MEASUREMENT OF GREEN ECONOMY RESEARCH AND DEVELOPMENT 2010/11-2016/17

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Trade & Industrial Policy Strategies (TIPS) is a research organisation that facilitates policy development and dialogue across three focus areas: trade and industrial policy, inequality and economic inclusion, and sustainable growth

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Executive summary

In 2015, Trade & Industrial Policy Strategies (TIPS), at the request of the then Department of Science and Technology, undertook a project to define 'green research and development (R&D)' and determine the levels of green R&D investment in South Africa. This was a first-of-its-kind endeavour in South Africa but also globally. In collaboration with the Centre for Science, Technology and Innovation Indicators (CeSTII) at the Human Sciences Research Council (HSRC), TIPS worked to extract the green R&D component of the country's annual R&D survey results. In 2019, TIPS was requested by the Department of Science and Innovation (DSI) to update and, where possible, enhance the initial 2015 research. The purpose of the study was to assess progress made towards the Medium-Term Strategic Framework (MTSF) target set by DSI for the period 2014-2019. While the principles and definitional framework remained the same as the 2015 study, TIPS, in collaboration with the DSI and CeSTII, refined the understanding of green R&D in 2019.

This report not only provides the adjusted figures for the 2010/11-2012/13 period but also shows the trends in green R&D expenditure over seven years, from 2010/11 to 2016/17. The relevance and accuracy of the estimates for green R&D expenditure were ensured through a two-phase approach:

- First, the research relied on a collaborative approach between DSI, CeSTII and TIPS (as in 2015) to provide a consistent green R&D definition and selection of codes;
- Second, the research worked on a seven-year period, using results from the annual R&D survey data. With a questionnaire response rate of up to 68.9% in the latest iteration used for this report (2016/17), the R&D survey provides the most comprehensive and appropriate current source of data for determining R&D expenditure in the country. Other available sources on relevant green economy expenditure simply do not provide adequate information on R&D expenditure in particular.

According to the R&D statistical survey results between 2010/11-2016/17, the gross domestic expenditure on R&D (GERD) in South Africa stood at R20.3 billion in 2010/11 and R35.7 billion (in nominal terms) in 2016/17. In real terms (in constant 2016/17 prices), the GERD was R28.3 billion in 2010/11 and R35.7 billion in 2016/17, growing at a compound annual growth rate (CAGR) of 3.4% over the period.

For the current Medium-Term Strategic Framework (MTSF) period from 2014-2019, the target was to maintain the rand value of investments in green economy-related R&D made in 2011. Green R&D expenditure is reported in two distinctive frameworks: research fields (RF codes) and socio-economic objects (SEO codes). RF indicate the scientific domain of the R&D, while SEO indicates the area where the R&D is intended to be used/applied. Both public and private sector have expenditure in RF and SEO.

For the 2010/11 year, in nominal terms, green R&D expenditure in South Africa was estimated at R4.5-R5.1 billion in 2019 (compared to a slightly higher estimate of R4.8-5.3 billion in 2015). In 2016/17, green R&D expenditure, in nominal terms, reached R6.1-R7.1 billion. In real terms, this corresponds to a 35%-39% increase over the period. In nominal terms, this rises to 88%-94%. In real terms, green

R&D had a CAGR between 4.3%-4.8% from 2010/11-2016/17. The green share of R&D stood at 16%-18% in 2010/2011 and slightly increased over the period to between 17%-20% in 2016/17.

Public sector expenditure in 2010/11 was between R3.0-R3.8 billion and increased to between R4.2-R5.5 billion in 2016/17 in real terms. Over the period, it grew by 5.0%-5.3% on a CAGR. Public sector expenditure accounted for 70%-77% of green R&D compared to 23%-30% by the private sector in 2016/17. While total private sector expenditure was between R1.3-R1.5 billion in 2010/11, expenditure increased to between R1.6-R1.8 billion in 2016/17, at a CAGR of 2.8%-3.0%.

The top three disciplinary fields in terms of RF codes, namely agricultural sciences, biological sciences, and environmental sciences, accounted for 68% of green R&D expenditure in 2010/11. This grew to 72% in 2016/17. The agricultural sciences RF represented 40% of green R&D in 2010/11 and grew to 44% in 2016/17. While the biological sciences were the second largest RF in green R&D with a 17% share of expenditure in 2010/11, this declined to 12% in 2016/17, making it the fourth largest. Environmental sciences were the third largest RF in 2010/11, with an expenditure share of 11%, however, this increased to 16% in 2016/17, making it the second largest. The earth sciences were the fourth largest RF in 2010/11, with a share of 10%, but this increased to 13% in 2016/17, making it the third largest.

Based on SEO codes, the top three sectors, accounting for 55% of green R&D in 2010/11, were plant production and plant products (27%), natural sciences, technologies and engineering (18%), and natural resources (10%). However, in 2016/17, the top three disciplinary fields, namely plant production and plant products (22%), environmental knowledge (14%), and natural resources (12%), accounted for 48% of green R&D. Environmental knowledge in particular grew the most (in shares) over the seven years from 8% in 2010/11 to 14% in 2016/17. The share of energy supply SEO declined from 9% in 2010/11 to 6% in 2016/17, and environmental management and other aspects SEO share doubled (in shares) in one year from 5% in 2015/16 to 10% in 2016/17.

Recommendations for further work in green R&D measurement involve elaborating on a detailed book of code descriptions for both RF and SEO codes used by CeSTII. While the R&D survey is designed according to the international Frascati guidelines, the interpretation and meaning of the various codes used is currently the tacit knowledge of CeSTII staff and has not been captured explicitly. The development of new data streams that would be based on surveys developed beyond the annual R&D survey is another avenue that would create an opportunity for more structured green economy-specific surveys. Furthermore, other innovative ways of collecting information on green R&D could be envisaged, for example through a Voluntary Green Index, or by developing a broader economy-wide green innovation model. In terms of the scope and purpose of the estimate for green R&D expenditure, however, this project has provided (in 2015) and refined (in 2019) a first-ever assessment for green R&D in South Africa and serves as a starting point in measuring and strategically supporting green economy efforts in R&D and innovation interventions.

Overall, R&D expenditure in South Africa is still insufficient to fast-track the transition to a green economy. Further efforts are required to spur R&D investment overall, and green R&D specifically. Particularly attention should be paid to foster investment by the private sector as well as diversify the fields of green R&D expenditure.

Historically, only an overall target for R&D expenditure (1.5% of GDP) has been used to benchmark progress in the field. For reference, in 2016, R&D expenditure reached 0.82% of GDP in South Africa. This study enables the use of another metric, focused on green R&D. It did not, however, venture into measuring investment in innovation or the impact of expenditure spending. To determine strategic ways of supporting green R&D in the country, further work is needed to better understand the green R&D and innovation value chain. The measurement of green R&D is but one input measure in a complex set of factors that make up both the innovation system and the enablers for a green economy transition. This work is the beginning of a discussion on the role of innovation and R&D in the transition to a green economy.

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Abbreviations

CAGR	Compound Annual Growth Rate
CeSTII	Centre for Science, Technology and Innovation Indicators
DEFF	Department of Environment, Forestry and Fisheries
DPME	Department of Performance Monitoring and Evaluation
DSI	Department of Science and Innovation
EDD	Economic Development Department
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on Research and Development
HSRC	Human Sciences Research Council
MTSF	Medium-Term Strategic Framework
NDP	National Development Plan
NPC	National Planning Commission
R&D	Research and Development
RF	Research Field
SEO	Socio-Economic Objectives
TIPS	Trade & Industrial Policy Strategies
UNDESA	United Nations Division for Sustainable Development
UNEP	United Nations Environment Programme

1. Introduction

The transition to a green economy has globally been acknowledged as the pathway to sustainable development. The shift to a green economy provides a blueprint to address the many challenges faced by countries across the globe, such as climate change, poverty, inequality and unemployment. In South Africa, the transition to a sustainable future (which is notably carbon constrained) requires the decoupling of economic growth from natural resource degradation and depletion. The National Development Plan (NDP) (NPC, 2012) and more specifically the MTSF 2014-2019, under Outcome 10 (DPME, 2014), states the need to "protect and enhance our environmental assets and natural resources". The NDP made a clear long-term vision that, by 2030, South Africa's transition to an environmentally sustainable, climate change resilient, low-carbon economy and just society will be well under way (NPC, 2012: 199). To achieve this halt on environmental degradation, and to encourage more sustainable growth, there is a need to build human capital and a technological base to implement programmes that will grow the economy without increasing South Africa's emissions profile and other environmental externalities.

Five sub-outcomes for achieving the protection and enhancement of South Africa's environmental assets and natural resources are identified in the NDP:

- Sub-outcome 1: Ecosystems are sustained and natural resources are used efficiently;
- Sub-outcome 2: An effective climate change mitigation and adaptation response;
- Sub-outcome 3: An environmentally sustainable, low-carbon economy resulting from a well-managed just transition;
- Sub-outcome 4: Enhanced governance systems and capacity; and
- Sub-outcome 5: Sustainable human communities.

Under Sub-outcome 3, the DSI, in partnership with the Department of Environment, Forestry and Fisheries (DEFF) and National Treasury, has committed to maintaining investment in research, development and innovation to support the transition to a green economy. The indicator for this commitment is to monitor the rand value of public and private sector investment in R&D supporting a green economy. For the current MTSF period from 2014-2019, these departments are targeting to maintain the rand value of investments in green economy-related R&D made in 2011.[1] The choice of the 2011 start date for assessment arises from the signature and development of the Green Economy Accord (EDD, 2011) and the country's National Strategy for Sustainable Development and Action Plan 2011-2014 (DEA, 2011), endorsed by Cabinet. This 2011 choice also builds from prior collaborative commitments, such as the 2010 national green economy summit statement that committed to "increas[ing] new knowledge and skills towards development, deployment and commercialisation of innovative science and technology solutions aimed at advancing a green economy" (DEA, 2010: 62). Importantly, this target complements the overall target for R&D expenditure, set globally at 1.5% of GDP. For reference, in 2016, R&D expenditure reached 0.82% of GDP in South Africa.

[1] An initial target of increasing green R&D investment by 300% was set but subsequently revised following the research conducted in 2015.

In 2015, TIPS, at the request of the then Department of Science and Technology, undertook a project to define 'green research and development (R&D)' and determine the levels of green R&D investment in South Africa. This was a first-of-its-kind endeavour in South Africa but also globally. In collaboration with CeSTII at the HSRC, TIPS worked to extract the green R&D component of the country's annual R&D survey results. In 2019, TIPS was requested by DSI to update and, where possible, enhance the initial 2015 research. While the principles and definitional framework remained the same as the 2015 study, TIPS, in collaboration with the DSI and CeSTII, refined the understanding of green R&D in 2019.

This report not only provides the adjusted figures for the 2010/11-2012/13 period but also shows the trends in green R&D expenditure over seven years, from 2010/11 to 2016/17. The relevance and accuracy of the estimates for green R&D expenditure were ensured through a two-phase approach:

- First, the research relied on a collaborative approach between DSI, CeSTII and TIPS (as in 2015, see Ryan et al. 2016) to provide a consistent green R&D definition and selection of codes;
- Second, the research worked on a seven-year period, using data from the annual National Survey of Research and Experimental Development (R&D survey).[2] With a questionnaire response rate of up to 68.9% in the latest iteration used for this report (2016/17), the R&D survey provides the most comprehensive and appropriate current source of data for determining R&D expenditure in the country. Other available sources on relevant green economy expenditure simply do not provide adequate information on R&D expenditure in particular.

This report provides an update of the seminal 2015 study on the green R&D baseline, based on a refined selection of green R&D research field (RF) and socio-economic objectives (SEO) codes, and determines expenditure between 2010/11-2016/17. The updated code selection is detailed on page 34 in the Appendix.

The report is structured with the key findings in section 2 and a breakdown of public and private expenditure in sections 3 and 4 respectively. Lastly, recommendations for further work are provided in section 5. In the appendix, the changes in code selection are provided, and additional details on expenditure graphs and the green R&D definition is outlined.

[2] Available at http://www.hsrc.ac.za.

Box 1: Key concepts of R&D and Innovation, and the process of generating R&D statistics

Defining 'green economy R&D' can be approached in different ways, depending on the purpose of the exercise. In this report, an effort is made to estimate the green economy-related R&D expenditures in South Africa using the data drawn from the National Survey of Research and Experimental Development (R&D Survey). The R&D Survey collects data from R&D performing units in five institutional sectors, namely government; science councils; higher education; business sector; and not-for-profit. R&D statistics that are used in this report are based on R&D expenditures reported by R&D performing units across the economy. The survey is available online at http://www.hsrc.ac.za.

The concept of R&D is explained in the Frascati Manual, as comprising of "creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge" (OECD 2015, p. 28).

Scientific knowledge domains defined in the Frascati Manual (see OECD 2015, pp. 57-59) are the natural sciences, engineering and technology, the medical and health sciences, the agricultural and veterinary sciences, the social sciences, the humanities and the arts. There are sub-categories of these, which are then used to determine the RF codes/descriptions at a granular level. SEO are also defined in the Frascati Manual (OECD 2015, p. 335).

Furthermore, R&D can be categorised by types, namely: basic research, applied research and experimental development) (OECD 2015, p. 29). Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is original investigation undertaken in order to acquire new knowledge, directed primarily towards a specific, practical aim or objective. Experimental development is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.

Importantly, R&D is different from innovation. Innovation is about introducing a product or service in the market or putting it into use. It may be an outcome of R&D or other processes. The definition of R&D, as it is used in the R&D Survey, excludes investments made in the economy towards 'green innovations'. A different exercise is necessary to quantify other forms of green innovation investments. Such can include investment that create necessary platforms for R&D activities and other forms of innovation investment, such as new production machinery, Information and Communications Technology, digital platforms, and new skills development. Clearly, estimates of such investments are far larger than just R&D.

This has implications for the estimate for green R&D. In some instances, the 'green' objective of R&D is more apparent at the outset but in others, it is not. This can be gleaned from the scientific domain within which the R&D is classified or from the description of the R&D project. Scientific domains are represented by a concept of Field of research and development (FORD or RF codes) or the knowledge domain in which R&D is conducted. R&D project objectives/descriptions can also be categorised into Socio-Economic Objectives (SEO), which reflects the 'intended or targeted areas of use'. At times also, even if intended, the 'green' objectives of R&D may not be attained – just because R&D in its nature is uncertain. Results of R&D that demonstrate 'green' outcomes would be easy to identify once an innovation is introduced in the market/to users. Unfortunately, results of R&D may take years to materialise.

