8 PUBLIC SECTOR MODEL

In this chapter, the conceptual model developed in Chapter 5 is applied to the South African public sector. A similar model structure, employing the dynamic model derived from theory, is used. The quantification of the stocks and flows is however chosen to be descriptive of the sector's specific characteristics.

Time series data of R&D inputs into this sector was gathered from R&D surveys based on the Frascati manual for the years 1977 to 2003. Although numerous issues might exist in terms of the data gathered over the years (especially with the data gathered from the Frascati surveys - see section **Error! Reference source not found.** for a detailed discussion), it is however by far the most accurate records available. Although noting the issues surrounding the accuracy and usefulness of the data and model, the data available is considered useful for the purposes of this study.

Data on patents registered by South Africans in South Africa was obtained from the South African Patent journal published by the South African patent office. Furthermore, data on the scientific output generated in the sector was gathered from the ISI web of science.

The actual data and data tables gathered is presented in Appendix B, while the data as well as the conclusions drawn from data trends are discussed in this chapter. The following section provides a brief overview of R&D organisations in the South African public sector.

8.1 Definition of the Public sector

The definition of the Public sector in this thesis follows the same definition as described in the Frascati survey. The reason for this is that this thesis makes use of the data gathered from the Frascati survey. The broad definition of the Public sector (called Government sector in the survey) is *(OECD, 2002 a)*[1]:

- *All departments, offices and other bodies which furnish, but normally do not sell to the community, those common services, other than higher education, which cannot otherwise be conveniently and economically provided, as well as those that administer the state and the economic and social policy of the community. (Public enterprises are included in the business enterprise sector.)*

- *NPIs controlled and mainly financed by government, but not administered by the higher education sector."*

The following section provides a brief over view of the biggest organizations surveyed in the Public sector in South Africa

[1] See The Frascati Manual (OECD, 2002a) for a more detailed description of the followed in the R&D surveys to categorise organisations into sectors.

8.1 Overview of the Sector

There are eight ***Science Councils*** (SC) in South Africa (CENIS, 1999: 149):

- Council of Scientific and Industrial Research (CSIR)
- Human Sciences Research Council (HSRC)
- Medical Research Council (MRC)
- Mineral Technology Council (MINTEK)
- South African Bureau of Standards (SABS)
- Council for Geosciences (CGS)
- Agricultural Research Council (ARC); and
- National Research Foundation (NRF), which is the funding agency of the country.

There are four state funded National Research Institutes (***National Facilities***) in South Africa, namely the South African Astronomical Observatory (SAAO), Hartebeeshoek Radio Astronomy Observatory (HartRAO), National Accelerator Centre, and the JLB Smith Institute for Inchtyology (Mouton, 2001:7).

There are a number of ***government departmental in-house research institutes*** and centres, including the National Institute of Virology (Deptment of Health), Weather Bureau, National Botanical Institute (Department of Environmental Affairs and Tourism) and the National Department for Curriculum Research and Development (Department of Education) (Mouton, 2001:7).

The following section briefly discusses the data gathered from Frascati R&D surveys, the ISI web of science and the South African patent office. The quantification of the stocks developed for the conceptual model is also described and explained.

8.2 Data Gathering and Analysis

8.2.1 R&D expenditure

The financial expenditure data was gathered from the South African R&D surveys. Table 8-1 lists the data gathered regarding R&D expenditure in the public sector from R&D surveys. (See Appendix B, section **Error! Reference source not found.** for actual data and description of the survey methodology).

Table 8-1: Data Gathered for R&D Expenditure in the Public Sector

Data Input	Source	Table
Source funding from business sector to public sector	R&D survey (1977-2003)	**Error! Reference source not found.**
Source funding from HES to the public sector	R&D survey (1977-2003)	**Error! Reference source not found.**
Own funds public sector (1980-2003)	R&D survey (1977-2003)	**Error! Reference**

		source not found.
Percentage R&D expenditure (capital) in public sector	R&D survey (1977-2003)	**Error! Reference source not found.**
Percentage R&D expenditure (human resources) in public sector	R&D survey (1977-2003)	**Error! Reference source not found.**
- Expenditure on researchers - Expenditure on technicians - Expenditure on support staff	R&D survey (1977-2003)	**Error! Reference source not found.**
Percentage R&D expenditure on basic R&D in public sector	R&D survey (1977-2003)	**Error! Reference source not found.**
Percentage R&D expenditure on applied R&D in public sector	R&D survey (1977-2003)	**Error! Reference source not found.**
Percentage R&D expenditure on experimental development in public sector	R&D survey (1977-2003)	**Error! Reference source not found.**
Investment in capital stock in public sector	R&D survey (1977-2003)	**Error! Reference source not found.**

Figure 8-1 is a graphical representation of the distribution of R&D expenditure in the public sector. R&D expenditure is divided into three main categories, namely human resources, capital investment and running costs.

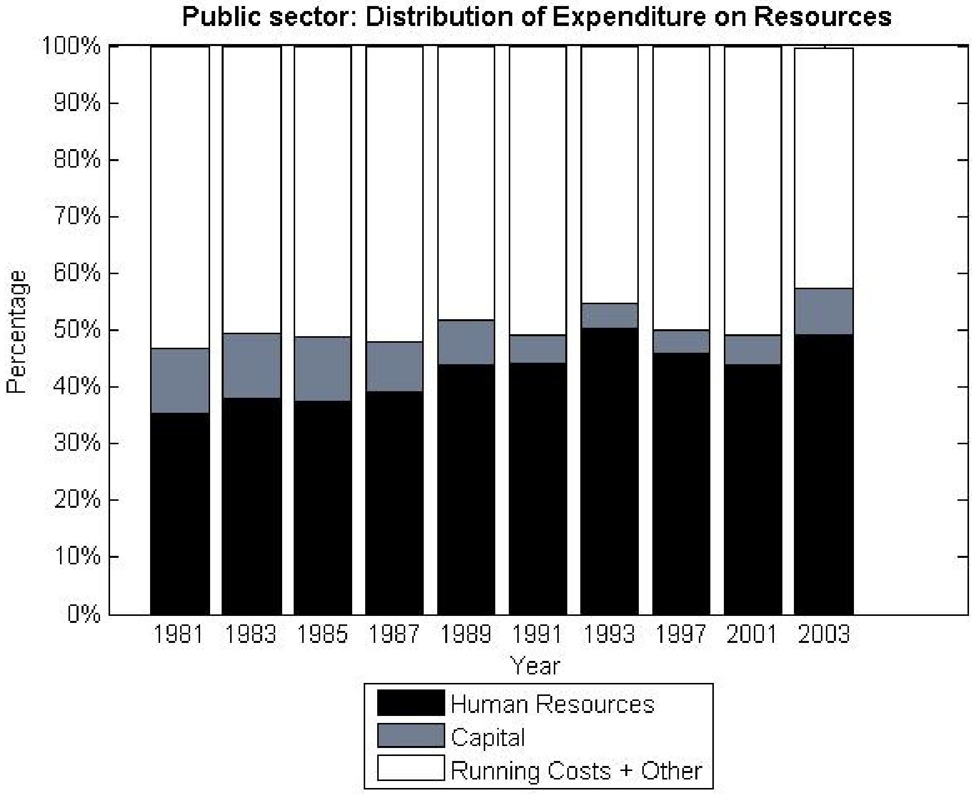


Figure 8-1 Distribution of Expenditure in the Public sector

The distribution of the expenditure clearly indicates that a relatively small percentage of funding is directed towards capital resources. For the years 1977 to 2003, an average of approximately 7.76% (standard deviation 3.11%) of the total expenditure was directed towards capital. The percentage has decreased from roughly 11 % in 1981 to approximately 5% in 2003. The data available also does not provide much detail in terms of the type of investment to different fields of science or the type of capital resources. Land and buildings are included in the investment data. We can therefore conclude that a relatively small percentage of R&D expenditure is directed towards investment in capital resources.

The calculation of the percentage of R&D expenditure on labour in the public sector seems to be a relatively constant percentage of approximately 43% of the total expenditure in the system. The average of the percentage for the years 1977 to 2003 is 42.58% (standard deviation of 6.27%). The calculations therefore indicate human resources have been one of the main sources of expenditure on R&D in the public sector.

