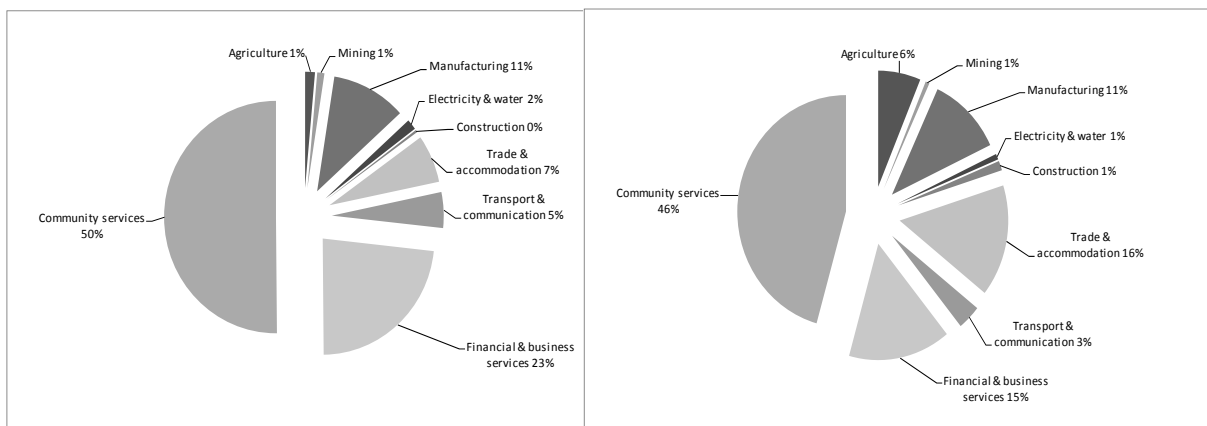


Figure 4: Industrial Sectors by government R-D Expenditure in terms of GDP growth (left) and in terms of employment (right). All figures in percentage                                        Source: Authors' Own

As it can be also deduced that government R&D expenditure has major multiplier effects on the South African economy, calculated in terms of GDP, employment and capital Formation. Given that capital

is a scarce resource in South Africa, the criteria measures the effectiveness of capital utilization in terms of employment, creation and contribution to GDP, relative to the rest of the economy.

## 6. Discussion & Conclusion

This study provides a comprehensive analysis of the economic impacts associated with research and development efforts of the South African economy, and quantifying such impacts is where the study primarily contributes. The key focus of the paper is how the benefits of research, development and innovation are derived and translated into tangible opportunities for society and the economy in particular. As part of this process, understanding that R & D spillovers are unanimously considered as one of the main driving forces of technological change, innovation and economic growth is of great importance.

The findings are based not only on  aspects of government funding through science and research councils, but by a broader understanding of the evidence based on the economic impact of research, development and innovation covering a cross-section of variables. Given the well-understood challenges in assessing impact, our findings are satisfactory in their nature and hope to present more than a glimpse of the full impact of the research and development. Despite the breadth of this paper it has not yet been possible to establish a baseline which will enable a judgement on the extent to which impacts in future years will have risen or fallen. This challenge arises as a result of the constraints of finding up to date data and surveys.

There are a wide range of methods used to evaluate R&D impact – operating at the level of individual projects or programs, institutions and nations with each method with its own characteristics and advantages. While different methods can appeal to different target groups, none is complete in itself and none offers unambiguous or certain results. Studies of the same project or program at different times or across different time spans can produce widely varying results, reflecting the uncertainty of research and the way in which the value of research outputs can change, depending on the context within which they exist – including subsequent advances in research. Measuring the impact of R&D is necessary and can be useful but it is important to use the results of such evaluations with care, recognizing their fragility. Certainly, challenges are numerous and adequate solutions still have to be developed to address the methodological issues. Implicitly the preferred methodological approach was informed by the innovation literature and the selected approach was based on Input-Output modelling (Social Accounting Matrix). According to both local and international literature, IO-Model finds wide application in the evaluation of the impact of R-D on the economy.

The total income generated directly and indirectly through R&D expenditure, a significant percentage of it will reach the poor communities in South Africa, followed by the financial and businesses and manufacturing sectors, in terms of employment and contribution to the country's GDP. Community

services are impacted through the backward linkages derived from the R&D expenditure by research institutions on intermediate inputs such as water, electricity and health. It is worth noting that the impact on the low income households comes through the linkages that the R&D expenditure by public institutions and agencies has on other sectors of the economy.

The results have shown positive and significant impact with government R&D expenditure generating R8.2 billion of GDP, comprising remuneration to employees and returns on capital, and on an annual basis, R&D expenditure by public institutions and agencies will sustain 39 900 jobs, through direct, indirect and induced effects. The impact on the Balance of Payments is a positive R3.60 billion per annum over the lifespan of the activities related to R&D expenditure by public institutions and agencies.

An important contribution of this study is the development of an analytical model that can provide a comprehensive analysis of economic impacts associated with R&D, and not specifically government R&D, for the South African economy. Describing and quantifying the linkage between research, development and innovation and economic impacts provides a basis for a greater understanding of the value which the economy and its communities derive from research, development and innovation. The results of the analysis indicates that the real economic significance of the resources devoted to R & D lies not in spending, but in the results achieved and is measured in terms of contribution to innovation as a key determinant of economic and social wellbeing, productivity, growth and development.

Future NIS research is expected to focus on improving the indicators used to map interactions in national innovation systems as well as the linkages to the innovative performance of firms and countries. These indicators are at an early stage of development and do not approach the robustness of more conventional measures such as R&D expenditures (OCED, 1997). This paper is one such study focusing on non-conventional macroeconomic indicators in mapping the interactions of the South African national innovation system.

The IO-model allows for the calculation of the impact of government R&D expenditures in several sectors of the economy. This can be used to analyse policy implications, because it shows which sector's R&D expenditures induces the largest direct and/or indirect effects. The business sector, for example, can be identified as one of the impact multipliers, providing the mechanisms through which research outputs can be transformed into products and processes that impact upon society. Through this modelling approach it is possible to establish business linkages that create links from research outputs to societal value.

An area for further research in South Africa is to compile an IO-model that could separately distribute R & D expenditure on each sector by product or technology. It will go a long way in enhancing the

process to separately identify the effect of industrial linkages and therefore the effect of R & D efforts.

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