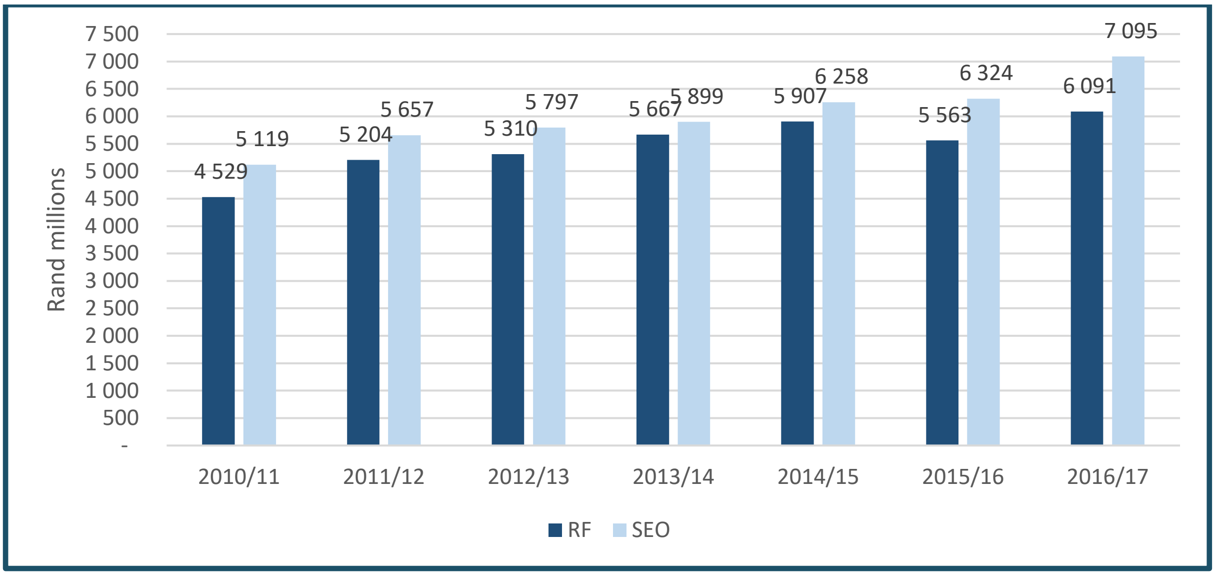
Source: Frascati (2015); Oslo Manual (2018)

2. Key Findings

This section summarises the findings on overall green R&D expenditure in South Africa between 2010/11-2016/17. The share of green R&D, research types and expenditure by sectors as well as sources of funds are summarised in terms of key trends and developments for the period. These are drawn from South Africa's annual R&D survey, conducted by CeSTII on behalf of DSI. They are based on a revised 2019 green R&D RF selection (Table 1 in the Appendix) and SEO codes selection (Table 2 in the Appendix), compiled in consultation with DSI and CeSTII. This provides an economy-wide snapshot of the green R&D expenditure over a seven-year period. However, due to the reliance on a survey and codes which were not designed for the purpose of measuring green R&D, this assessment remains an estimate of expenditure.[3] Green R&D expenditure is reported in two distinctive frameworks: research fields (RF codes) and socio-economic objects (SEO codes). As discussed in the Box 1 and the data section, the RF and SEO codes are simply two ways in which to view the expenditure results. RF and SEO are not cumulative and must be looked at separately as two snapshots of green R&D expenditure in South Africa. Differences between RF and SEO figures cannot be avoided, as they are the result of the structure of the dataset and the data extraction process.

As shown in Figure 1, in real terms, the total expenditure on green R&D in 2010/2011 was between R4.5 billion (based on RF codes) and R5.1 billion (based on SEO codes). This increased to between R6.1 billion (based on RF codes) and R7.1 billion (based on SEO codes) in 2016/2017.

Figure 1: Total green R&D expenditure and green share of R&D based on both RF and SEO code selections (2010/11-2016/17), in constant 2016/17 Rand values[4]

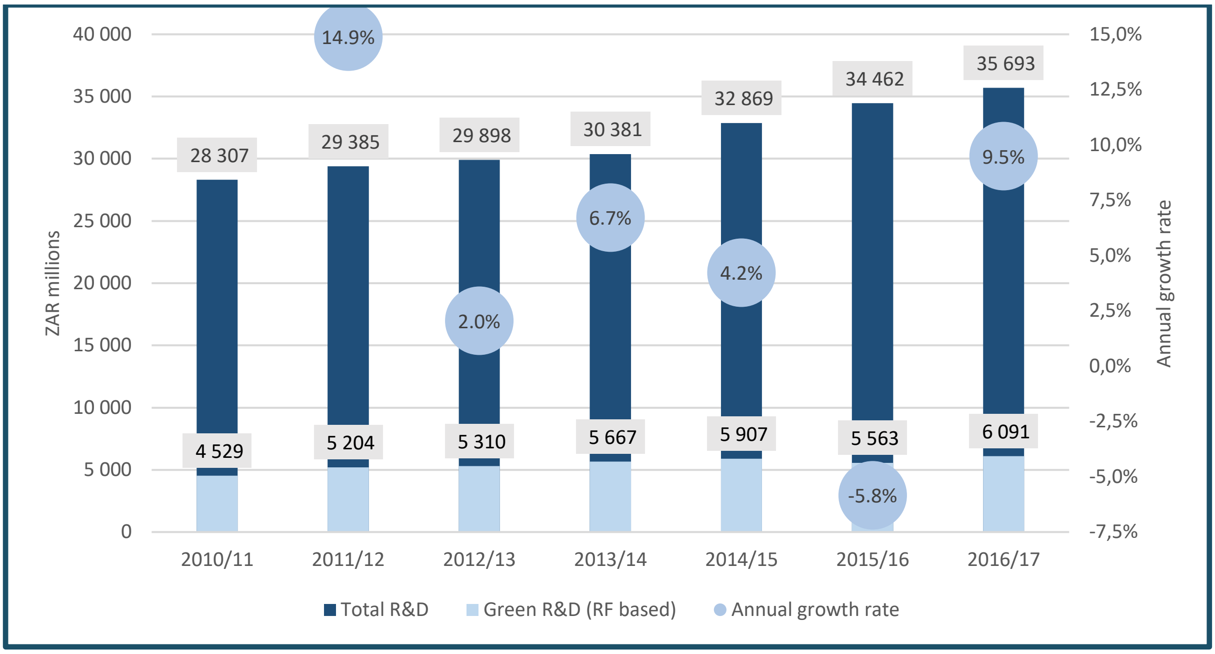


Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

[3] Following the analytical framework developed in Ryan, et al. (2016), expenditure captured under a specific code is either included or excluded from the green R&D estimate. It is not possible, due to data and anonymity limitations, to disaggregate the codes on an investment-level basis nor to include only a share of a given five-digit level code. As a result, the methodology provides an estimate of green R&D in South Africa at a five-digit level. This estimate is then reported at a three-digit level to maintain confidentiality.
[4] Expenditure values in nominal terms displayed in Figure 26 in the Appendix.

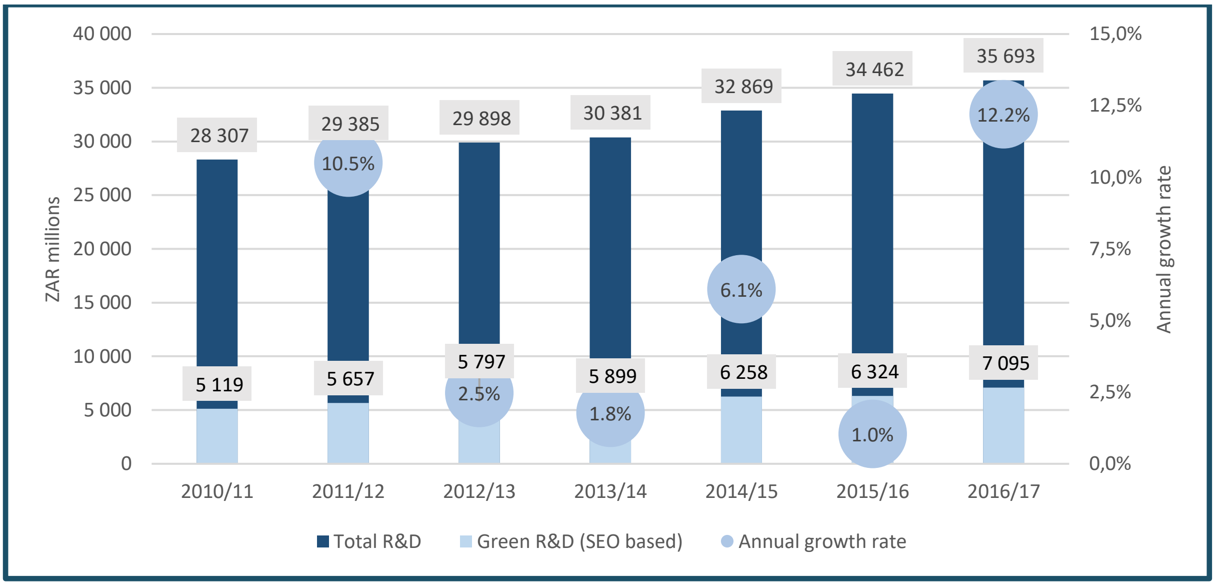
From 2010/11 to 2016/17, in real terms, total R&D increased from about R28.3 billion to about R35.7 billion (Figure 2 and Figure 3). Over the years, the green share of total R&D has generally fluctuated between 16% and 19% based on the RF codes, while this has fluctuated between 18% and 20% based on SEO codes.

Figure 2: Green R&D, based on RF code selections (2010/11-2016/17), in constant 2016/17 Rand values



Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 3: Green R&D, based on SEO code selections (2010/11-2016/17), in constant 2016/17 Rand values



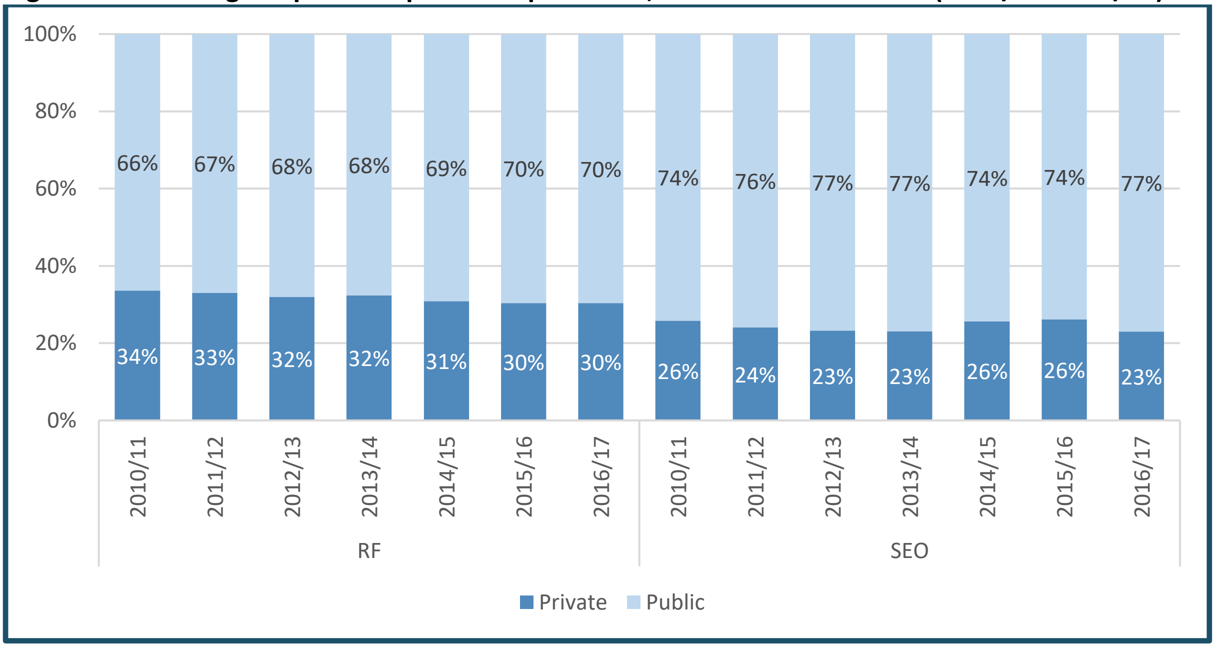
Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Both total R&D and the green R&D grew between 2010/11-2016/17. In real terms, the compound annual growth rate of total R&D in 2016/17 was 3.4% while that of green R&D was 4.3% (based on RF codes) and 4.8% (based on SEO codes), over the same period. For comparison, total R&D, green R&D based on RF codes and green R&D based on SEO codes grew respectively by 9.4%, 9.9% and 8.4% in nominal terms over the same period. For a breakdown of expenditure in the public and private sector, see Sections 3 and 4 of this report.

Public sector versus private sector expenditure on green R&D

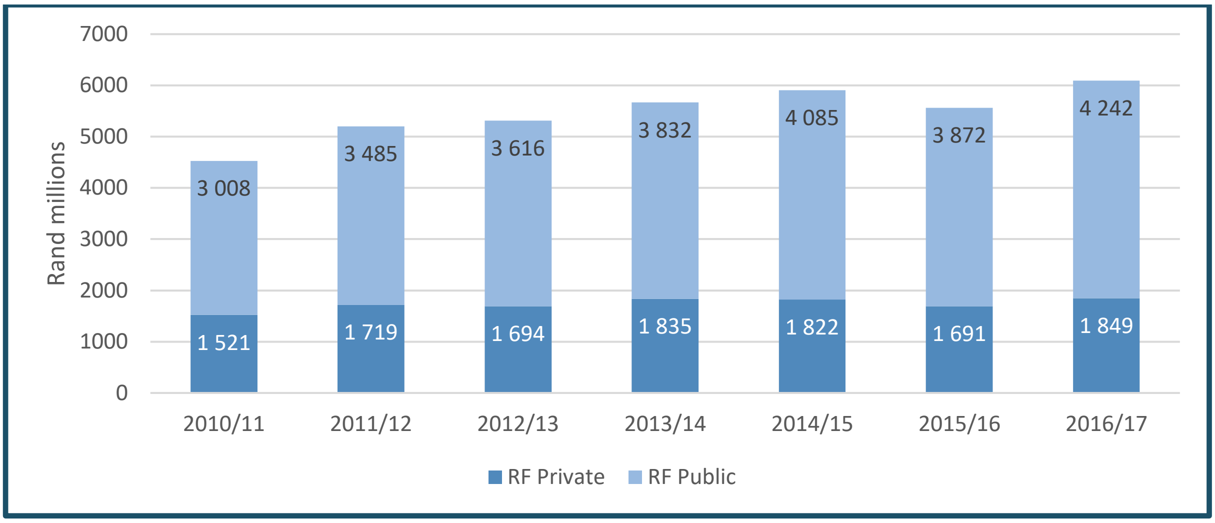
Public sector green R&D expenditure in terms of RF code selection was between 66%-70% of total green R&D between 2010/11-2016/17 (Figure 4). In terms of SEO code selection, the public sector expenditure of green R&D expenditure was between 74%-77% of green R&D expenditure for the same period. Correspondingly, the share of private sector green R&D was between 30%-34% in terms of RF code selection and 23%-26% in terms of SEO selection. In real terms, while green R&D expenditure by the public sector showed a 5.0%-5.3% compound annual growth rate over the period, the compound annual growth rate of private sector green R&D was lower, at 2.8%-3.0%. Figure 5 and Figure 6 capture the values of public and private expenditure in constant 2016/17-rand values.