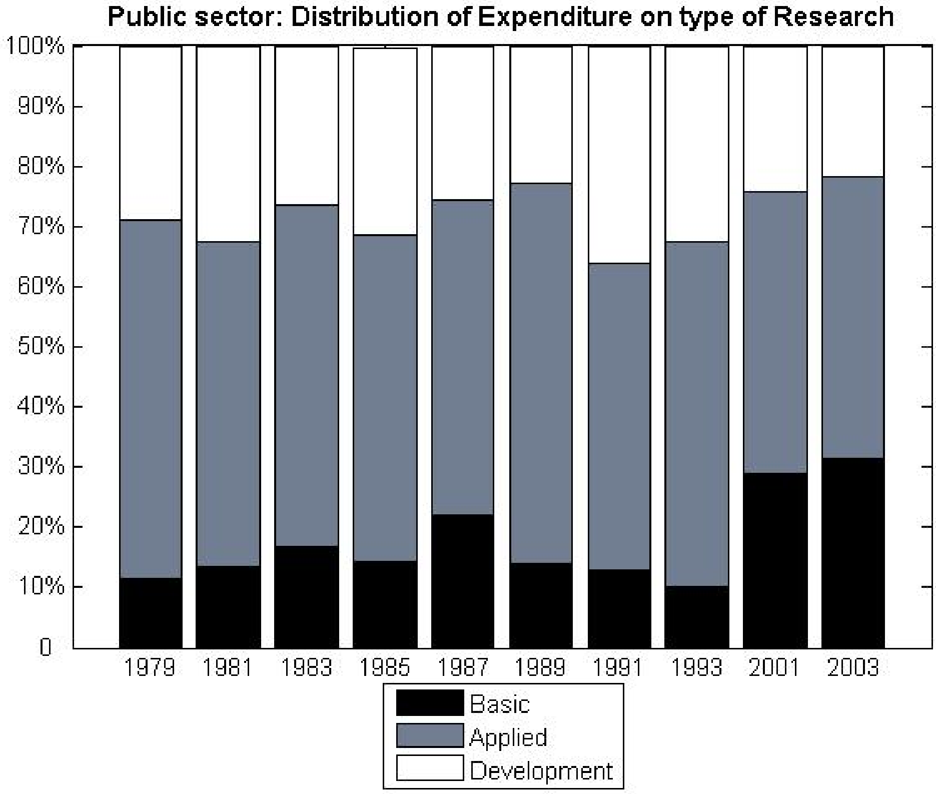


Figure 8-2: **Expenditure on Type of Research in the Public Sector**

The public sector focuses mainly on applied research, with a substantial amount of research being done on experimental development. Over the period 1979 to 2003, an average of roughly 55% of R&D expenditure in the sector was directed towards applied research, with an average of roughly 28% directed towards experimental development over the period 1979 to 2003.

The following table summarises the analysis of R&D expenditure in the South African public sector.

Table 8-2: **Conclusions from HES Expenditure Data Gathered**

Parameter	Average for 1977 to 2003	Standard Deviation
% R&D expenditure (capital) in HES	7.76%	3.31%
% R&D expenditure (human resources) in HES	42.58%	6.1%
Expenditure on Researchers Expenditure on Technicians Expenditure on Support staff	56.34% 26.87% 16.76%	8.8% 3.86% 10.04%
Percentage expenditure on basic research Percentage expenditure on applied research Percentage expenditure on experimental development	15.87% 54.36% 28.38%	6.04% 5.5% 4.25%

Except for the NRF, science councils receive core funding from three sources, namely contract income on the basis of 'full cost recovery for services', funding from applications to the Innovation Fund on an open competition basis as well as a part of the parliamentary grant for core funding (Marais, 1999:106).

In April 1988, government adopted the system 'Framework Autonomy and Base Line funding' for the management of science councils. Government subsidies were fixed to force councils to secure funding from clients in the public or private sectors. This system was specifically enforced to increase linkages between councils and industry (Kaplan, 1995:8).

The policy and framework of framework autonomy was designed to enhance the execution of R&D in national interest and to undertake contract research. This resulted in greater degrees of autonomy were granted to public entities as well as a decrease in public funding on a range of institutions. The frame work autonomy baseline funding policy (Marais, 1999):

- gave highest possible autonomy in terms of matters of internal organisation
- made applied and problem oriented research self-funding through contract research; and
- made provision for the cost of basic research to be borne by the state.

There were however a number of negative consequences of the culture of research within the councils. Research portfolios within councils became more market driven, while inevitably less attention was given to socio-economic and development goals. Collaboration between institutes declined and competition became the order of the day (CENIS, 2000: 35). More recently, this shift towards a more market driven model came under fire.

It is thus hypothesised that as the percentage contract research funding received by organisations in the public sector increases, the focus shifts away from the creation of scientific output, such as scientific publications and patents that will remain in the name of organisations in the public sector.

Figure 8-3 depicts an increasing trend in the percentage of R&D expenditure sourced from the private sector.

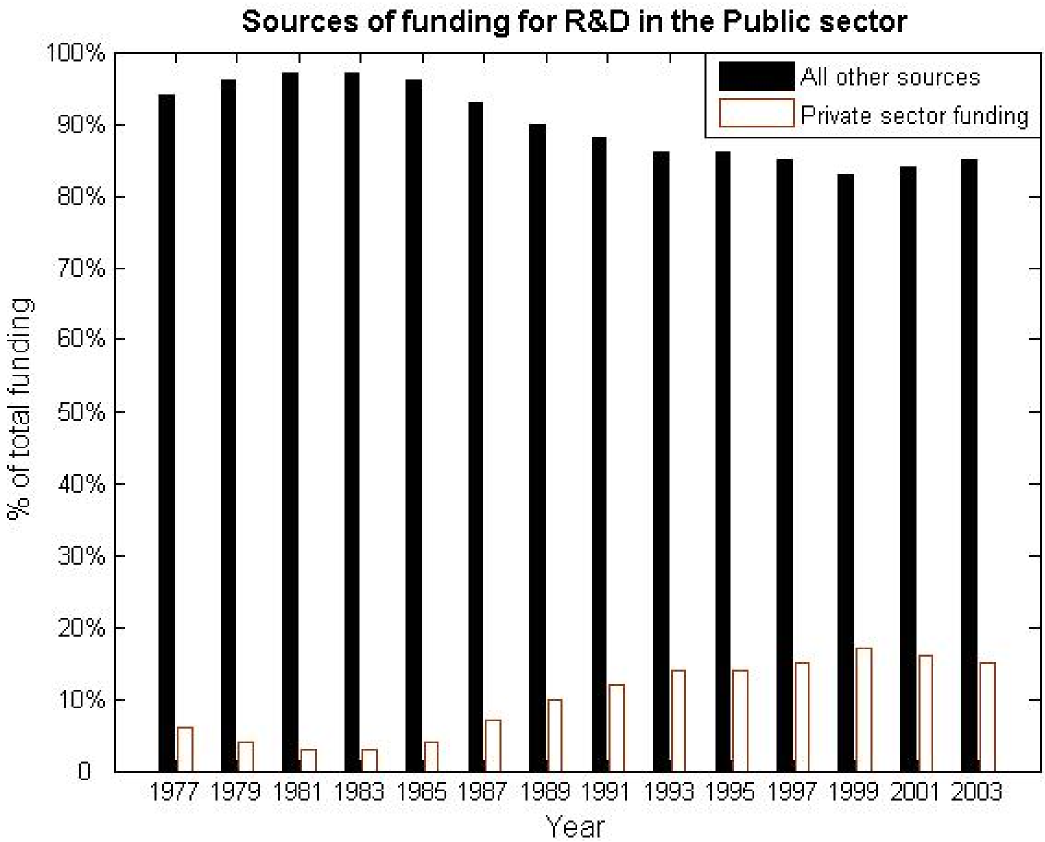


Figure 8-3: Increasing Trend in Funding from the Private Sector

A rough approximation is made that all funding flowing from the private sector to the public sector is directed towards contract funding and that all other types of funding flowing into the sector is thus considered to be non-contract funding.

This trend depicts increased contract income and funding for R&D in the public sector. This phenomenon is in line with the automatic expectation from the implementation of the 'Framework Autonomy and Base Line funding' of 1988. This policy was implemented for the management of the science councils in a bid to gradually decrease government funding, thus forcing them to earn contract income from the industry.

8.2.2 Human resources in the public sector

Table 8-3: Data Gathering for Human Resources in the Public Sector

Data Input	Source	Table
Total human resources stock (1980-2003)	R&D survey (1977-2003)	**Error! Reference source not found.**
Fulltime equivalent researchers	R&D survey (1977-2003)	**Error! Reference source not found.**
Percentage time spent on R%D	To be computed	**Error! Reference source not found.**

Figure 8-4 is a graphical representation of human resources data gathered from the Frascati manuals.

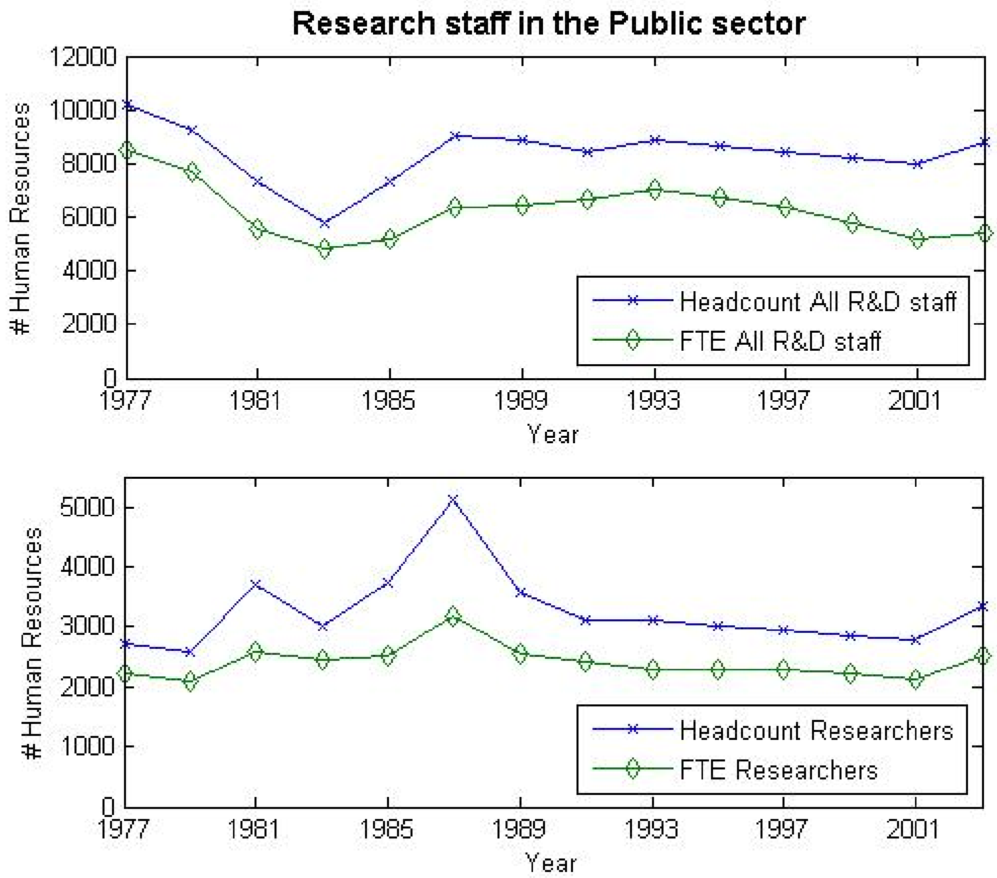


Figure 8-4: **Data Gathered for Human Resources in the Public Sector**

Both the above graphs present the headcount as well as fulltime equivalent human resources. The first graph represents data for the total research staff and the fulltime equivalent of all human resources involved in R&D activities in the sector.