Figure 4: Percentage of public vs private expenditure, RF and SEO selections (2010/11-2016/17)



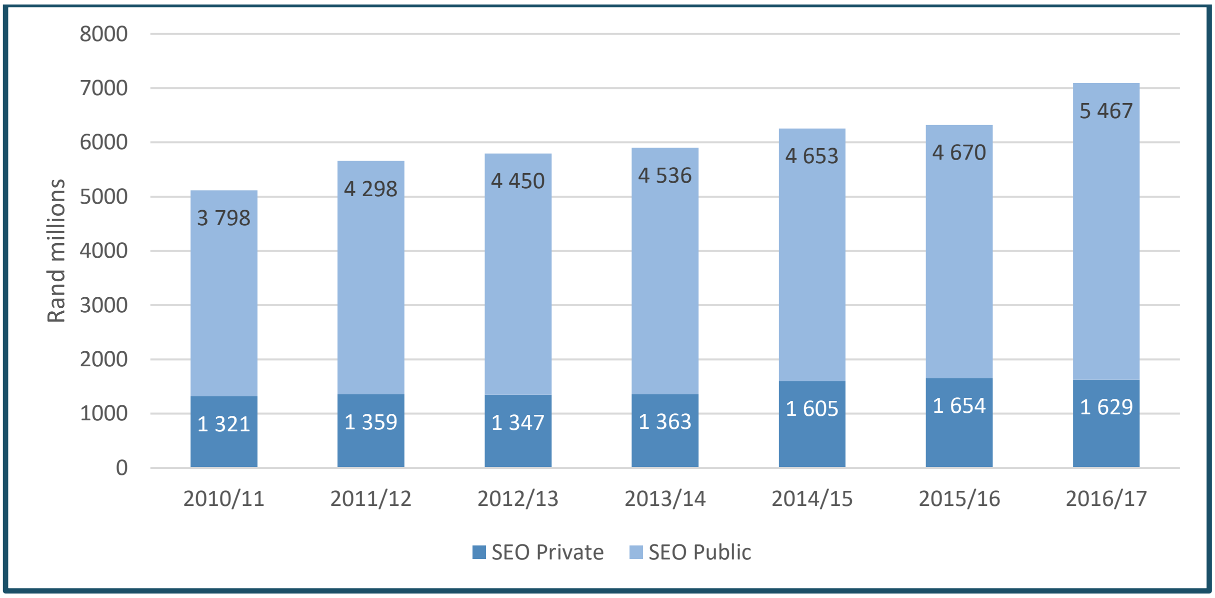
Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 5: Public vs private expenditure, RF code selections (2010/11-2016/17), in constant 2016/17 Rand values



Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 6: Public vs private expenditure, SEO code selections (2010/11-2016/17), in constant 2016/17 Rand values

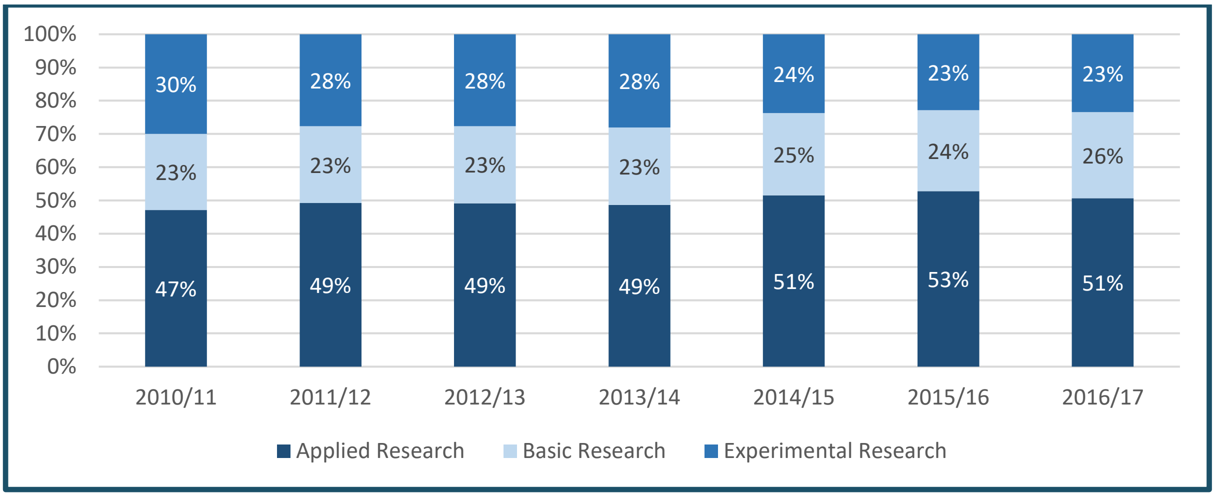


Source: *Authors, based on CeSTII data 2010/11-2016/17 deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)*

Research types in green R&D

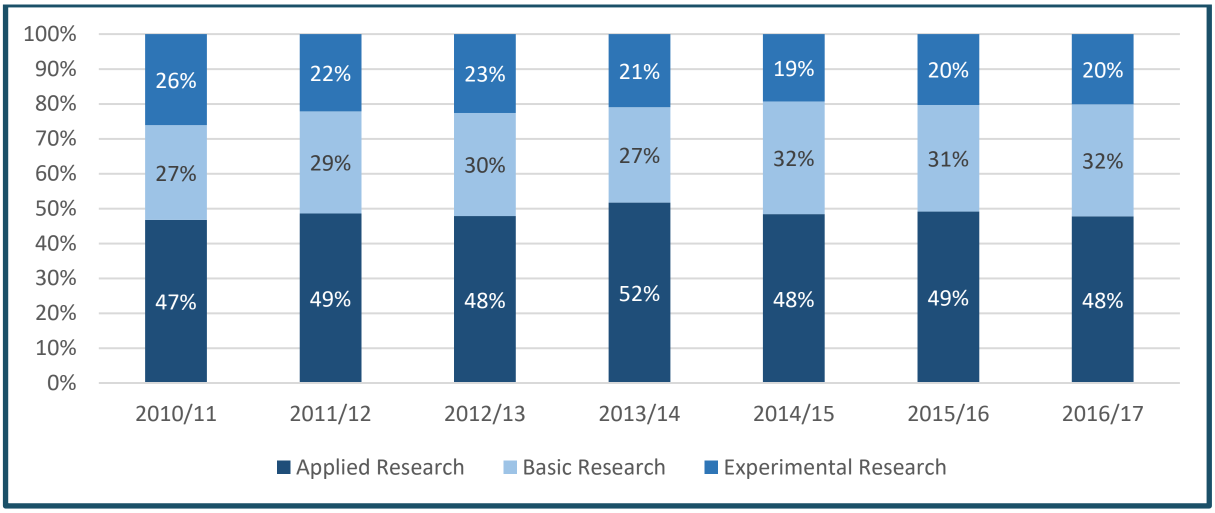
Figure 7 and Figure 8 show that applied research is the most common type of research conducted over the 2010/11 to 2016/17 period. Facet graphs (Figure 31 and Figure 32) in the Appendix show that science councils and business enterprises are the main drivers of applied research, while higher education is a driver of basic research. Business enterprises and science councils lead in experimental research.

Figure 7: Proportion of the types of research by RF code selection (2010/11-2016/17)



Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 8: Proportion of the type of research by SEO code selection (2010/11-2016/17)



Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

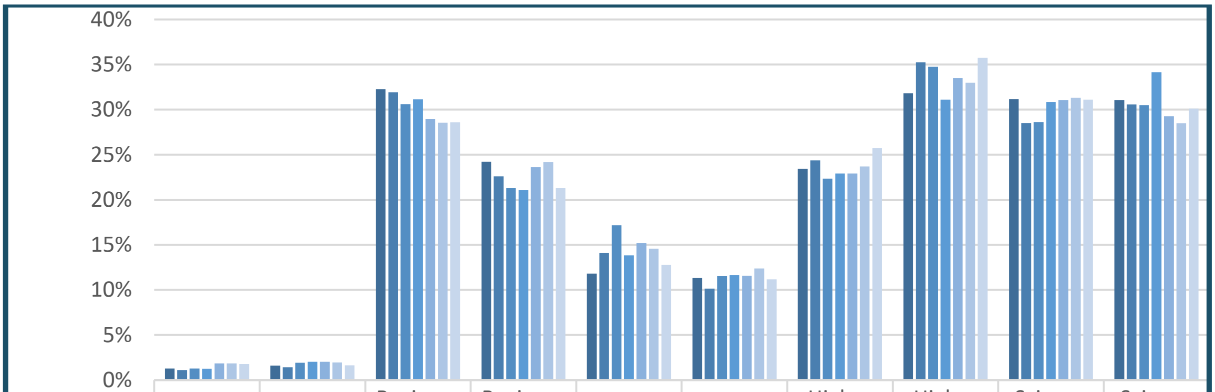
Figure 33 in the Appendix shows the distribution of green R&D expenditure in different research types based on RF codes. Agricultural sciences is the most dominant RF for green R&D expenditure across different institutions. The expenditure by the higher education sector is generally spread across various RF while other sectors have quite a distinct focus on certain green RF codes. For instance, government research entities focus mostly on agricultural sciences. Science councils focus mostly on agricultural sciences, followed by environmental sciences. Most of the expenditure from business enterprises, though spread across sectors, is in agricultural sciences, followed by engineering sciences. Business enterprises also had a spike in expenditure towards environmental sciences in 2016/17. While the proportion of green R&D from not-for-profit organisations is relatively low, most of their green R&D is in the agricultural sciences and, to a lesser degree, environmental sciences.

Similarly, Figure 34 in the Appendix shows the distribution of green R&D expenditure in different research types based on SEO codes. In general, government research institutions have their expenditure spread across various SEOs. Higher education also has its expenditure spread across various SEOs; however, natural sciences, technologies and engineering, and natural resources have relatively higher expenditures. Science councils have dominant expenditures in plant production and plant products, animal production and animal primary products, and natural sciences, technologies and engineering. Business enterprises focus mostly on plant production and plant products, followed by energy supply.

The distribution of green R&D by sectors

The distribution of the sectors in which green R&D expenditure takes places has remained relatively consistent over the seven-year period. Figure 9 below shows that business enterprises, higher education and science councils remain the dominant sectors for green R&D.[5] Notable changes are a decline in the share of expenditure from business enterprises from 24-32% in 2010/11 down to between 21-29% in 2016/17, and an increase in the share of expenditure from higher education.

Figure 9: Share of expenditure per sector comparing RF and SEO code elections (2010/11-2016/17)



	Not-for-profit RF	Not-for-profit SEO	Business enterprise RF	Business enterprise SEO	Government RF	Government SEO	Higher education RF	Higher education SEO	Science councils RF	Science councils SEO
2010/11	1%	2%	32%	24%	12%	11%	23%	32%	31%	31%
2011/12	1%	1%	32%	23%	14%	10%	24%	35%	29%	31%
2012/13	1%	2%	31%	21%	17%	12%	22%	35%	29%	31%
2013/14	1%	2%	31%	21%	14%	12%	23%	31%	31%	34%
2014/15	2%	2%	29%	24%	15%	12%	23%	34%	31%	29%
2015/16	2%	2%	29%	24%	15%	12%	24%	33%	31%	28%
2016/17	2%	2%	29%	21%	13%	11%	26%	36%	31%	30%

Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

[5] For definitions of various institutional groupings, please refer to CeSTII (2019).

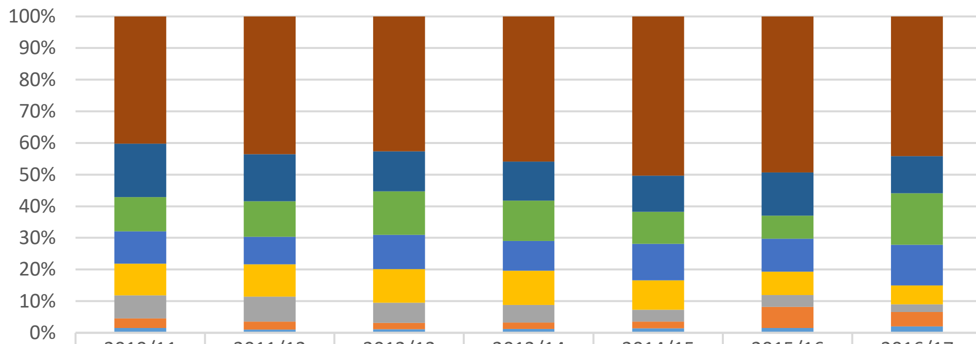
Growth in RF codes

In terms of overall green R&D expenditure based on RF codes, Figure 10 shows that agricultural sciences represented 40% of green R&D in 2010/11, a share that grew to 44% in 2016/17. Biological sciences expenditure declined from 17% in 2010/11 to 12% in 2016/17, whereas the third largest research field, environmental sciences, increased from 11% in 2010/11 to 16% in 2016/17. These top three sectors accounted for 68% of green R&D in terms of RF codes in 2010/11. The green R&D expenditure for Earth sciences is notable and in fact overtook expenditure in biological science in 2014/15 and 2016/17. Hence, the top three sectors in 2016/17 were agricultural sciences, environmental sciences, and earth sciences, accounting for 73% of green R&D.

Growth in SEO codes

Figure 11 shows that, in terms of SEOs, plant production and plant products accounted for 22% of green R&D in 2016/17, down from 27% in 2010/11. While natural sciences, technologies and engineering maintained a second position in SEO codes, its share declined from 18% in 2010/11 to 11% in 2016/17. Environmental knowledge grew from 8% in 2010/11 to 14% in 2016/17, which in 2016/17 represented the third largest SEO code. The share of energy supply, in SEO terms, declined from 9% in 2010/11 to 6% in 2016/17, and the share of environmental management and other aspects doubled in one year from 5% in 2015/16 to 10% in 2016/17.

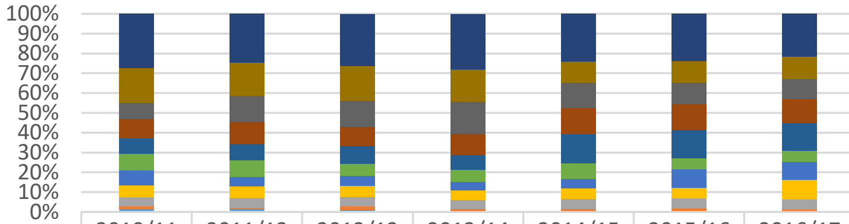
Figure 10: Percentage of total green R&D shares by research field (2010/11-2016/17)



	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Agricultural Sciences	40%	44%	43%	46%	50%	49%	44%
Biological Sciences	17%	15%	13%	12%	11%	14%	12%
Environmental Sciences	11%	11%	14%	13%	10%	7%	16%
Earth Sciences	10%	9%	11%	9%	12%	11%	13%
Engineering Sciences	10%	10%	11%	11%	9%	7%	6%
Applied Sciences & Technologies	7%	8%	6%	6%	4%	4%	2%
Social Sciences	3%	3%	2%	2%	2%	7%	5%
Marine Sciences	1%	1%	1%	1%	1%	2%	2%

Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 11: Percentage of total green R&D shares by SEO codes (2010/11-2016/17)



	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Plant Production and Plant Products	27%	25%	26%	28%	24%	24%	22%
Natural Sciences, Technologies & Engineering	18%	17%	18%	16%	11%	11%	11%
Animal Production and Animal Primary Products	8%	13%	13%	16%	12%	11%	10%
Natural Resources	10%	11%	10%	11%	14%	13%	12%
Environmental Knowledge	8%	8%	9%	8%	15%	14%	14%
Energy supply	9%	8%	6%	6%	8%	6%	6%
Economic Framework	8%	5%	5%	4%	5%	10%	9%
Environmental Management & Other Aspects	6%	6%	5%	5%	5%	5%	10%
Environmental Aspects of Development	5%	5%	5%	5%	5%	5%	5%
Commercial Services	2%	1%	2%	1%	1%	1%	1%
Energy resources	1%	1%	1%	1%	1%	1%	1%

Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

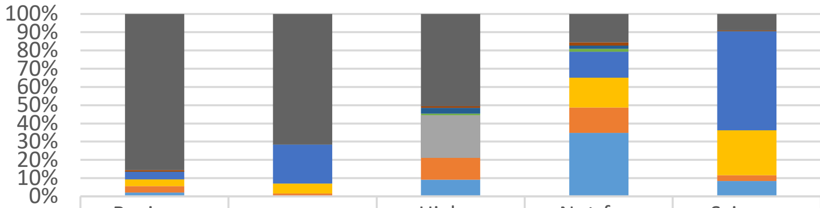
Funding sources

Funding sources according to RF code selection (Figure 12) show that, in the period 2010/11-2016/17, business enterprises funded green R&D activities mainly from internal funds (86%) and used government grants and contracts for around 8% of green R&D.[6] Government green R&D was also predominantly funded from own sources of funds (71%), government grants (22%) and government contracts (6%). Higher education used 50% of own funds for green R&D, followed by all other government sources (23%), and foreign sources (12%). The not-for-profit sector was mostly financed by local businesses (35%), followed by government contracts (17%), and internal funds (16%). Science councils remain largely public sector-funded with only 3% of foreign funds and 8% of funding sourced from local businesses. The sector with the highest proportion of its green R&D funding being foreign sources was the not-for-profit sector (14%), followed by higher education (12%).

These trends are similar in terms of SEO code selection (Figure 13), however, government's own sources of funds are about 9 percentage points higher at around 80% of its funding. Foreign sources of funds are also higher in the not-for-profit sector at 22% and higher education (13%). The other patterns of funding are largely consistent between RF and SEO code selections in terms of sources of funds from 2010/11-2016/17.

[6] For definitions of various funding streams, please refer to CeSTII (2019).

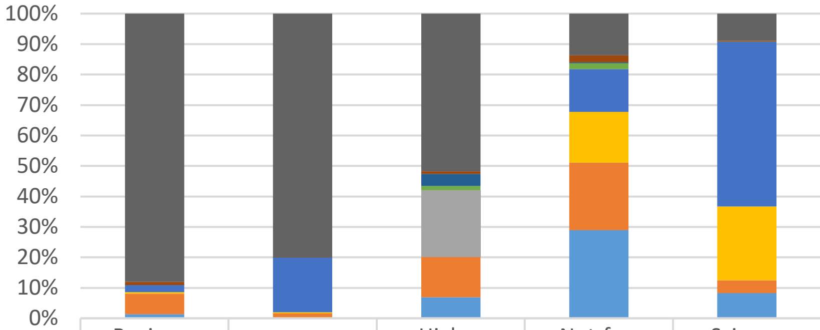
Figure 12: Source of funds by RF code selection (2010/11-2016/17)



	Business enterprise	Government	Higher education	Not-for-profit	Science councils
Own funds - Internal sources	85,6%	71,4%	50,6%	15,6%	9,1%
Other SA Sources - Not For Profit Organisations	0,9%	0,1%	0,8%	1,7%	0,3%
Other SA Sources - Individual Donations	0,0%	0,0%	3,1%	1,8%	0,0%
Other SA Sources - Higher Education	0,0%	0,0%	1,0%	1,7%	0,1%
Government - Grants	4,3%	21,4%	0,0%	14,1%	54,2%
Government - Contracts	3,7%	5,5%	0,0%	16,5%	24,7%
Government - All other	0,0%	0,0%	23,3%	0,0%	0,0%
Foreign - All Sources	3,4%	1,2%	12,1%	13,8%	3,2%
Business - Local business	2,2%	0,3%	9,1%	34,8%	8,5%

Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 13: Source of funds by SEO code selection, (2010/11-2016/17)



	Business enterprise	Government	Higher education	Not-for-profit	Science councils
Own funds - Internal sources	88,1%	80,0%	51,8%	13,7%	8,9%
Other SA Sources - Not For Profit Organisations	1,0%	0,1%	0,8%	2,3%	0,4%
Other SA Sources - Individual Donations	0,0%	0,0%	4,0%	0,3%	0,0%
Other SA Sources - Higher Education	0,0%	0,0%	1,4%	1,9%	0,1%
Government - Grants	2,3%	18,0%	0,0%	14,1%	54,0%
Government - Contracts	0,5%	0,4%	0,0%	16,6%	24,2%
Government - All other	0,0%	0,0%	21,8%	0,0%	0,0%
Foreign - All Sources	6,8%	1,3%	13,4%	22,2%	4,1%
Business - Local business	1,3%	0,2%	6,9%	28,9%	8,3%

Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

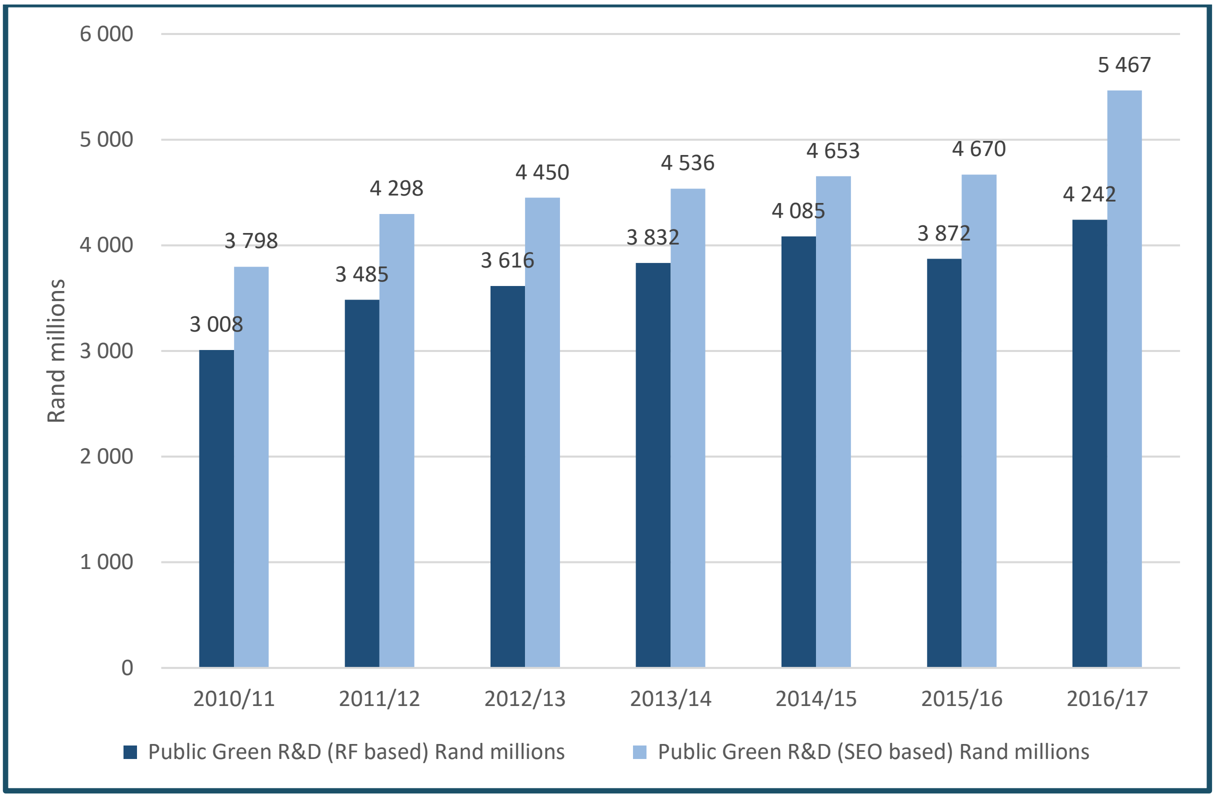
Funding sources towards various RFs and SEOs were further disaggregated (Figure 35 and Figure 36 respectively). The figures show that across the different green R&D codes, and over the years, most of the funding came from internal sources, then government grants, and government contracts. This is the case for both RF-based selection and SEO-based selection. While there are generally less fluctuations when looking at the RF-based selection (Figure 35), there are notable fluctuations with the SEO-based selection (Figure 36), particularly the funding derived from government contracts and government grants. For instance, in recent years, environmental knowledge as well as environmental management and other aspects have seen a rise in government contracts and grants, while on the contrary, natural sciences, technologies and engineering has had a sharp decline in government contracts since 2014/15.

3. Results based on public sector expenditure

Public sector expenditure on green R&D represents a significant share of total green R&D, between 66%-70% of total green R&D (in RF terms) and between 74%-77% (in SEO terms), over the 2010/11-2016/17 period.

Public green R&D expenditure was between R3.0-3.8 billion in 2010/11 and has grown to R4.2-5.5 billion in 2016/17, in real terms (see Figure 14). This corresponds to a CAGR of 5.0%-5.3% over the period 2010/11-2016/17.

Figure 14: Public green R&D expenditure, RF and SEO code selections (2010/11-2016/17), in constant 2016/17 Rand values

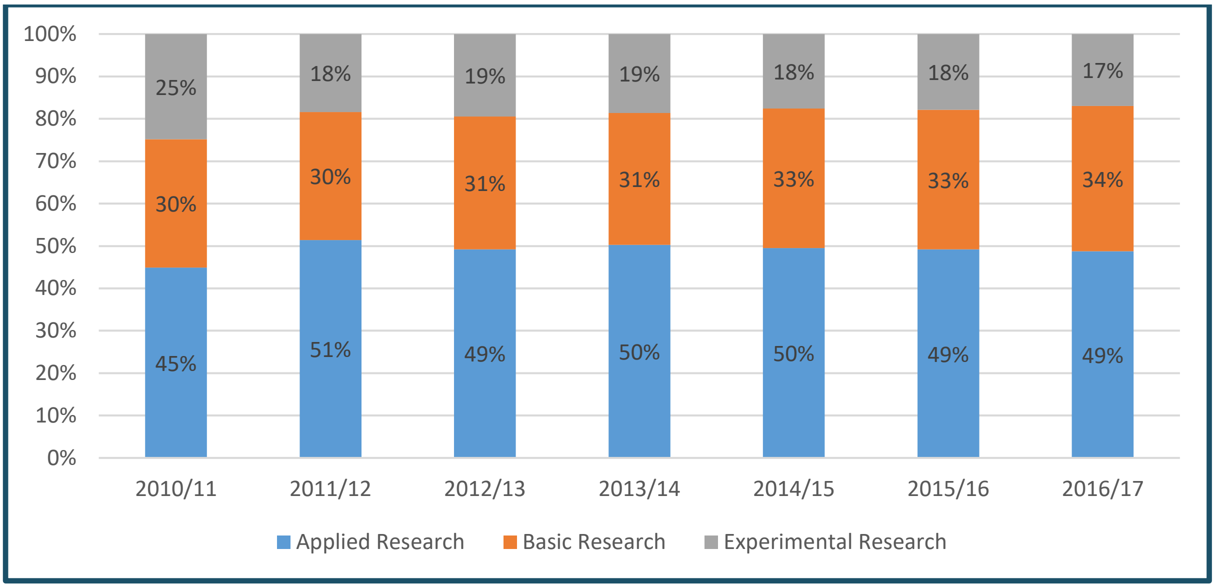


Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Public sector proportion of expenditure by research type

Figure 15 shows that, based on RF codes, the main type of public sector green R&D has been in applied research, which stood between 45%-51% of public sector expenditure over the 2010/11-2016/17 period. Basic research was between 30%-34% of public green R&D in the same period, while experimental research accounted for between 17%-25%.

Figure 15: Proportion of the types of research by RF code selection (2010/11-2016/17)



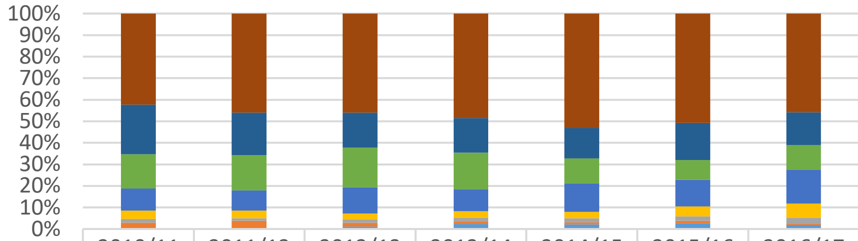
Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Public sector proportion of expenditure by research fields and socio-economic objectives

Based on RF selection (Figure 16), expenditure in agricultural sciences has dominated public sector green R&D, representing between 42%-53% of green public R&D over the years. The top three sectors in RF-based public green R&D expenditure in 2010/11 were agricultural sciences (42%), biological sciences (23%) and environmental sciences (16%), accounting for 81% of RF-based public green R&D expenditure. In 2016/17, the top three sectors were agricultural sciences (46%), earth sciences (16%), and biological sciences (15%), accounting for 77% of RF-based public green R&D expenditure.

Based on the SEO selection (Figure 17), the top three sectors were plant production and plant products (25%), natural sciences, technologies and engineering (23%) and natural resources (13%), accounting for 61% of SEO-based public green R&D expenditure in 2010/11. There was a shift in 2016/17, with the top three sectors being environmental knowledge (17%), natural resources (16%), plant production and plant products (15%), accounting for 48% of SEO-based public green R&D expenditure. Plant production and plant products fell from 25% in 2010/11 to 15% in 2016/17, while natural sciences, technologies and engineering declined from 23% in 2010/11 to 14% in 2016/17. Environmental knowledge saw the greatest growth as a share of public green R&D, from 8% in 2010/11 to 17% in 2016/17.