To obtain a more complete picture of the importance of the role that the different types of human resources play in the sector, the average expenditure spent on the human resources groups, the headcount and the FTE is analysed.

Table 8-4: **Distribution of Human Resources in the Public Sector in South Africa**

	Expenditure		Headcount		Fulltime Equivalent	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
Researcher	56%	9%	41%	11%	39%	8%
Technical	27%	4%	27%	4%	29%	5%
Support	17%	11%	32%	13%	32%	12%

The information in Table 8-4 can be depicted in the following pie charts.

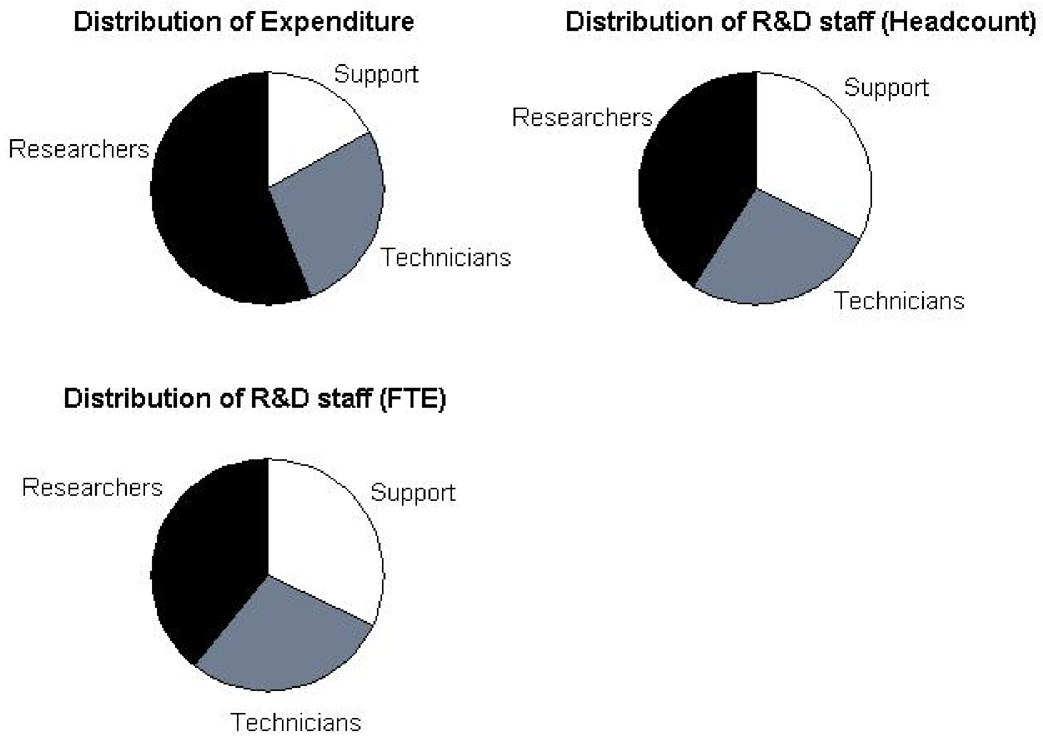


Figure 8-5 Distribution of expenditure on Human Resources

From evidence provided in Figure 8-5, it can be concluded that technical personnel and support personnel comprises a large portion of expenditure on human resources in the public sector. The same can be said for the recorded fulltime equivalent R&D staff employed in the system. Support and technical staff will consequently not be excluded from the analysis. We can however see that most of the R&D expenditure on HR is directed towards researchers, who constitute the largest percentage of the headcount as well as the fulltime equivalent staff in the system.

Since the Frascati surveys were conducted biannually, the data points in the time series process is only available for every second year, while the data on the R&D output generated in the system is available yearly. The evidence obtained in Figure 8-5 concludes that all three groupings of R&D staff should be included in the analysis. A definite trend is depicted in the graphical representation of the human resources in Figure 8-4. For this reason, the data is thus extrapolated to be compatible with the R&D output which is available for every year.

The method used to analyse and calculate the percentage time spent by personnel on R&D is as follows: the fulltime equivalent staff is divided by the headcount personnel as reported in the Frascati based R&D Surveys. The result then is used as the average percentage time that R&D personnel reportedly spend on R&D activities:

- percentage time all staff = FTE staff (survey)/HC staff (survey); and
- percentage time researchers = FTE researchers (survey data) per HC researchers (survey).

The percentage time spent by personnel in the public sector as an average for the years 1977 to 2003 is 76% (deviation 6.49%). The average time spent by researchers in the system is in a similar region at 74.33% (deviation 6.59). The data can be tabulated as follows:

Table 8-5: Conclusions from Public Sector Human Resources Data Gathered

Parameter	Average for 1977 to 2003	Standard Deviation
Percentage time spent on R%D (all R&D staff)	76%	6.49
Percentage time spent on R%D (researchers)	74.3%	6.59

8.2.3 Data gathered on the development of knowledge

We have already determined that apart from basic research, the public sector performs a large percentage applied and developmental research. The sector's R&D outputs will therefore be insufficiently represented when only considering scientific publications generated in the sector.

The measurement of basic and applied research in the public sector

The following is a graphical representation of the respondents' feedback in the Delphi study on the applicability of scientific output as a proxy for basic and applied research output in the South African public Sector (see section **Error! Reference source not found.**).

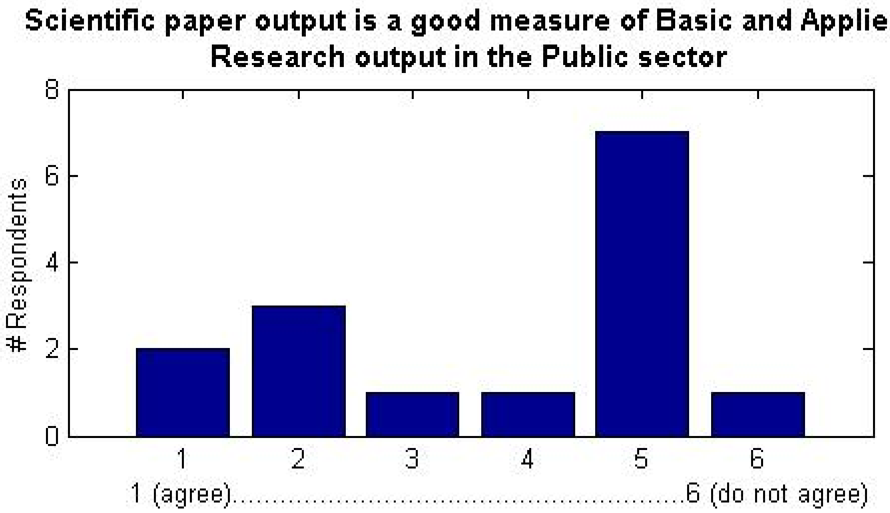


Figure 8-6: Measurement of Basic and Applied Research Output

The mode and median for the feedback gained from the expert panel was five, indicating that the aggregated expert opinion is that scientific publication output is not an adequate measure of basic and applied research output in the public sector.

It is however interesting that a number of respondents view this measure as an appropriate means of measuring basic and applied research output in this sector. Five of the 14 respondents responded with a ranking of one or two, indicating that it is a good measure to use. Due to a lack of any better measure available, it is therefore decided to continue the analysis by using scientific publication output as a indicator.

The obvious shortcomings of following this approach must however be kept in mind when interpreting the results gained from the model simulation runs.

The measurement of experimental development in the Public sector
The following is a graphical representation of the respondents' feedback in the Delphi study on the applicability of patent counts as an indicator for experimental development output in the South African public sector (see section **Error! Reference source not found.**).