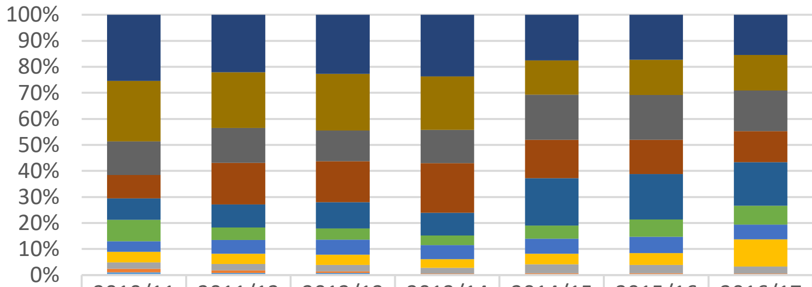
Figure 16: Proportion by RF code selection of public sector expenditure (2010/11-2016/17)



	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Agricultural Sciences	42%	46%	46%	48%	53%	51%	46%
Biological Sciences	23%	20%	16%	16%	14%	17%	15%
Environmental Sciences	16%	16%	18%	17%	12%	9%	11%
Earth Sciences	10%	9%	12%	10%	13%	12%	16%
Social Sciences	4%	4%	3%	3%	3%	5%	7%
Marine Sciences	2%	1%	1%	1%	2%	2%	3%
Applied Sciences & Technologies	3%	4%	2%	1%	1%	1%	0%
Engineering Sciences	0%	0%	1%	2%	2%	3%	2%

Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 17: Proportion by SEO code selection of public sector expenditure (2010/11-2016/17)



	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Plant Production and Plant Products	25%	22%	23%	24%	18%	17%	15%
Natural Sciences, Technologies & Engineering	23%	21%	22%	20%	13%	14%	14%
Natural Resources	13%	13%	12%	13%	17%	17%	16%
Animal Production and Animal Primary Products	9%	16%	16%	19%	15%	13%	12%
Environmental Knowledge	8%	9%	10%	9%	18%	18%	17%
Economic Framework	8%	5%	4%	4%	5%	7%	7%
Environmental Aspects of Development	4%	5%	6%	5%	6%	6%	6%
Environmental Management & Other Aspects	4%	4%	4%	3%	4%	5%	10%
Energy supply	2%	2%	2%	2%	3%	3%	3%
Commercial Services	1%	1%	1%	1%	1%	1%	0%
Energy resources	1%	1%	1%	0%	0%	0%	0%

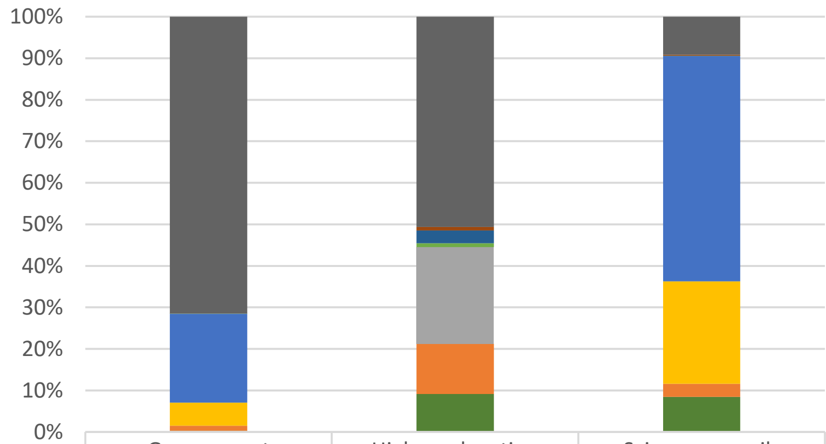
Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Public sector source of funds

During the period 2010/11-2016/17, the source of funds of the public sector green R&D expenditure (Figure 18) was as follows:

- Government mainly self-funded, at 71% through its own internal funds and 21% through government grants (21%), which are intra-governmental transfers;
- Higher education was also mostly funded from internal funds (50%) and from other government sources (23%); while
- Science councils were funded mostly by both government grants (54%) and government contracts (25%).

Figure 18: Proportion of public sector sources of funding from 2010/11-2016/17



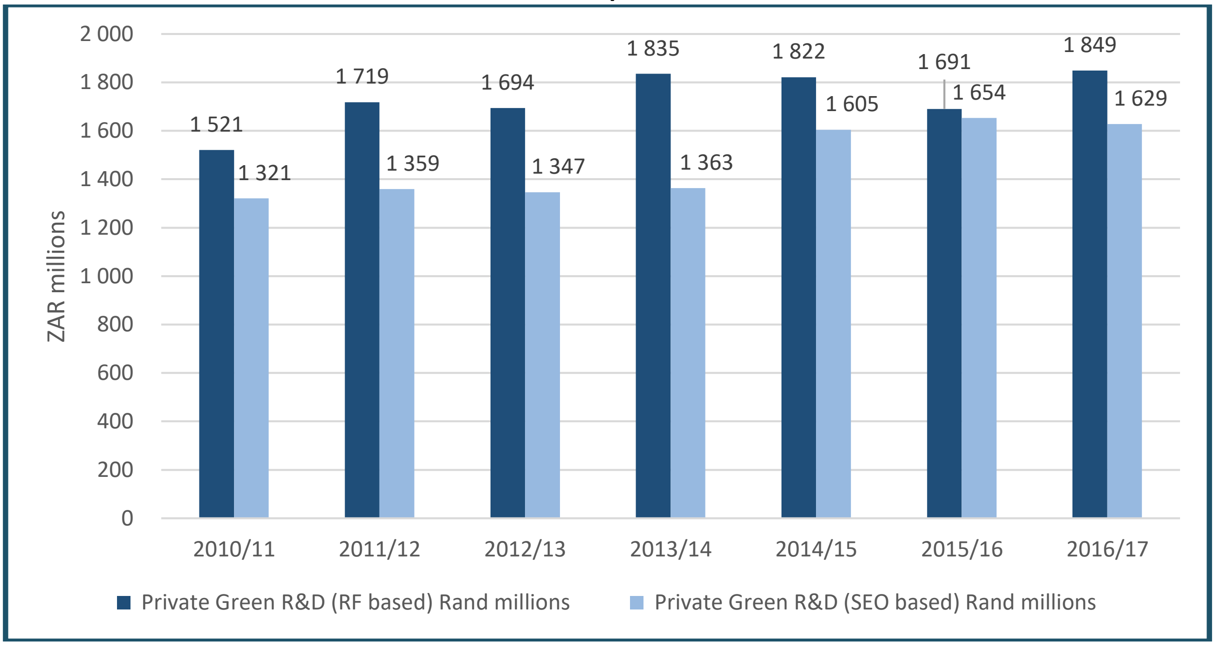
	Government	Higher education	Science councils
Own funds - Internal sources	71%	51%	9%
Other SA Sources - Not For Profit Organisations	0%	1%	0%
Other SA Sources - Individual Donations	0%	3%	0%
Other SA Sources - Higher Education	0%	1%	0%
Government - Grants	21%	0%	54%
Government - Contracts	6%	0%	25%
Government - All other	0%	23%	0%
Foreign - All Sources	1%	12%	3%
Business - Local business	0%	9%	8%

Source: Authors, based on CeSTII data 2010/11-2016/17

4. Results based on private sector expenditure

Overall, private sector expenditure on green R&D is less than public sector green R&D. In RF terms, private sector expenditure was between 30%-34% of total green R&D. In SEO terms, it was between 23%-26% over the period 2010/11-2016/17. The expenditure of private green R&D (Figure 19) was between R1.3-1.5 billion in 2010/11 and grew to R1.6-1.9 billion in 2016/17, growing in real terms at a CAGR of 2.8%-3.0%.

Figure 19: Private green R&D expenditure, RF and SEO code selections (2010/11-2016/17), in constant 2016/17 Rand values

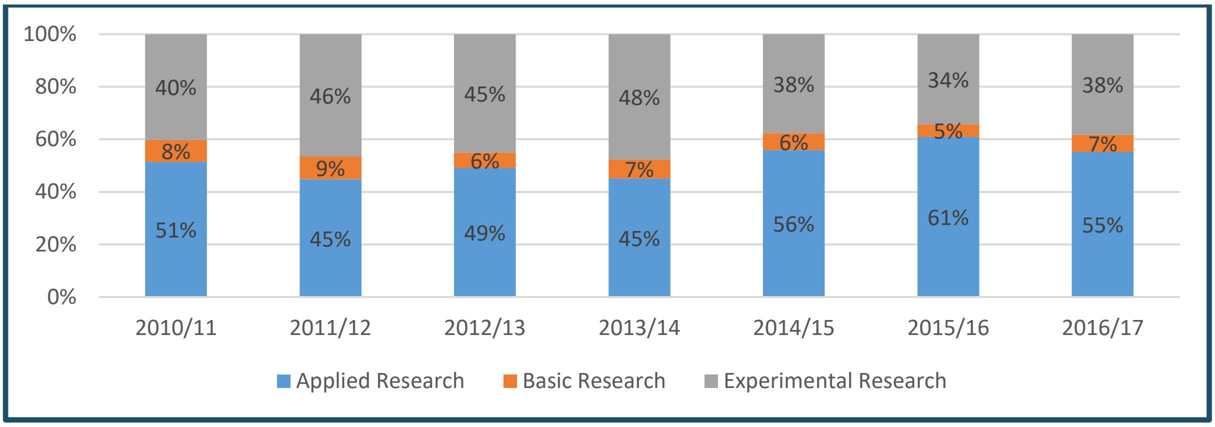


Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Private sector proportion of expenditure by research type

Figure 20 shows that, based on RF codes, the main type of R&D has been in applied research, representing between 45%-61% (depending on the years) of private sector green R&D expenditure in the period 2010/11-2016/17. While experimental research accounted for between 34%-48% research expenditure in the private sector, basic research was between 5%-9% of R&D in the period 2010/11-2016/17, compared to 30%-34% by the public sector.

Figure 20: Proportion of research types by RF code selection of private sector expenditure (2010/11-2016/17)



Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

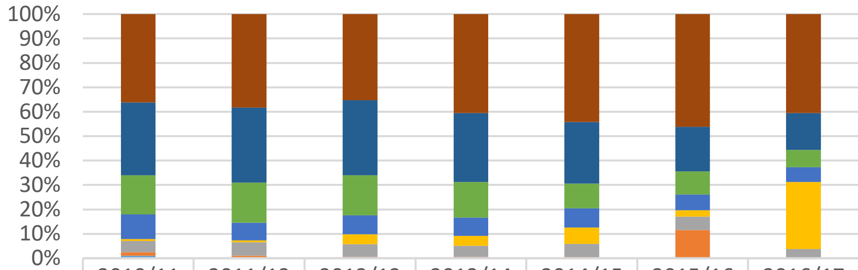
Private sector proportion of expenditure by research field and socio-economic field

Based on RF selections (Figure 21), agricultural sciences has dominated private sector expenditure, representing between 35%-46% of green private sector R&D over the 2010/11-2016/17 period. In 2010/11, the top three sectors were agricultural sciences (36%), engineering sciences (30%), and applied sciences and technologies (16%), which accounted for 82% of the RF-based private green R&D expenditure. There was a shift in 2016/17, with the top three being agricultural sciences (40%), environmental sciences (27%), and engineering sciences (15%), which accounted for 82% of the RF-based private green R&D expenditure.

A sharp increase in environmental sciences, from 3% in 2015/16 to 27% in 2016/17, is a noteworthy outlier, which also translates into the overall increase (between public and private expenditure) on environmental sciences from 7% to 16% in the same period. The share of private sector green expenditure on engineering sciences has halved from 30% in 2010/11 to 15% in 2016/17, as has the share of applied sciences and technologies from 16% to 7% in the same period.

Based on SEO selections (Figure 22), the top three SEOs of private green R&D in 2010/11 were plant production and plant products (33%), energy supply (26%), and environmental management and other aspects (11%), accounting for 70% of SEO-based private green R&D expenditure. In 2016/17, the top three were plant production and plant products (43%), energy supply (16%), and economic framework (16%), accounting for 75% of the total. Expenditure on economic framework has risen sharply from 6% in 2010/11 to 16% in 2016/17, essentially due to growth in the last two years (2015/16-2016/17).

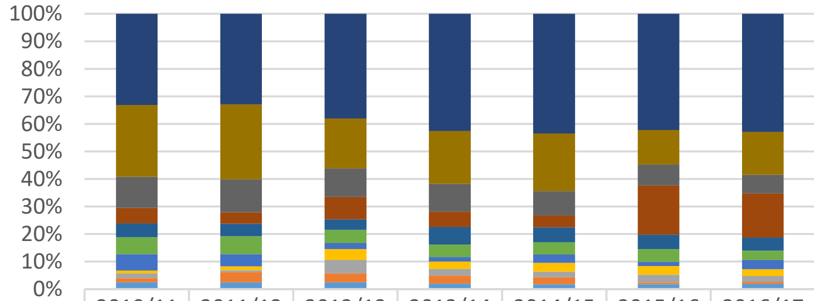
Figure 21: Proportion of private sector expenditure by RF code selection (2010/11-2016/17)



	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Agricultural Sciences	36%	38%	35%	40%	44%	46%	40%
Engineering Sciences	30%	31%	31%	28%	25%	18%	15%
Applied Sciences & Technologies	16%	16%	16%	15%	10%	10%	7%
Earth Sciences	10%	7%	8%	7%	8%	6%	6%
Environmental Sciences	1%	1%	4%	4%	7%	3%	27%
Biological Sciences	5%	5%	5%	5%	5%	5%	4%
Social Sciences	1%	1%	0%	0%	0%	11%	0%
Marine Sciences	1%	0%	0%	1%	0%	0%	0%

Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 22: Proportion of private sector expenditure by SEO code selection (2010/11-2016/17)



	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Plant Production and Plant Products	33%	33%	38%	43%	43%	42%	43%
Energy supply	26%	27%	18%	19%	21%	12%	16%
Environmental Management & Other Aspects	11%	12%	10%	10%	9%	8%	7%
Economic Framework	6%	4%	8%	6%	4%	18%	16%
Animal Production and Animal Primary Products	5%	5%	4%	6%	5%	5%	5%
Environmental Knowledge	6%	6%	5%	4%	5%	5%	3%
Environmental Aspects of Development	6%	4%	2%	2%	3%	2%	3%
Natural Sciences, Technologies & Engineering	1%	1%	4%	3%	3%	3%	2%
Commercial Services	2%	1%	5%	2%	2%	3%	2%
Natural Resources	2%	4%	3%	3%	3%	1%	1%
Energy resources	2%	2%	2%	2%	2%	2%	2%

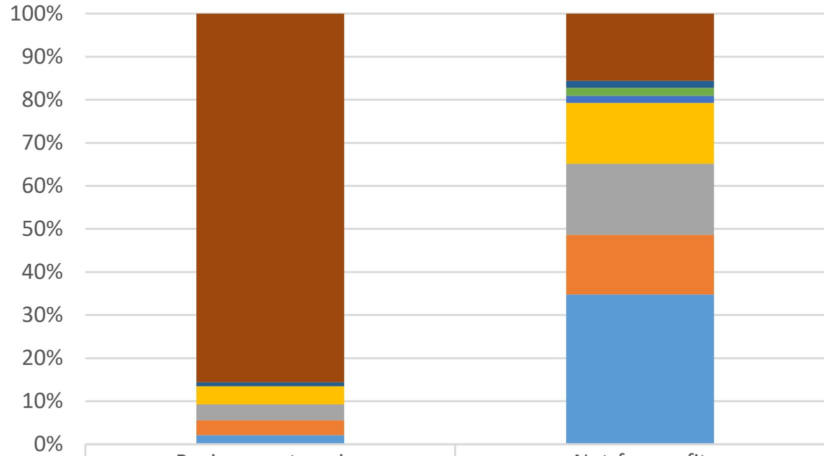
Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Private sector source of funds

During the period 2010/11-2016/17, the private sector green R&D expenditure has been funded as follows:

- Business enterprises have largely relied on their own internal funds (86%); while
- Not-for-profits were mostly supported by local business (35%), government contracts (17%), as well as own internal funds (16%).

Figure 23: Proportion of private sector sources of funding from 2010/11-2016/17



	Business enterprise	Not-for-profit
Own funds - Internal sources	86%	16%
Other SA Sources - Not For Profit Organisations	1%	2%
Other SA Sources - Individual Donations	0%	2%
Other SA Sources - Higher Education	0%	2%
Government - Grants	4%	14%
Government - Contracts	4%	17%
Foreign - All Sources	3%	14%
Business - Local business	2%	35%

Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

5. Recommendations

1) **Elaborate a code book defining what is captured under each code:** The main recommendation for further work is to elaborate on the detailed description of RF and SEO codes. Other countries, such as Australia,[7] have a code book which makes it easier for classification. The tacit knowledge of these codes (i.e. what is exactly captured under each code) is currently the knowledge of CeSTII's staff. Moreover, the team that worked on this project has formulated new concepts and approaches for understanding 'green-related R&D'. A process, led by the DSI and involving the experts from both CeSTII, TIPS and others, should be established to define the RF and SEO codes to be used going forward (i.e. a definition book). To bypass the absence of a definition book, the project team relied on extensive engagement with the CeSTII team, but the compilation of such a definition book would make future iteration of the green R&D work more transparent and easier to update.

2) **Refine the understanding of what is captured under each code:** In addition to compiling a definition book, an overall deeper understanding of what each code captures would be important to refine the measurement of green R&D. Through knowledge sharing with stakeholders, including respondents, this would also improve the quality of the R&D survey. At the moment, codes are included in the green R&D selection on the basis that they encompass a majority of green R&D expenditure. While this conclusion can be reached with a high degree of confidence for most codes, the lack of information about what is captured under each code makes this decision difficult and less robust in some cases. Furthermore, the analysis could be fine-tuned by accessing the information at the five-digit level, rather than three-digit level. While the data included in the report is based on a five-digit code selection, the data has then been aggregated at the three-digit level. This is necessary to respect confidentiality and anonymity clauses with survey respondents. However, reporting data at the five-digit level would enable a more granular and detailed understanding of green R&D expenditure in the country.

3) **Keep the code selection for green R&D up-to-date:** While the NDP has adopted the United Nations Environment Programme (UNEP) definition of green economy, another constraining factor is the absence of what it means in practice. Shifting to a green economy involves an economy-wide transformation and cannot be limited to a number of sectors. It requires a transformation in practice at the economic, social and environmental levels, making it hard to grasp. Further work is required to refine the green economy framework that was developed in this project and enhance its application to the measurement of the green economy in South Africa. It should remain a priority to keep a relevant definition of the green economy for the purpose of green R&D measurement. Importantly, green R&D is an evolving concept and the definitional framework should remain abreast of development in both the green economy and R&D spaces. While some codes may, as of June 2019, not capture green R&D expenditure, it is possible (and indeed highly likely) that they do so in the future. To stay relevant and as accurate as possible the code selection should be regularly updated. CeSTII could work with stakeholders in the medium to long term (for instance, every five years) to update this framework.

[7] See https://www.arc.gov.au for more details on Australia's code books.

4) **Consider building new datasets for green R&D:** The lack of appropriate data beyond the R&D survey is a major constraint for measuring green R&D. Creating new data streams would constitute a new initiative in itself, looking at how to mobilise current datasets and surveys to construct a green economy dashboard of indicators. For the R&D component of this, an entire new survey needs to be considered, as the manner in which the R&D survey is compiled makes extracting the "green component" difficult. For the scope of this project, it was not possible to develop new datasets and the analysis of the various available data sources (see Ryan et al. 2016) shows that, for the time being, the R&D survey remains the most adequate solution. Such developments should be aligned with international efforts in this respect.

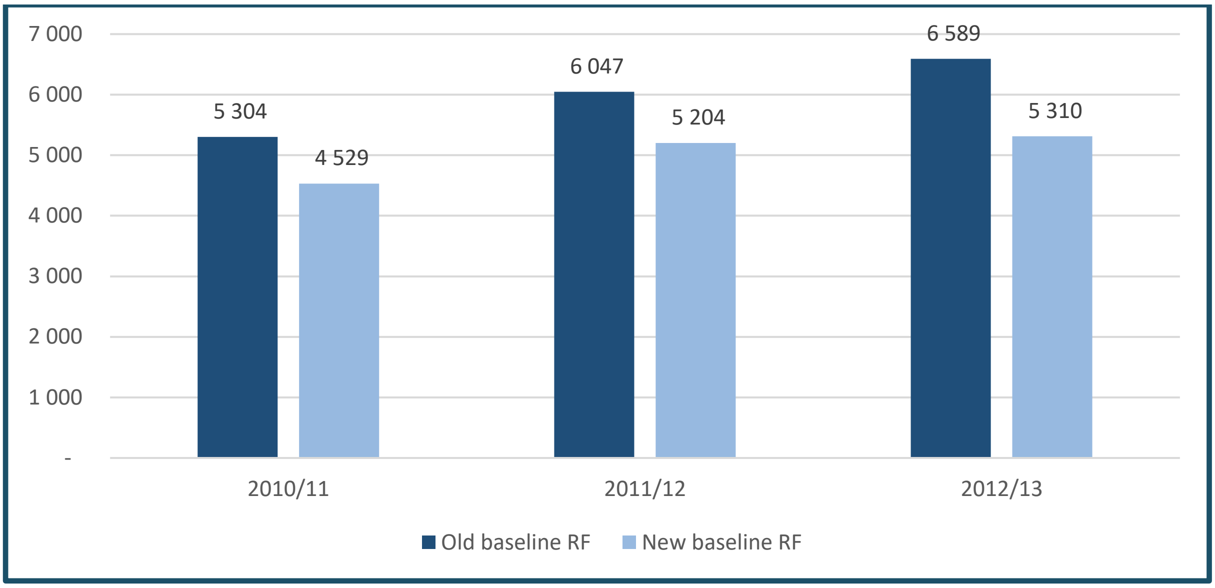
5) **Explore alternative approaches to measure green innovation as complementary frameworks:** While working with current data sets, and considering creating a new survey, such approaches add to the burden of further surveys for research. An alternative approach is to consider constructing a voluntary green index that measures performance in a number of factors, including green R&D. Encouraging voluntary participation in such an index is one way to encourage better reporting by organisations and for a better comparison across public and private sector entities. Such an initiative would need to have a strong rationale for participating, very clear guidelines on reporting (with links to international standards for comparison) and may require significant marketing and promotion to encourage the voluntary participation. It could, however, provide a competitive platform for demonstrating the performance of organisations, particularly to start understanding the impact of green R&D expenditure and the linkages with green innovation. Importantly, it could also enhance the response rate of the R&D survey.

6) **Further promote R&D in support of the transition to a green economy:** While the target of maintaining the rand value of expenditure has been achieved, green R&D in South Africa is still insufficient to fast-track the transition to a green economy. Further efforts are required to spur R&D investment overall, and green R&D specifically. The public sector remains by far the main contributor to green R&D expenditure, a trend which is furthermore increasing. Existing mechanisms aimed at fostering R&D expenditure by the private sector, such as the R&D tax incentive, should be continued and enhanced. Support should moreover be progressively channelled towards expenditure in direct support of a green economy. In addition, green R&D expenditure is strongly skewed towards life sciences, such as agricultural sciences. The transition to a green economy is a cross-cutting shift impacting every aspect of the economy and society. As such, more efforts are necessary to widen the spectrum of green R&D and support green R&D expenditure in all sectors and fields.

6. Appendix

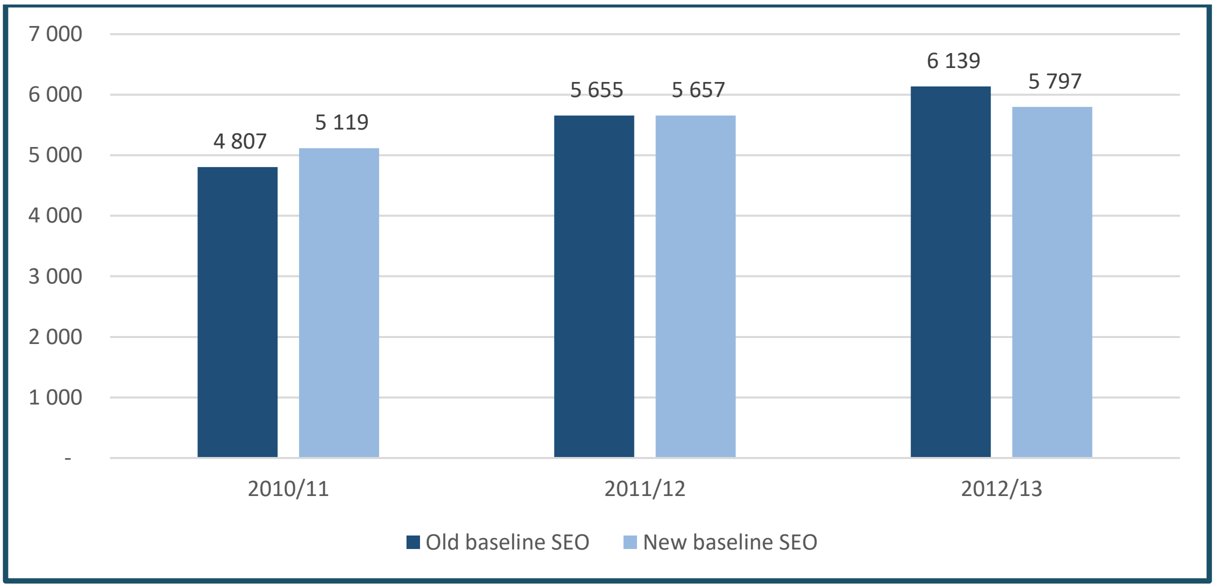
Changes to the original green R&D baseline

Figure 24: 2015 versus 2019 baseline for RF code selection, in constant 2016/17-rand values



Source: Authors, based on CeSTII data 2010/11-2016/17

Figure 25: 2015 versus 2019 baseline for SEO code selection, in constant 2016/17-rand values



Source: Authors, based on CeSTII data 2010/11-2016/17

Table 1: Comparison of RF code selections, 2015 and 2019

	2015 RF Selection		2019 RF Selection	
Earth Sciences	RF10401	Geology	RF10401	Geology
	RF10402	Geophysics	RF10402	Geophysics
	RF10403	Geochemistry	RF10403	Geochemistry
	RF10404	Oceanography	RF10404	Oceanography
	RF10405	Hydrology, Water resources	RF10405	Hydrology, Water resources
	RF10406	Atmospheric sciences	RF10406	Atmospheric sciences
			RF10407	Palaeontology
	RF10408	Physical Geography	RF10408	Physical Geography
	RF10409	Climatic Research	RF10409	Climatic Research
	RF10410	Space and Earth Science	RF10410	Space and Earth Science
	RF10499	Other earth sciences not classified elsewhere	RF10499	Other earth sciences not classified elsewhere
Applied Sciences and Technologies	RF10602	Manufacturing and process technologies and engineering		
	RF10603	Nuclear technology	RF10603	Nuclear technology
	RF10605	Resource-based industry		
	RF10606	Energy Industry		
	RF10608	Water technology	RF10608	Water technology
	RF10699	Other applied sciences and technologies not elsewhere classified		
Engineering Sciences	RF10708	Environmental Engineering	RF10708	Environmental Engineering
	RF10709	Nuclear engineering and radiation technology	RF10709	Nuclear engineering and radiation technology
	RF10710	Mechanisation and design engineering	RF10710	Mechanisation and design engineering
	RF10712	Environmental biotechnology	RF10712	Environmental biotechnology
	RF10713	Industrial biotechnology	RF10713	Industrial biotechnology
	RF10715	Nano-technology		
Biological Sciences	RF10804	Botany	RF10804	Botany
	RF10805	Zoology	RF10805	Zoology
	RF10806	Ecology	RF10806	Ecology
	RF10807	Genetic engineering		
	RF10808	Biotechnology	RF10808	Biotechnology
			RF10809	Bioinformatics
			RF10899	Other biological sciences not elsewhere classified
Agricultural Sciences	RF10901	Soil and water sciences	RF10901	Soil and water sciences
	RF10902	Crop and pasture production (including rice)	RF10902	Crop and pasture production (including rice)
	RF10903	Horticulture (including plantation and fruit crops)	RF10903	Horticulture (including plantation and fruit crops)
	RF10904	Animal production	RF10904	Animal production
			RF10905	Veterinary sciences

	RF10906	Forestry sciences	RF10906	Forestry sciences
	RF10907	Fisheries sciences	RF10907	Fisheries sciences
	RF10908	Food and nutrition development	RF10908	Food and nutrition development
	RF10909	Aquaculture	RF10909	Aquaculture
	RF10910	Plant physiology	RF10910	Plant physiology
	RF10911	Agricultural biotechnology	RF10911	Agricultural biotechnology
	RF10999	Other agricultural sciences not elsewhere classified	RF10999	Other agricultural sciences not elsewhere classified
Environmental Sciences	RF11101	Environmental studies	RF11101	Environmental studies
	RF11102	Environment technology/industry	RF11102	Environment technology/industry
	RF11103	Environmental issues and assessment	RF11103	Environmental issues and assessment
	RF11104	Environmental management and bioremediation	RF11104	Environmental management and bioremediation
	RF11199	Other environmental science not elsewhere classified	RF11199	Other environmental science not elsewhere classified
Material Sciences	RF11202	Functional materials		
	RF11204	New materials and technologies		
Marine Sciences	RF11301	Marine biology	RF11301	Marine biology
	RF11302	Algae biotechnology	RF11302	Algae biotechnology
	RF11303	Fishing technology	RF11303	Fishing technology
	RF11304	Marine chemistry	RF11304	Marine chemistry
	RF11399	Other marine sciences not elsewhere classified	RF11399	Other marine sciences not elsewhere classified
Social Sciences	RF20102	Economics		
	RF20104	Political sciences and public policy		
	RF20108	Geography	RF20108	Geography
	RF20110	Law		
			RF20115	Anthropology
	RF20116	Transportation studies	RF20116	Transportation studies
	RF20117	Emerging issues		
	RF20119	Tourism	RF20119	Tourism

Source: Authors, in collaboration with DSI and CeSTII

Note: Yellow represents the code that was included in 2015 but excluded in 2019 (12 RF codes were removed). Green represents the code that was included in 2019 but excluded in 2015 (5 new RF codes were added).