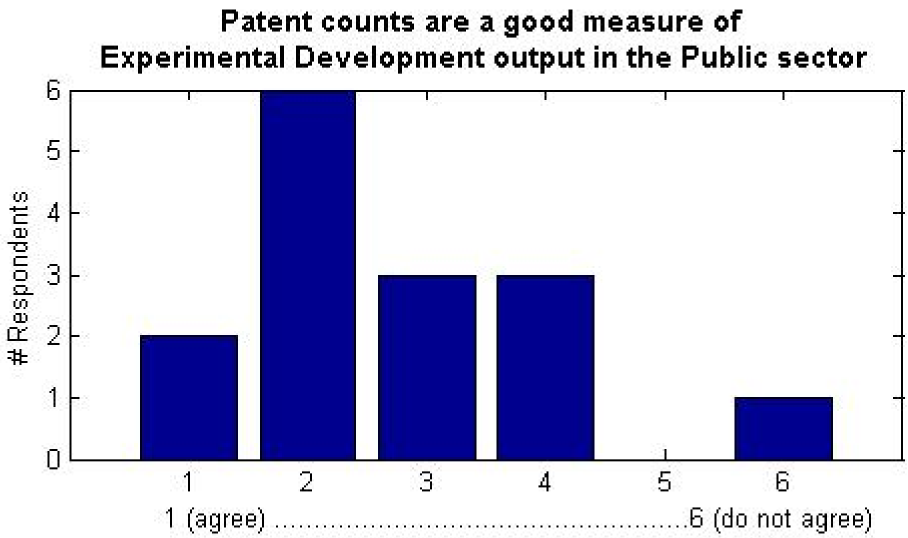


Figure 8-7 **Measurement of Experimental Development in the Public Sector**

The feedback gathered from the respondent's yield that patents proof to be a relatively good choice of measurement for experimental development output generated in the public sector. The responses reveals that the mode is two, thus indicating that the respondents view this measure as a valid proxy for measuring experimental development output in the public sector. It is also established that from the 12 respondents, only four ranked above three, which indicates that patent output is a relatively good measure of experimental development output in the South African public sector. Naturally, this approach has its weaknesses, which is also reflected in the average rating of 2.73 by the expert panel.

The above discussion therefore concludes that the following proxies can be used to measure different types of research and the corresponding output in the public sector:

- the proxy used for R&D outputs from basic, strategic and applied research performed in this sector is the amount of scientific publications produced in the public sector; and
- the proxy used for R&D outputs from developmental research performed in this sector is the amount of patents granted to organisations in the public sector.

Table 8-6: Data sources for the measurement of knowledge in the Public sector

Data Input	Source
Sector knowledge creation (scientific papers) (1980-2003)	ISI web of science, South African patent office
Knowledge depreciation rate (citation curve)	ISI web of science (1977-2003)
Sector knowledge creation (patents) (1980-2003)	SAPTO
Knowledge depreciation rate (citation curve)	To be estimated

8.2.3.1 R&D output from basic and applied research

The following is a graphical representation of the scientific output generated in the public sector in South Africa.

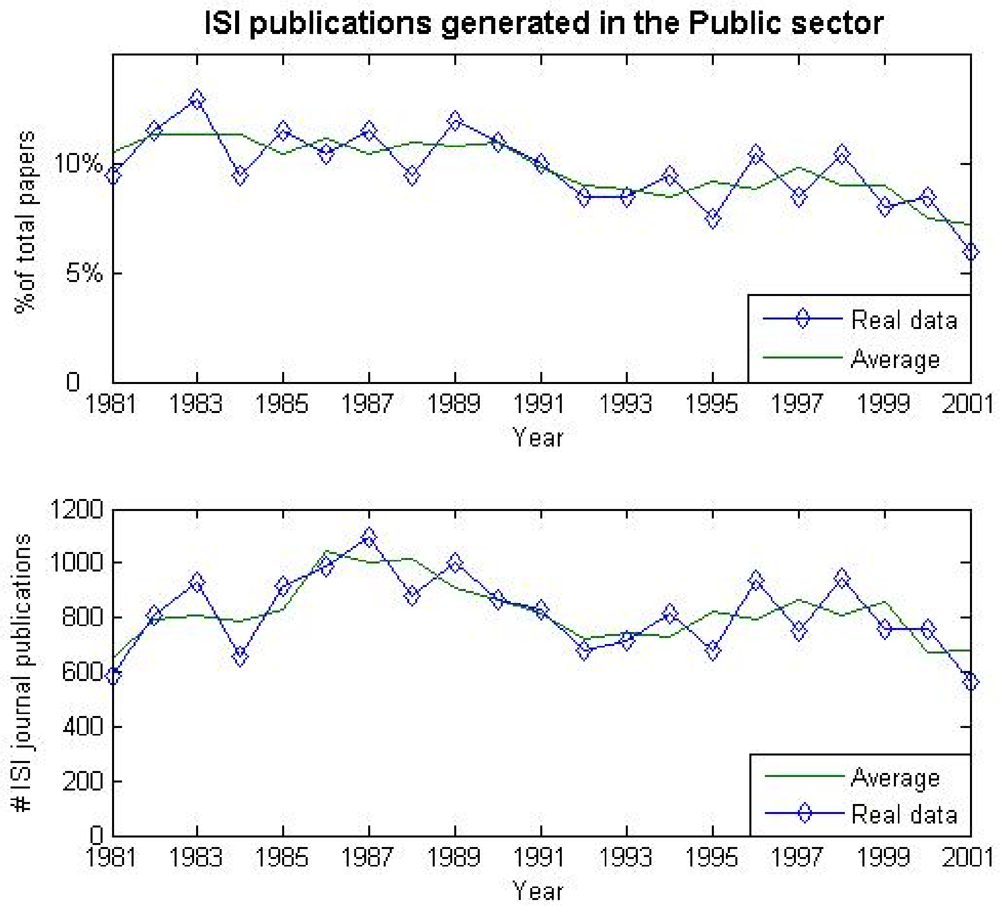


Figure 8-8: Scientific Output Generated in the South African Public Sector

Figure 8-8 depicts the scientific output generated in the sector in two different graphs. The first reveals the percentage of the outputs generated in the sector as a percentage of scientific output generated in South Africa as a whole. The second shows a trend in which the scientific output generated in the sector is depicted in the number of scientific journal articles generated from the sector and published in ISI journals.

The trend in Figure 8-8 that the scientific output created in the public sector thus reveals a gradual decline starting in the late 1980s.

8.2.3.2 R&D outputs from developmental research

The second proxy used for the generation of knowledge in the public sector is the patents registered by organisations in the public sector.

The USPTO data reflects a negligible amount of patents originating from the South African public sector. This result forces the author to consider the patents registered at the South African patent office as a proxy.

Unfortunately, a general state of disarray exists at the South African patent office, with no database or account of patents granted being accessible at a central location. This was one of the main factors impeding the analysis of the patents granted to the public sector in South Africa. Finding patent data for the public sector proved difficult and time consuming.

Patents journals are published on a monthly basis to report the most recent patents granted at the South African patent office. Each patent journal from 1985 to 2004 thus had to be analysed individually. All patent entries in the journals were scrutinised for a South African (ZA)[2] country of origin address. Once obtained, the name of the assignee was checked. The patent was subsequently assigned to one of three categories: HES, public sector or private sector, on an assignee name basis.

The following is a graphical representation of the number of patents granted to organisations in the public sector at the South African patent office from 1985 to 2004.

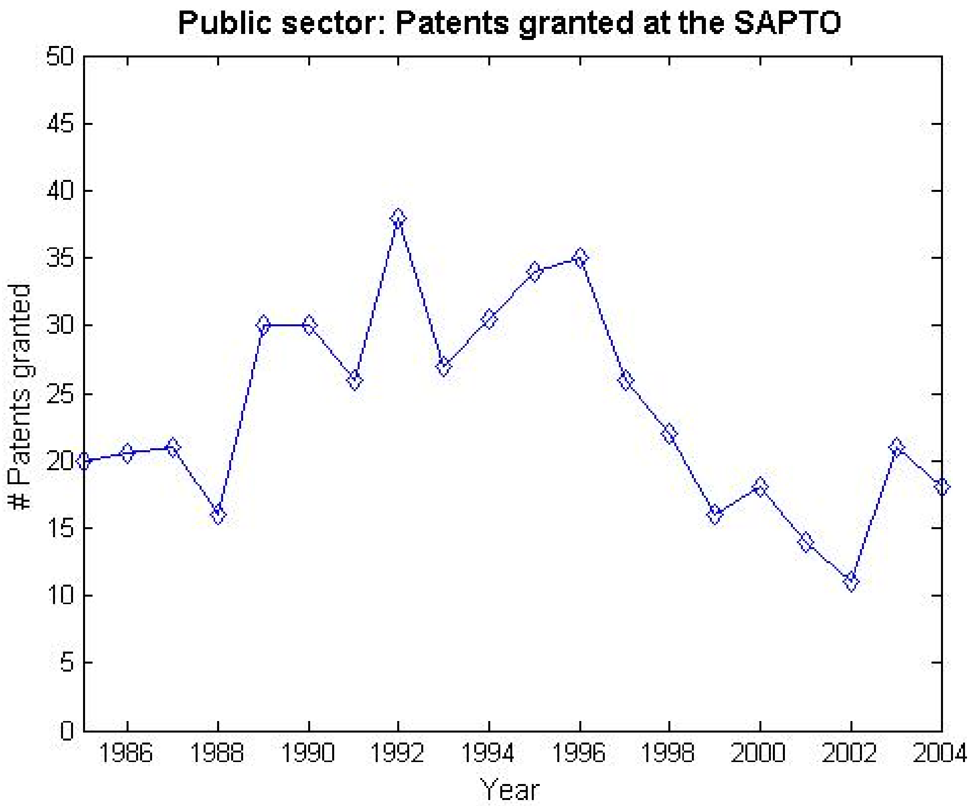


Figure 8-9 Patents Granted to Organisations in the Public Sector (SAPTO)

Data obtained from the patent journals from the South African patent office (1985 to 2004) indicates that the South African public sector revealed a decreasing trend in patents granted over the past decade.