Table 2: Comparison of SEO code selections, 2015 and 2019

	2015 SEO Selection		2019 SEO Selection	
Plant Production and Plant Products	S20101	Field crops	S20101	Field crops
	S20102	Plantation crops	S20102	Plantation crops
	S20103	Horticultural crops	S20103	Horticultural crops
	S20104	Forestry	S20104	Forestry
	S20105	Primary products from plants	S20105	Primary products from plants
	S20106	By-product utilisation	S20106	By-product utilisation
	S20199	Other plant production and plant primary products not elsewhere classified	S20199	Other plant production and plant primary products not elsewhere classified
Animal Production and Animal Primary Products	S20201	Livestock	S20201	Livestock
	S20202	Pasture, browse and fodder crops	S20202	Pasture, browse and fodder crops
	S20203	Fisheries products	S20203	Fisheries products
	S20204	Primary and by-products from animals	S20204	Primary and by-products from animals
	S20299	Other animal production and animal primary products not elsewhere classified	S20299	Other animal production and animal primary products not elsewhere classified
Energy resources	S20401	Exploration		
	S20402	Mining and extraction		
	S20403	Preparation and supply of energy source materials		
	S20404	Non-conventional energy resources		
	S20405	Nuclear Energy	S20405	Nuclear Energy
	S20499	Other energy resources not elsewhere classified		
Energy supply	S20501	Energy transformation		
	S20502	Renewable energy	S20502	Renewable energy
	S20503	Energy distribution	S20503	Energy distribution
	S20504	Conservation and efficiency	S20504	Conservation and efficiency
	S20505	Energy Issues		
	S20599	Other energy supply not elsewhere classified		
Commercial Services	S21001	Electricity, gas and water services and utilities	S21001	Electricity, gas and water services and utilities
	S21002	Waste management and recycling	S21002	Waste management and recycling
Economic Framework	S21107	Socio-economic development	S21107	Socio-economic development
	S21108	Economic development and environment	S21108	Economic development and environment
Natural Resources	S21201	Soil resources	S21201	Soil resources
	S21202	Water resources	S21202	Water resources
	S21203	Biodiversity	S21203	Biodiversity
	S21205	Industrial raw materials		

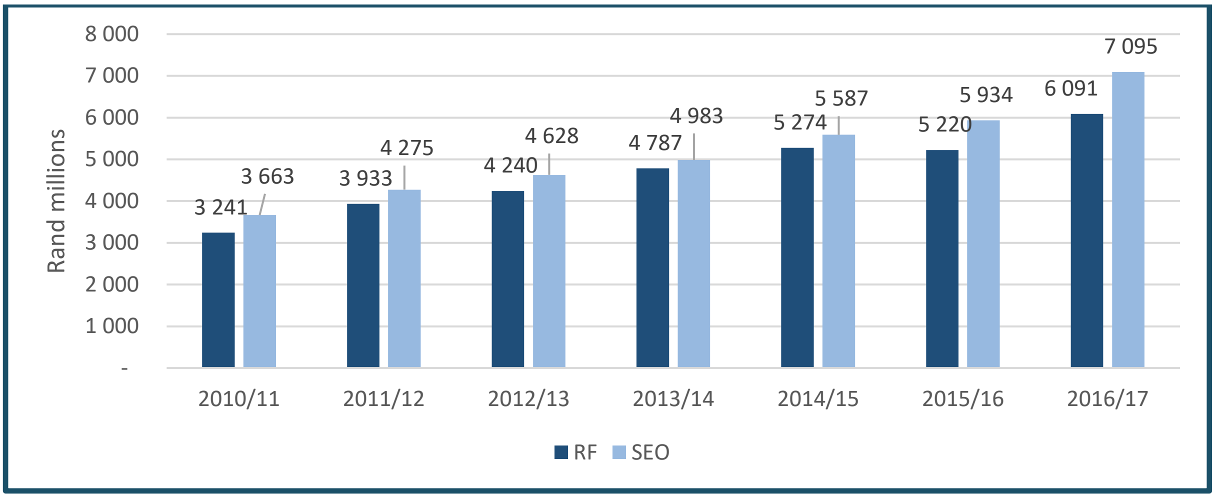
	S21006	Mineral resources		
	S21299	Other natural resources not elsewhere classified		
Environmental Knowledge	S40101	Climate and atmosphere	S40101	Climate and atmosphere
	S40102	Ocean	S40102	Ocean
	S40103	Water	S40103	Water
	S40104	Land	S40104	Land
	S40105	Nature conservation	S40105	Nature conservation
	S40106	Social environment	S40106	Social environment
	S40107	River	S40107	River
	S40199	Other environmental knowledge not elsewhere classified	S40199	Other environmental knowledge not elsewhere classified
Environmental Aspects of Development	S40201	Plant production and plant primary products (including forestry)	S40201	Plant production and plant primary products (including forestry)
	S40202	Animal production and animal primary products (including fishing)	S40202	Animal production and animal primary products (including fishing)
	S40203	Mineral resources (excluding energy)	S40203	Mineral resources (excluding energy)
	S40204	Energy resources	S40204	Energy resources
	S40205	Energy supply	S40205	Energy supply
	S40206	Manufacturing	S40206	Manufacturing
	S40207	Construction	S40207	Construction
	S40208	Transport	S40208	Transport
	S40209	Information and communication services	S40209	Information and communication services
	S40210	Commercial services	S40210	Commercial services
	S40211	Environmental economic framework	S40211	Environmental economic framework
	S40299	Other environment aspect of development not elsewhere classified	S40299	Other environment aspect of development not elsewhere classified
Environmental Management and Other Aspects	S40301	Environmental management	S40301	Environmental management
	S40302	Waste management and recycling	S40302	Waste management and recycling
	S40399	Other environmental aspects not elsewhere classified	S40399	Other environmental aspects not elsewhere classified
Natural Sciences, Technologies and Engineering	S50104	Earth sciences	S50104	Earth sciences
	S50105	Information, computer and communication technologies		
	S50108	Biological sciences	S50108	Biological sciences
	S50109	Agricultural sciences	S50109	Agricultural sciences
Social Sciences and Humanities	S50201	Social sciences		

Source: Authors, in collaboration with DSI and CeSTII

Note: Yellow represents the code that was included in 2015 but excluded in 2019 (13 SEO codes were removed). Green represents the code that was included in 2019 but excluded in 2015 (no new codes were added).

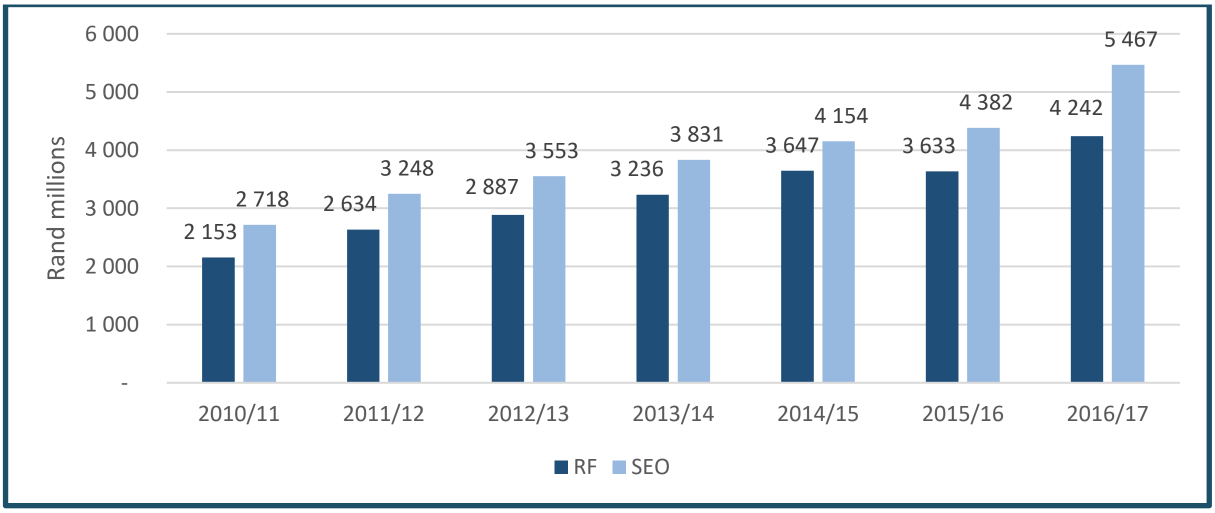
Green R&D in nominal terms

Figure 26: Total green R&D expenditure, based on both RF and SEO code selections (2010/11-2016/17), in nominal terms



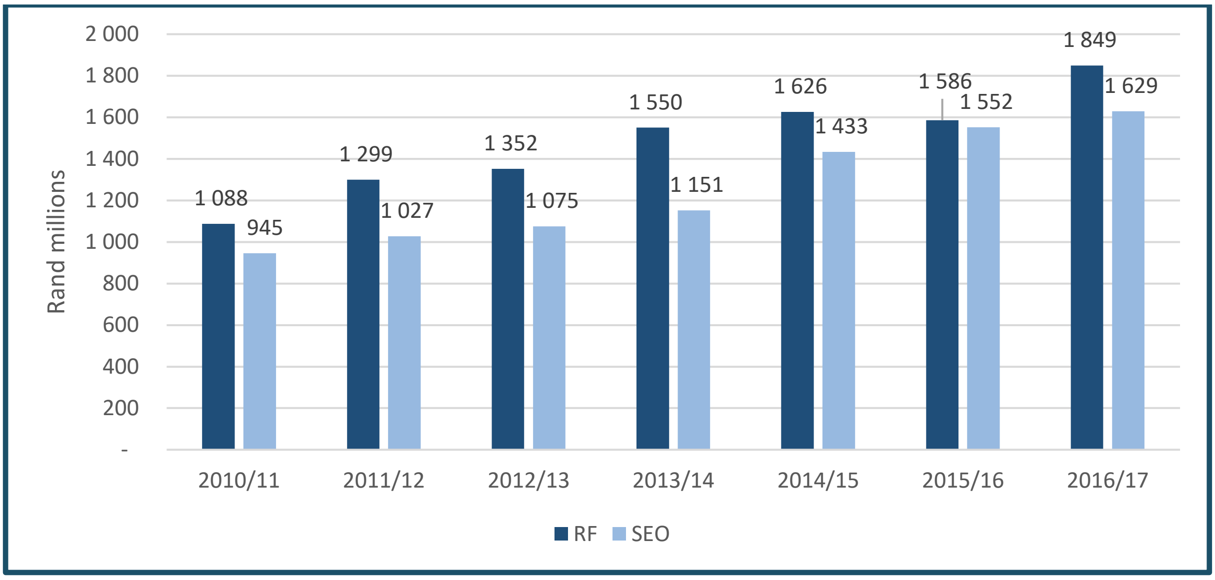
Source: Authors, based on CeSTII data 2010/11-2016/17

Figure 27: Public green R&D expenditure based on both RF and SEO code selections (2010/11-2016/17), in nominal terms



Source: Authors, based on CeSTII data 2010/11-2016/17

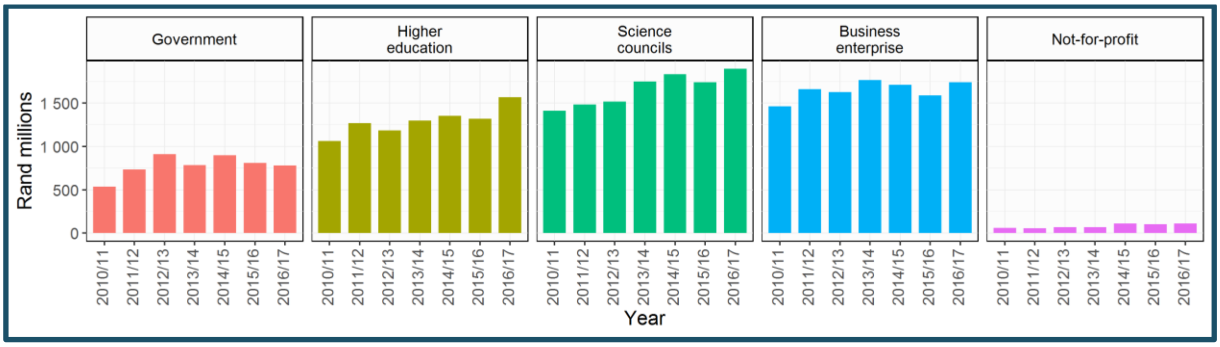
Figure 28: Private green R&D expenditure based on both RF and SEO code selections (2010/11-2016/17) in nominal terms



Source: Authors, based on CeSTII data 2010/11-2016/17

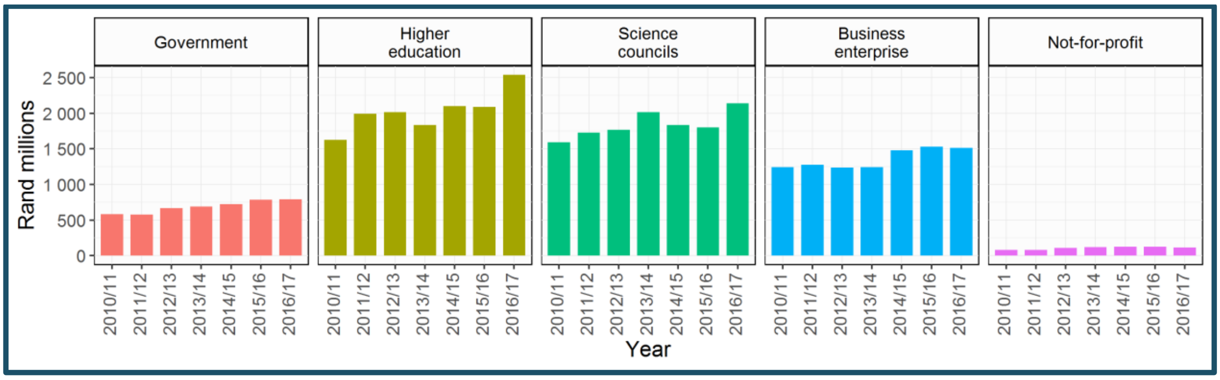
Facet graphs of Green R&D in real terms

Figure 29: Expenditure by sector, based on RF code selections (2010/11-2016/17), in constant 2016/17-rand values



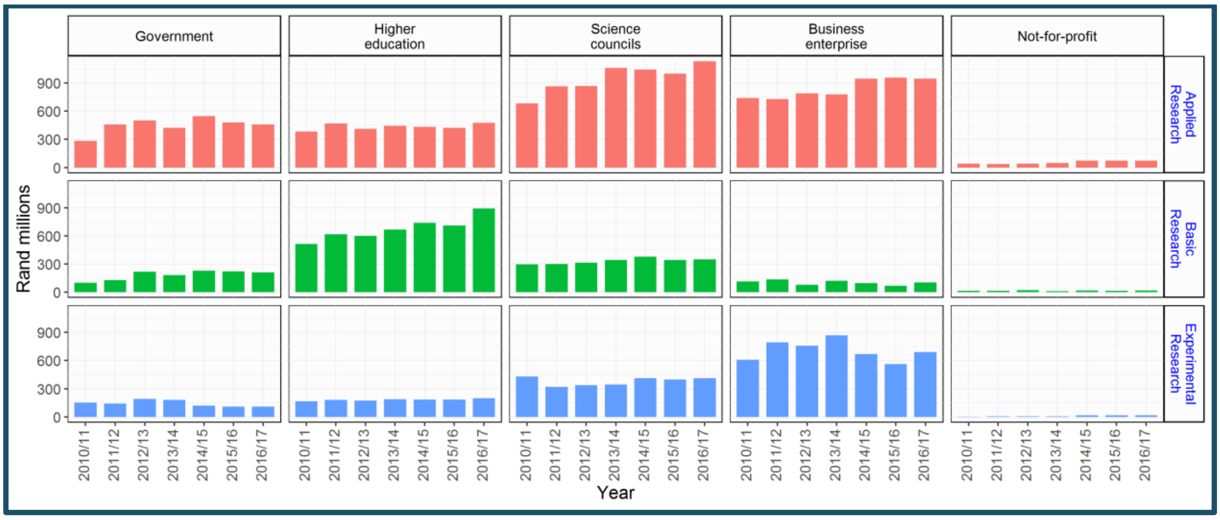
Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 30: Expenditure by sector, based on SEO code selections (2010/11-2016/17), in constant 2016/17-rand values



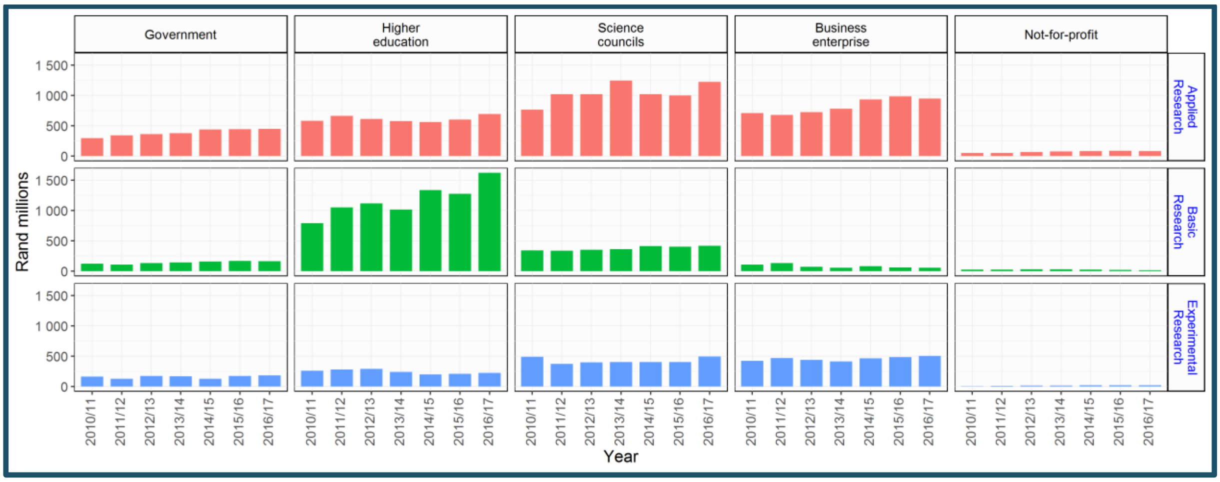
Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 31: Expenditure by sector and research type, based on RF code selections (2010/11-2016/17), in constant 2016/17 Rand values