8.2.4 Data gathered on the absorption of knowledge

Table 8-7: Sources of Data for the Measurement of the Absorption of Knowledge

Data Input	Source

[2] It is acknowledged that a measure of uncertainty exists in considering the priority country as a basis of finding the country that the inventor resides in. After discussions with a number of patent attorneys, it was concluded that the uncertainty is negligible and that a good approximation of patents granted to South Africans could be achieved by following this method.

Rate of knowledge absorption (references)	ISI Web of Science
Initialisation of absorbed knowledge stock in 1980	To be estimated
Depreciation of acquired knowledge stock	To be estimated
Initial acquired knowledge stock in 1980	To be estimated

Since papers are used as a measure of the development of new knowledge in the sector, the absorption of knowledge is also measured by the rate at which scientists reads, interprets and uses knowledge created in the external environment to perform R&D.

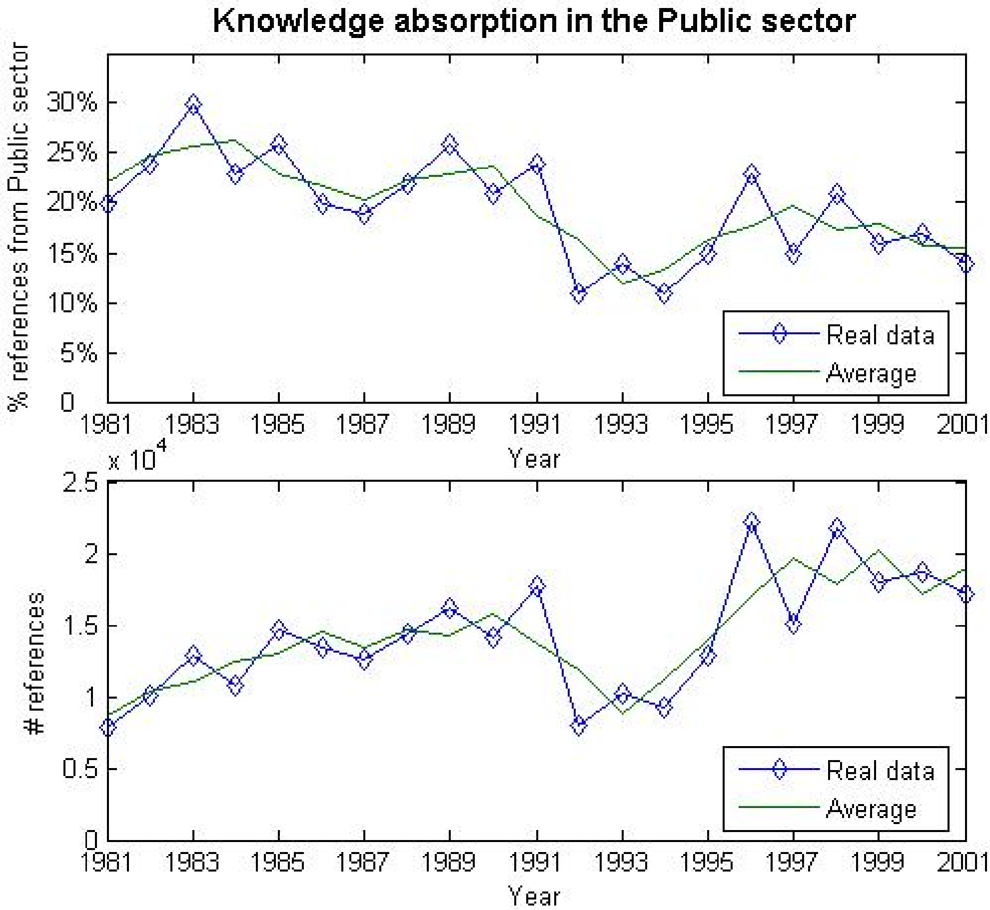


Figure 8-10: References Made to Knowledge Created in an External Environment

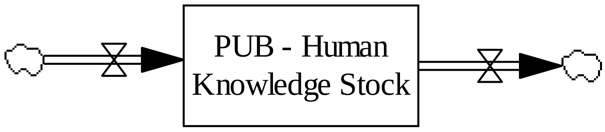
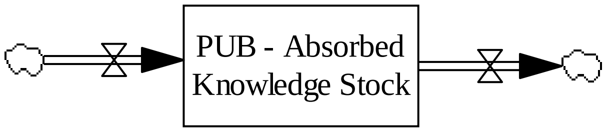
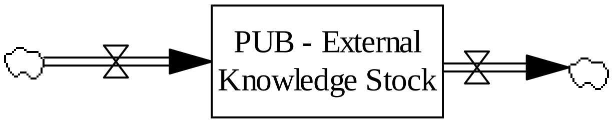
As the South African patent office does not examine patents before they are granted, no references to prior art are recorded in the patent files. No data is consequently available for knowledge absorption, which leads to the creation of new ideas, resulting in patents in the public sector.

8.3 Quantification of Stocks in the Public Sector

The following table describes the unit of measurement and quantifications of stocks for the public sector:

Table 8-8: Stocks for the Public Sector Model

Stock	Quantification

	FTE – Researchers employed during the year Unit: FTE research staff
	Cumulative years experience of FTE researchers Unit: Year
	R&D output generated in HIS Unit: Patents and Papers
	Stock of absorbed knowledge is measured by counting the amount of foreign papers cited by scientists in the system Unit: Papers
	The stock of external knowledge is the amount of scientific publications or patents in the external Units: Papers and Patents

The following section describes the data gathered and the fundamental R&D inputs to the public sector.

8.4 Model Development and Calibration

See Appendix G for the stock and flow diagram for the Public sector model

8.4.1 Human resources subsystem

This section describes the population of the conceptual model with the data gathered. The first subsystem developed is the human resources subsystem.

The Frascati survey data revealed that the recorded amount of R&D staff employed in 1981 in South Africa was 7 352, from which an even distribution of people for all age cohorts is assumed. The initial values for the cohorts can therefore be calculated as follows:

Table 8-9: Initialisation of Age Cohorts

Age	Years	Percentage	Starting values
25-40	15	15/35 = 42.86%	3152
41-50	10	10//35 = 28.57%	2100
51-60	10	10/35 = 28.57%	2100
Total	35	35/35 = 100.00%	7352

The following table summarises the assumptions made in the development of the human resources subsystem in the public sector:

Table 8-10: Parameters for Estimation in the Public Sector Model

Parameter	Estimated Value
Average retirement age	65 years
Recruitment distribution between cohorts: • Young • Experienced • Mature	 77% 11% 11%
Natural attrition percentage of cohorts: • Young • Experienced • Mature	 5% 5% 5%
Initial values for the HR stocks (1980) • young • experienced • mature	Total: 7352 3152 2100 2100
Decay rate of knowledge stocks and experience	10% per year
Average time spent on R&D	0.74 (10% variation)

The experience stock employs the co-flow structure as discussed in the development of the conceptual model diagram in Chapter 4. Experience gained from doing research is measured in terms of the FTE researchers working in the system during a specific time period.

Initially, an experiment was conducted on the model to test its behaviour in the development of experience in R&D. All experience stocks were initialised with zero values. The target academic and research staff in the system was set to a constant value of 7 352. The percentage time spent by researchers on R&D is set at 74%.

An examination of the average level of experience possessed by the different age cohorts of academic and research staff as the system reaches equilibrium yields an interesting observation. Figure 8-11 depicts the output from the model for the simulation run for a constant average of 75% time spent on R&D.

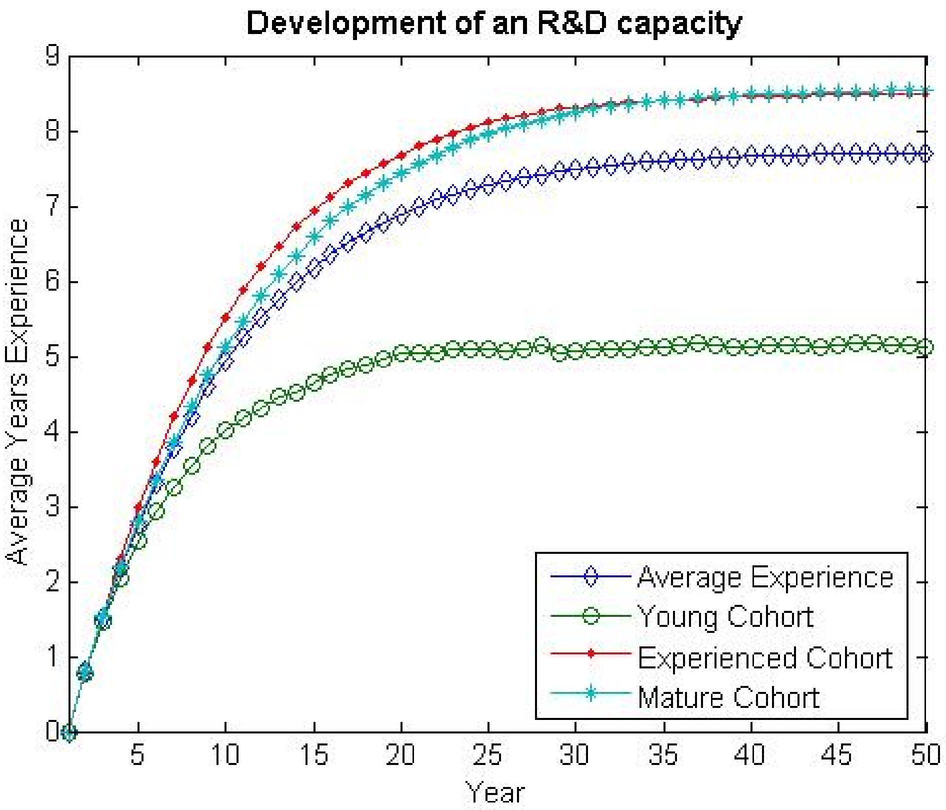


Figure 8-11 The Development of an R&D capacity (age cohorts)

Figure 8-11 reflects the expected trend that young researchers will not have the same capabilities and tacit knowledge of older, more experienced researchers. Interestingly, the equilibrium levels of experience per person approaches the same value for both the experienced and mature researchers stocks. This phenomenon can be explained by the dynamics included in the model that knowledge also decays through 'forgetting' and that for a fixed R&D intensity, the system approaches an equilibrium level where only knowledge gained within a given amount of years remain in the system.

It can therefore be concluded that the system reaches a state of equilibrium after a number of years. It is assumed that these equilibrium values are close enough approximations of the average starting value for experience per person in the cohorts. Using the equilibrium levels, we find values for the initial values of the experience stocks.

Table 8-11: Initial Values for the Experience Stocks

Stock Name	Initial Value
Young experience stock (25-39)	15760 (years) – 3152 with an average of five years experience
Experienced experience stock (40-49)	17850 (years) – 2100 with an average of 8.5 years experience
Mature experience stock (50+)	17850 (years) – 2100 with an average of 8.5 years experience

8.4.2 Absorption of knowledge subsystem

Regression analysis is employed to develop the following model for the absorption of knowledge into the system. The rate at which the system is able to absorb knowledge is calculated by the contribution made from different stocks in the system as well as the external environment. The following expression is formulated for the R&D knowledge absorption rate in the system:

- $R_{Absorption}$: absorption rate of knowledge in the system
- $S_{R\&Doutput}$: R&D output stock in the system
- S_{FTE} : stock of fulltime equivalent people in the system
- S_{World} : available external knowledge stock (patents); and
- S_{HC} : headcount personnel employed in the system.

A multiplicative model is developed for the absorption rate per fulltime equivalent person working in the system:

$$\frac{R_{Absorption}}{R^{*}_{Absorption}} = f * (\frac{S_{R\&Doutput}}{S^{*}_{R\&Doutput}} * \frac{S_{FTE}}{S^{*}_{FTE}})^{d} * (\frac{S_{World}}{S^{*}_{World}} / \frac{S_{HC}}{S^{*}_{HC}})^{e} \quad \textbf{8-1}$$

This expression is linearised by taking the log-linear form:

$$\ln(\frac{R_{Absorption}}{R^{*}_{Absorption}}) = f + d * \ln(\frac{S_{R\&Doutput}}{S^{*}_{R\&Doutput}} * \frac{S_{FTE}}{S^{*}_{FTE}}) + e * \ln(\frac{S_{World}}{S^{*}_{World}} / \frac{S_{HC}}{S^{*}_{HC}})$$

8-2

The following estimates for the parameters are obtained from the SAS analysis output:

Table 8-12: SAS Output for the Estimation of Model Parameters

Dependent Variable AbsorbedR

Ordinary Least Squares Estimates

SSE	0.2953922	DFE	15
MSE	0.01969	Root MSE	0.14033
SBC	-14.223913	AIC	-16.895028
Regress R-Square	0.5317	Total R-Square	0.5317
Durbin-Watson	3.3536	Pr < DW	0.9979
Pr > DW	0.0021		

NOTE: Pr<DW is the p-value for testing positive autocorrelation, and Pr>DW is the p-value for testing negative autocorrelation.

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	0.2143	0.0750	2.86	0.0120
RDfte	1	0.3880	0.1719	2.26	0.0393
patwsperhc	1	0.1936	0.1211	1.60	0.1308

Q and LM Tests for ARCH Disturbances

Order	Q	Pr > Q	LM	Pr > LM
1	3.2076	0.0733	2.9992	0.0833
2	3.7507	0.1533	2.9994	0.2232
3	3.8340	0.2800	2.9994	0.3917
4	7.5941	0.1076	6.0103	0.1984
5	10.4175	0.0642	6.0293	0.3034
6	13.7073	0.0331	6.3609	0.3840
7	15.7191	0.0278	6.8765	0.4418
8	15.7699	0.0458	8.3467	0.4004
9	15.8418	0.0703	10.2484	0.3308
10	15.8851	0.1030	13.4042	0.2019

11	16.1797	0.1346	14.5944	0.2018
12	16.2023	0.1821	15.1744	0.2320

Maximum Likelihood Estimates

SSE	0.15202524	DFE	14
MSE	0.01086	Root MSE	0.10421
SBC	-22.691358	AIC	-26.252845
Regress R-Square	0.8553	Total R-Square	0.7590
Durbin-Watson	1.9361	Pr < DW	0.2412
Pr > DW	0.7588		

NOTE: Pr<DW is the p-value for testing positive autocorrelation, and Pr>DW is the p-value for testing negative autocorrelation.

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	0.1991	0.0350	5.70	<.0001
RDfte	1	0.3787	0.0819	4.62	0.0004
patwsperhc	1	0.2187	0.0577	3.79	0.0020
AR1	1	0.6712	0.1909	3.52	0.0034

Autoregressive parameters assumed given.

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	0.1991	0.0350	5.70	<.0001
RDfte	1	0.3787	0.0819	4.62	0.0004
patwsperhc	1	0.2187	0.0576	3.79	0.0020

The following section summarises the statistical analysis conducted to estimate model parameters. Please see appendix D (section **Error! Reference source not found.**) for a detailed account of the statistical analysis on the data.

The Regress R-Square statistic indicates that the model accounts for 54% of the variation of the data in predicting AbsorbedR.

As the first model fitted with zero lag proves to have autocorrelation, an autoregressive model is fitted with lag = 1. The Durban Watson test statistic is used to gauge autocorrelation. The test statistic is 2.1821 with (Pr < DW = 0.2412) > 0.05 and (Pr < DW = 0.7588) < 0.95., which indicates that the model does not have autocorrelation.

A colinearity test conducted on the data indicated that all the condition indexes from the regression model are smaller than the critical value. It can therefore be concluded that no colinearity is present. (For details on the test see paragraph **Error! Reference source not found.**).

The Phillips-Perron test was employed to test for stationarity. All variables included in the model are non-stationary (section **Error! Reference source not found.**). The test proved that the model residual is stationary and that the variables are cointegrated, which implies that the regression is not spurious. We can therefore conclude that the modelled relationship is non-spurious and that we can use the result to develop the model of R&D in the public sector further.

Due to the relative limited number of data points available (20 data points), the heteroscedasticity test is only interpreted up to two time lags. The probability for arch disturbances in the model for lags one and two are larger than 0.05, which reveals that the modelled relationship does not suffer from heteroscedastic errors.

The parameters are estimated as defined in the following expression:

$$\ln\left(\frac{R_{Absorptionr}}{R^*_{Absorption}}\right) = f + d * \ln\left(\frac{S_{R\&Doutput}}{S^*_{R\&Doutput}} * \frac{S_{FTE}}{S^*_{FTE}}\right) + e * \ln\left(\frac{S_{World}}{S^*_{World}} / \frac{S_{HC}}{S^*_{HC}}\right)$$

8-3

The following table summarises the parameter values as well as the variance introduced into the parameter in the model. The variance is the standard error of the model as reported in the SAS output.

Table 8-13: Estimated Parameter Values for Knowledge Absorption Trend

Parameter	Estimate	Variance (s.e.)
Intercept (f)	0.1990	0.0347
RDFTE (d)	0.3787	0.0812
WSperHC (e)	0.2189	0.0572

The model yields the following output for the absorption of knowledge (measured in terms of references made to scientific papers). A 30% variance is introduced in parameters and initial values in the model. This yields the following result for the average and computed standard deviation of model output of 100 simulation runs:

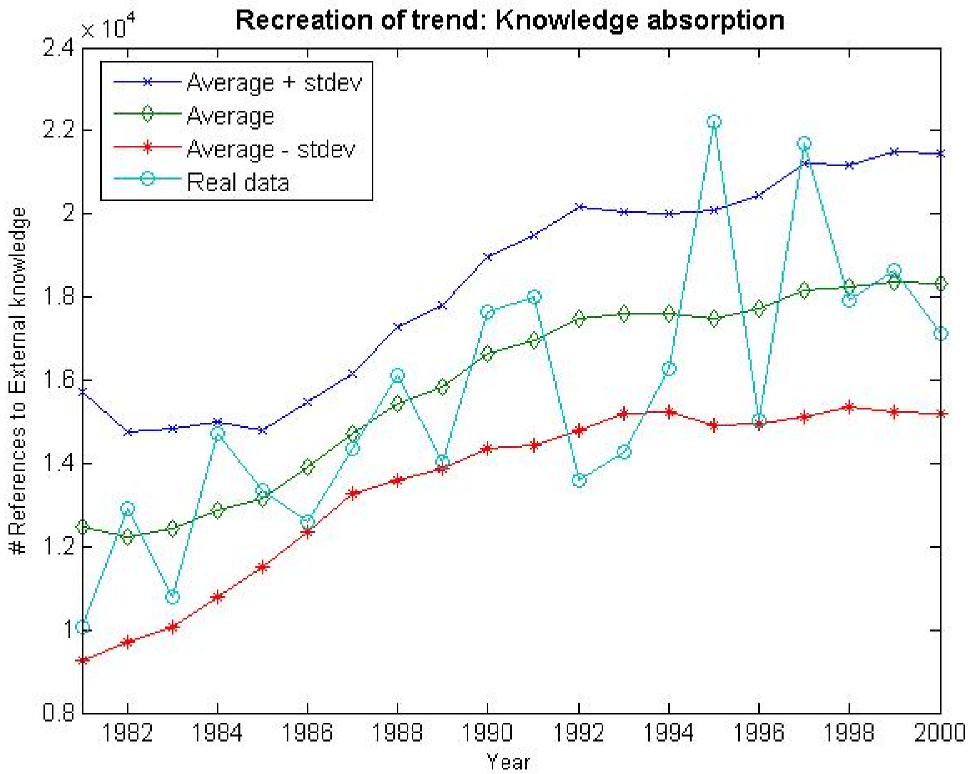


Figure 8-12: Model Recreation of the Absorption of Knowledge Trend Data

The coefficient of the determination (R^2), the fraction of the variance in the data explained by the model, is computed to be 0.54. This indicates that the average of the model runs explains roughly 54% of the variation in the data.