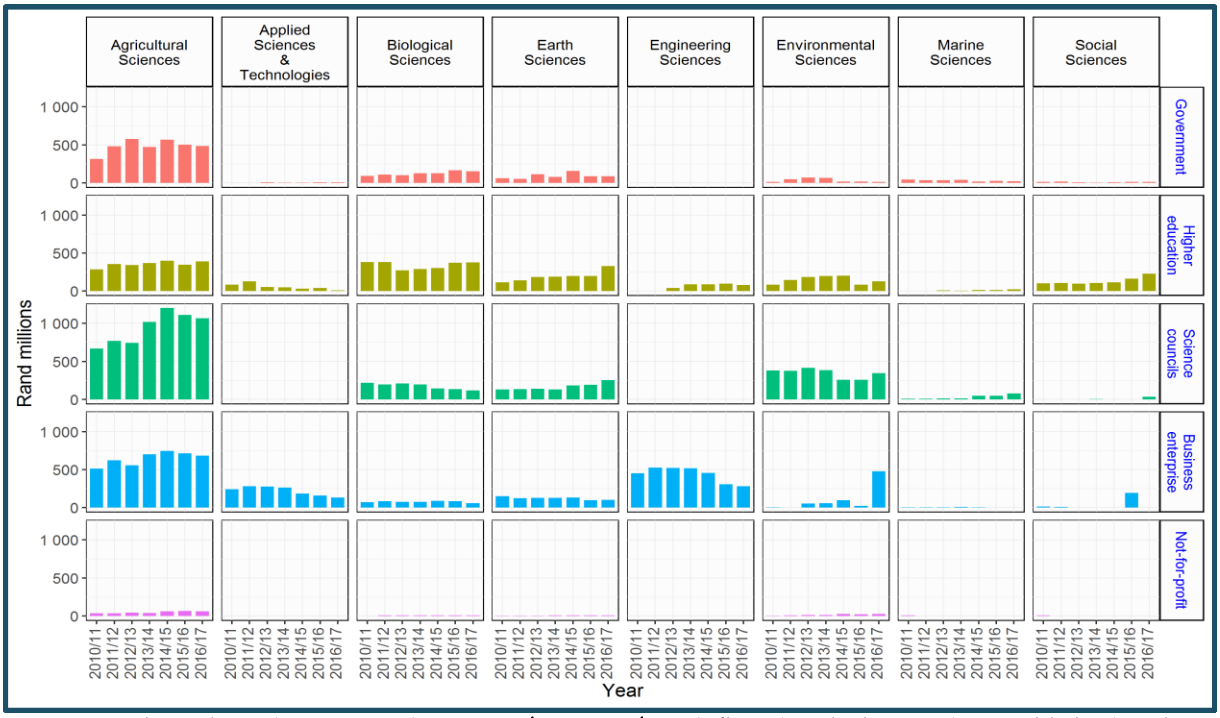
Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 32: Expenditure by sector and research type, based on SEO code selections (2010/11-2016/17), in constant 2016/17 Rand values



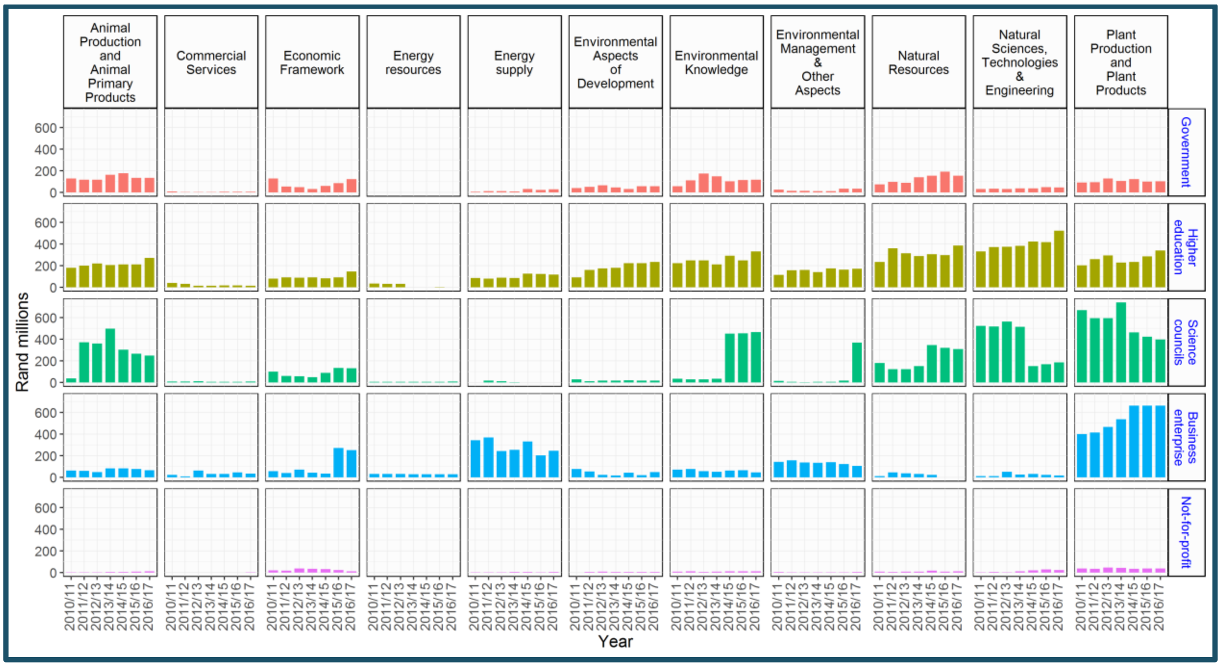
Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 33: Expenditure by research field and sector, based on RF code selections (2010/11-2016/17), in constant 2016/17 Rand values



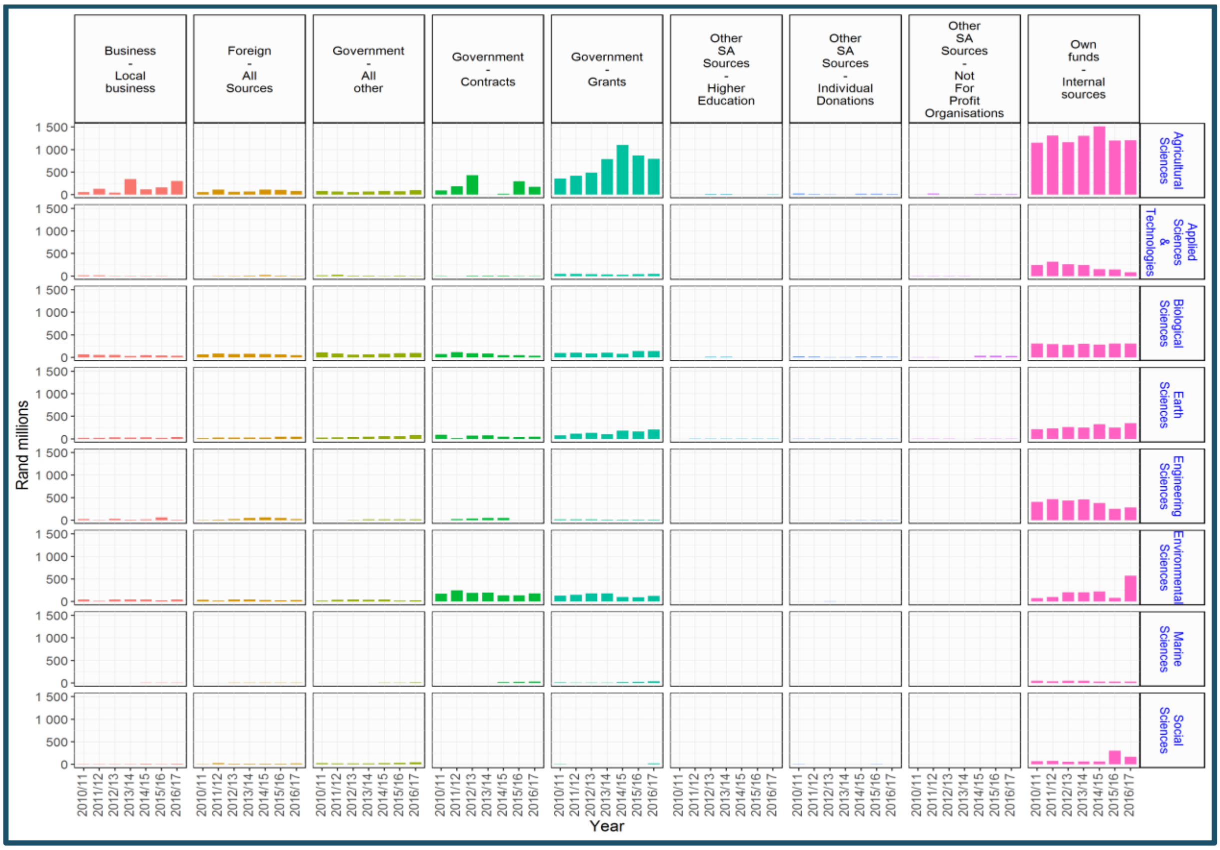
Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 34: Expenditure by research field and sector, based on SEO code selections (2010/11-2016/17), in constant 2016/17 Rand values



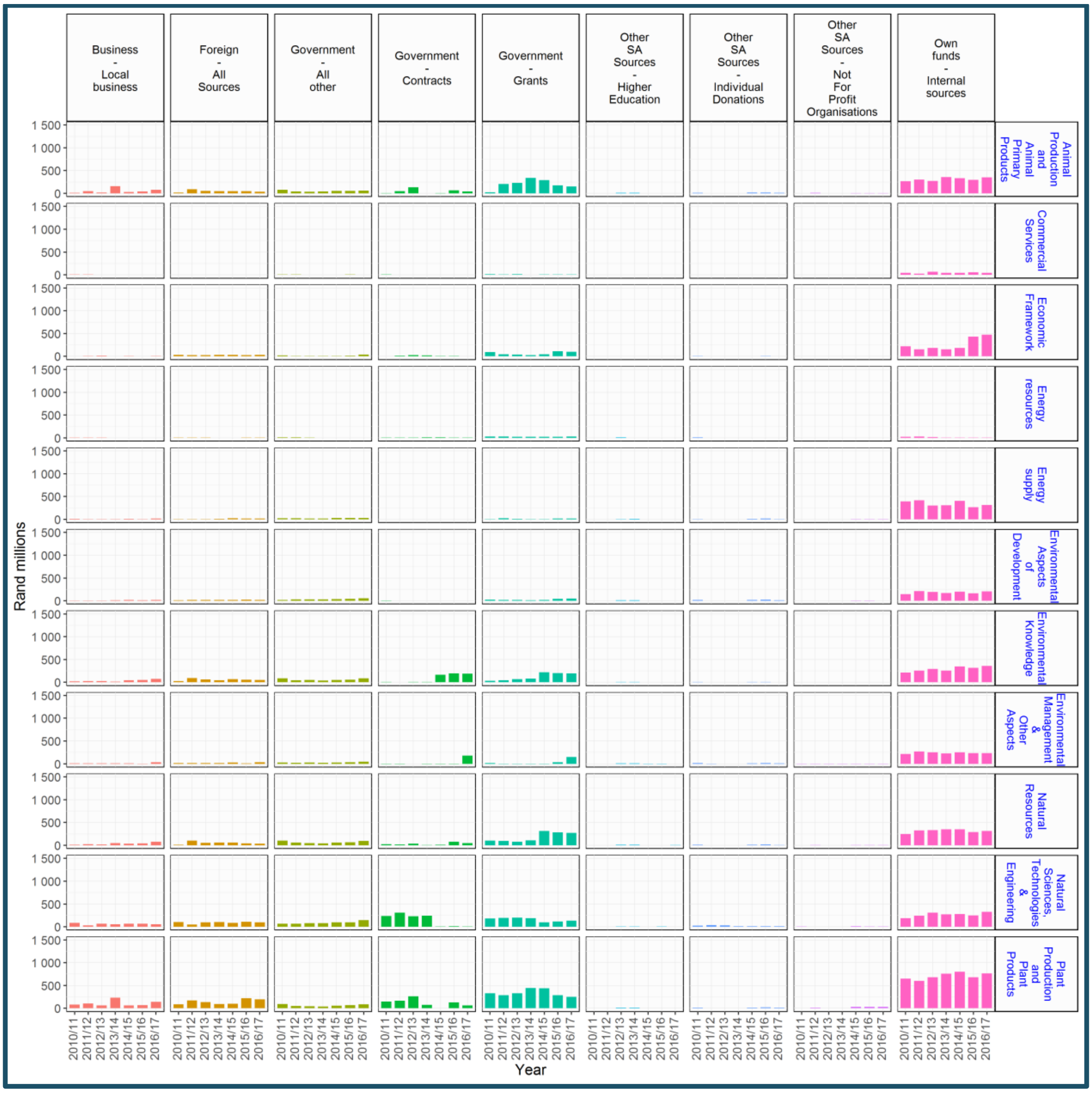
Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 35: Source of funds by RF (2010/11-2016/17), in constant 2016/17 Rand values



Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Figure 36: Source of funds by SEO (2010/11-2016/17), in constant 2016/17 Rand values



Source: Authors, based on CeSTII data 2010/11-2016/17, deflated with the CPI data published in the Statistics South Africa GDP survey P0441, 1st Quarter 2019 (Stats SA, 2019)

Nominal- versus real-term data

Economic data, such as expenditure in (green) R&D, can be reported in current and constant terms:

- data reported in current prices for each year are in the value of the currency for that particular year. This is also known as nominal terms. Current series are influenced by the effect of price inflation. When inflation is positive (this was the case for South Africa over the period studied), this artificially increases growth rates;
- data reported in constant prices show the data for each year in the value of a particular base-year. Constant series are used to measure the true growth of a series, i.e. adjusting for the effects of price inflation. This is also known as real terms.

In this report, the 2016/2017 financial year (ranging from March 2016 to February 2017) is used as the base year. As a result, all other years are expressed in 2016/2017 prices. Using real-term data (i.e. removing the impact of inflation) is necessary to obtain a true reflection of the evolution of (green) R&D expenditure over time. The raw data in nominal terms is reported in the Appendix for completeness.

Based on Statistics South Africa's monthly CPI data, the following deflators are used in this report:

Financial year	Deflator
2010/11	71,55
2011/12	75,58
2012/13	79,84
2013/14	84,5
2014/15	89,3
2015/16	93,8
2016/17	100,0

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