8.4.3 Development of Knowledge

8.4.3.1 Development rate of knowledge (basic and applied knowledge)

Regression analysis was employed to develop the following model for the production of new knowledge output. The rate at which the system is able to produce new knowledge output is calculated by the contribution made from different stocks in the system. The following expression is formulated for the R&D output produced by human resources in the public sector:

- R_{Paper} : rate at which R&D output is generated in the system (papers)
- S_{FTE} : ratio of fulltime equivalent R&D staff in the system
- $S_{Absorbed}$: absorbed knowledge stock in the system
- $A_{Contract}$: the ratio of research directed towards contract research; and
- $A_{Basi\&Applied}$: the ratio of research directed toward basic and applied research.

A multiplicative model is developed for the development rate of papers in the public sector:

$$\frac{R_{Paper}}{R^*_{Paper}} = d * \left(\frac{S_{Absorbed}}{S_{Absorbed}} * \frac{S_{FTE}}{S^*_{FTE}} * \frac{A_{Basic\&Applied}}{A^*_{Bsic\&Applied}}\right)^a \left(\frac{A_{State}}{A^*_{State}}\right)^b \left(\frac{S_{FTE}}{S^*_{FTE}}\right)^c \qquad \textbf{8-4}$$

This expression is linearised by taking the log-linear form:

$$\ln\left(\frac{R_{Paper}}{R^*_{Paper}}\right) = \ln(d) + a * \ln\left(\frac{S_{Absorbed}}{S^*_{Absorbed}} * \frac{S_{FTE}}{S^*_{FTE}} * \frac{A_{Basic\&Applied}}{A^*_{Bsic\&Applied}}\right) + b * \ln\left(\frac{A_{State}}{A^*_{State}}\right) + c * \ln\left(\frac{S_{FTE}}{S^*_{FTE}}\right) \qquad \textbf{8-5}$$

This expression is thus developed through the regression analyses with the subsequent estimation of the parameters a, b, c and d. The regression is executed and the following estimates for the parameters are obtained:

Table 8-14: SAS Output for Development of Basic and Applied Knowledge Output

```
                              Dependent Variable    RDPapersR

                              Ordinary Least Squares Estimates

          SSE                  0.34819932    DFE                      16
          MSE                     0.02176    Root MSE            0.14752
          SBC                  -12.273779    AIC              -16.256708
          Regress R-Square         0.4791    Total R-Square       0.4791
          Durbin-Watson            1.9593    Pr < DW              0.1850
          Pr > DW                  0.8150
NOTE: Pr<DW is the p-value for testing positive autocorrelation, and Pr>DW is the p-value
for testing negative autocorrelation.

                                     Phillips-Ouliaris
                                    Cointegration Test

                              Lags           Rho           Tau

                                 1      -22.9280       -4.7653
```

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	0.6953	0.1074	6.47	<.0001
absftetype	1	0.4942	0.3316	1.49	0.1555
FTEtot	1	0.8744	0.4561	1.92	0.0733
Percstate	1	5.1987	1.7089	3.04	0.0078

The following section summarises the statistical analysis conducted to estimate model parameters. Please see appendix D (Section **Error! Reference source not found.**) for a detailed account of the statistical analysis on the data.

The **R-Square 0.4791** statistic indicate that the model accounts for 47.9% of the variation of the papers produced in the public sector.

The Durban Watson test statistic was used to gauge autocorrelation use. The statistic is 1.9593 with (Pr < DW = 0.1850 > 0.05 and (Pr < DW = 0.8150) < 0.95, which indicates that the autoregressive model does not have autocorrelation.

Colinearity tests conducted on the data indicated that all the condition indexes from the regression model are much smaller than 30. We can thus conclude that no colinearity is present.

A Chi-square test for the first moment specification indicates that the model does not have heteroscedastic errors. The SPEC option performs a model specification test. The null hypothesis for this test maintains that the errors are homoscedastic, independent of the regressor and that several technical assumptions about the model specification are valid. With Pr = 0.2151, we fail to reject the null hypothesis, which leads to the conclusion that no heteroscedasticity is present in the model.

The Phillips-Perron test was used to gauge stationarity, which indicated that all variables included in the model are non-stationary. After fitting the model, it was tested for stationarity. The test proved that the model residual is stationary and that the variables are cointegrated. This implies that the regression is not spurious. We therefore conclude that the model is non spurious and that we can use the result to develop the model of R&D in the public sector further.

We continue to estimate the parameters for the following expression:

$$\ln\left(\frac{R_{Paper}}{R^*_{Paper}}\right) = \ln(d) + a*\ln\left(\frac{S_{Absorbed}}{S^*_{Absorbed}} * \frac{S_{FTE}}{S^*_{FTE}} * \frac{A_{Basic\&Applied}}{A^*_{Bsic\&Applied}}\right) + b*\ln\left(\frac{A_{State}}{A^*_{State}}\right) + \mathbf{c*}\ln\left(\frac{S_{FTE}}{S^*_{FTE}}\right)$$

8-6

The following table summarises the variable values as well as the variance introduced into the parameter in the model. The variance of the parameters is set equal to the standard error as reported in the SAS output.

Table 8-15: Estimated Parameter Values for Paper Creation Trend in Public Sector

Parameter	Estimate	Variance (s.e.)
Absftetype (a)	0.4942	0.3316
Percstate (b)	5.1967	1.7089

Ftetot ©	0.8744	0.4561
Intercept (d)	0.6953	0.1074

Special mention has to be made of the high estimated value for 'Percstate;, the effect that the percentage funding from the state (non-contract funding) will have on the focus on terms of the creation of R&D outputs, such as papers and patents in the system.

As A_{State} is the variable representing the percentage of the total R&D expenditure in the public sector directed towards non-contract work, it is therefore a variable with a range of $0 < A_{State} < 1$. The initial value is $A^*_{State} = 0.98$, resulting in a ratio with a range of $0 < (\frac{A_{State}}{A^*_{State}}) < 1.02$.

Figure 8-13 is a graphical representation of the effect that the percentage funding intended for non-contract research could have on the public sector's production of scientific publications.

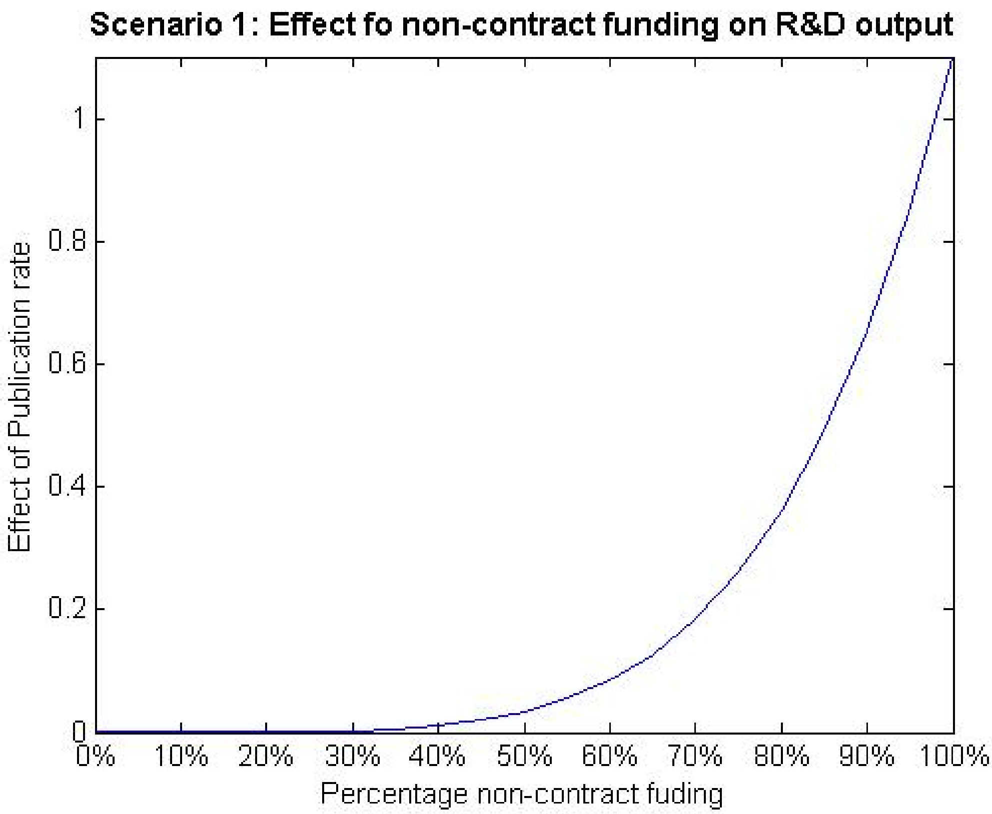


Figure 8-13: Effect of Non-contract funding on R&D Output

The following output is obtained from the model. The accuracy with which the trend is recreated is considered to be sufficient for the purpose of this study.

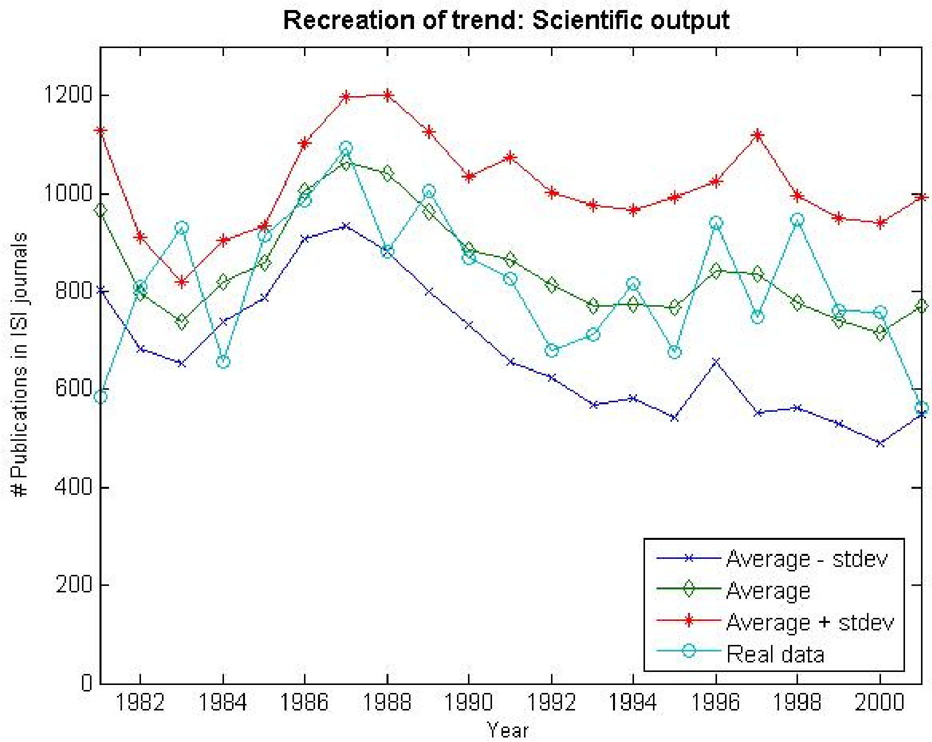


Figure 8-14: **Model Recreation of the Creation of Knowledge Trend Data**

A visual inspection indicates that the general trend is recreated quite well. The actual data gathered is however subject to an amount of fluctuation.

The coefficient of determination (R^2), the fraction of the variance in the data explained by the model, is computed at 0.46, which indicates that the average of the model runs equals contains roughly 46% of the variation in the actual data.

8.4.3.2 Development rate of knowledge (experimental development)

The production function for the creation of patents in the public sector differs from production functions estimated in the HES and private sectors. This can be ascribed to the lack of a measure for the absorbed knowledge in the public sector due to experimental development. The expression developed does therefore not include the feedback loop from the absorption of knowledge, as developed in the conceptual model. The expression is a simpler one, only taking into consideration the following:

- $R_{Patents}$: R&D output rate in the system (patents)
- S_{FTE} : FTE researchers in the system
- A_{ExpDev} : fraction of funding directed towards experimental development; and
- A_{State} : the ratio of research expenditure funded by the state, assumed to be directed towards non-contract research.

A multiplicative model is developed for the development rate of papers per fulltime person working in the system:

$$\frac{R_{Patent}}{R^*_{Patent}} = b*(\frac{S_{FTE}}{S^*_{FTE}} * \frac{A_{ExpDev}}{A^*_{ExpDev}} * \frac{A_{Statet}}{A^*_{State}})^a \qquad \textbf{8-7}$$

This expression is linearised by taking the log-linear form:

$$\ln(\frac{R_{Patent}}{R^*_{Patent}}) = \ln(b) + a*\ln(\frac{S_{FTE}}{S^*_{FTE}} * \frac{A_{ExpDev}}{A^*_{ExpDev}} * \frac{A_{Statet}}{A^*_{State}}) \qquad \textbf{8-8}$$

The following expression is thus used to perform the regression for estimating the parameters a and b. The regression is executed and the following estimates for the parameters are obtained:

Table 8-16: Regression Output of the Patent Creation Rate in the Public Sector

```
                                The REG Procedure
                                  Model: MODEL1
                            Dependent Variable: Rdout

                     Number of Observations Read          20
                     Number of Observations Used          20

                               Analysis of Variance

                                      Sum of           Mean
     Source                   DF     Squares         Square    F Value    Pr > F

     Model                     1     1.05369        1.05369      27.02    <.0001
     Error                    18     0.70194        0.03900
     Corrected Total          19     1.75563

                  Root MSE              0.19748    R-Square     0.6002
                  Dependent Mean        0.12720    Adj R-Sq     0.5780
                  Coeff Var           155.24845

                               Parameter Estimates

                                Parameter       Standard
      Variable          DF       Estimate          Error    t Value    Pr > |t|

      Intercept          1        0.02274        0.04852       0.47      0.6450
      ftepattypestate    1        1.02316        0.19683       5.20      <.0001


                                The REG Procedure
                                  Model: MODEL1
                            Dependent Variable: Rdout

                              Test of First and Second
                                Moment Specification

                            DF     Chi-Square    Pr > ChiSq

                             2           2.11        0.3488

                              The AUTOREG Procedure

                          Dependent Variable     Rdout

                          Ordinary Least Squares Estimates

                 SSE                  0.70194207    DFE                       18
                 MSE                     0.03900    Root MSE             0.19748
                 SBC                  -4.2437275    AIC               -6.2351921
                 Regress R-Square         0.6002    Total R-Square        0.6002
                 Durbin-Watson            1.5178    Pr < DW               0.0875
                 Pr > DW                  0.9125
NOTE: Pr<DW is the p-value for testing positive autocorrelation, and Pr>DW is the p-value
for testing negative autocorrelation.

                       Q and LM Tests for ARCH Disturbances
```

Order	Q	Pr > Q	LM	Pr > LM
1	0.0215	0.8834	0.0320	0.8580
2	0.1960	0.9067	0.0802	0.9607
3	0.9652	0.8097	0.5220	0.9140
4	2.5316	0.6390	2.3069	0.6795
5	2.5335	0.7714	2.4582	0.7828
6	4.7339	0.5784	5.5867	0.4710
7	5.0327	0.6560	5.7859	0.5650
8	5.3684	0.7176	7.9828	0.4352
9	6.8896	0.6486	10.8254	0.2879
10	8.3899	0.5908	11.1950	0.3425
11	8.4369	0.6737	12.4735	0.3291
12	9.1364	0.6912	12.4735	0.4084

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	0.0227	0.0485	0.47	0.6450
ftepattypestate	1	1.0232	0.1968	5.20	<.0001

The following section summarises the statistical analysis conducted to estimate model parameters. (See section **Error! Reference source not found.** for a detailed discussion).

The **Total** Regress R-Square 0.6002 statistic indicates that the model accounts for 60% of the variation of the percentage time spent by staff on R&D activities. The variable included in the model (ftepattypestate) is highly significant.

The Durbin Watson test statistic is 1.5178 with (Pr < DW = 0.0875 > 0.05 and (Pr < DW = 0.9125) < 0.95, which indicates that the model does not have autocorrelation.

Colinearity tests conducted on the data revealed that all the condition indexes from the regression model are much smaller than 30. We can therefore conclude that no colinearity is present.

The Phillips-Perron test was used to gauge for stationarity, which indicated that all variables included in the model are non-stationary. After fitting the model, it was tested for stationarity. The test proved that the model residual is stationary and the variables are cointegrated, thus implying that the regression is not spurious. We can therefore conclude that the model is not spurious and that we can use the result to develop the model of R&D in the public sector further.

The parameters have therefore been estimated for the following expression:

$$\ln\left(\frac{R_{Patent}}{R^*_{Patent}}\right) = \ln(b) + a * \ln\left(\frac{S_{FTE}}{S^*_{FTE}} * \frac{A_{ExpDev}}{A^*_{ExpDev}} * \frac{A_{Statet}}{A^*_{State}}\right) \qquad \textbf{8-9}$$

Table 8-17 summarises the variable values as well as the variance introduced into the parameter in the model. The variance of the parameters is set equal to the standard error as reported in the SAS output.

Table 8-17: Estimated Parameter Values for Patents Creation trend in Public Sector

Parameter	Estimate	Variance (s.e.)
Intercept (b)	0.0227	0.0485

ftepattypestate (a)	1.023	0.19

These parameters with the variance values were used in the model, which yields the following output for the development of scientific output, measured in terms of patents granted at the SAPTO.

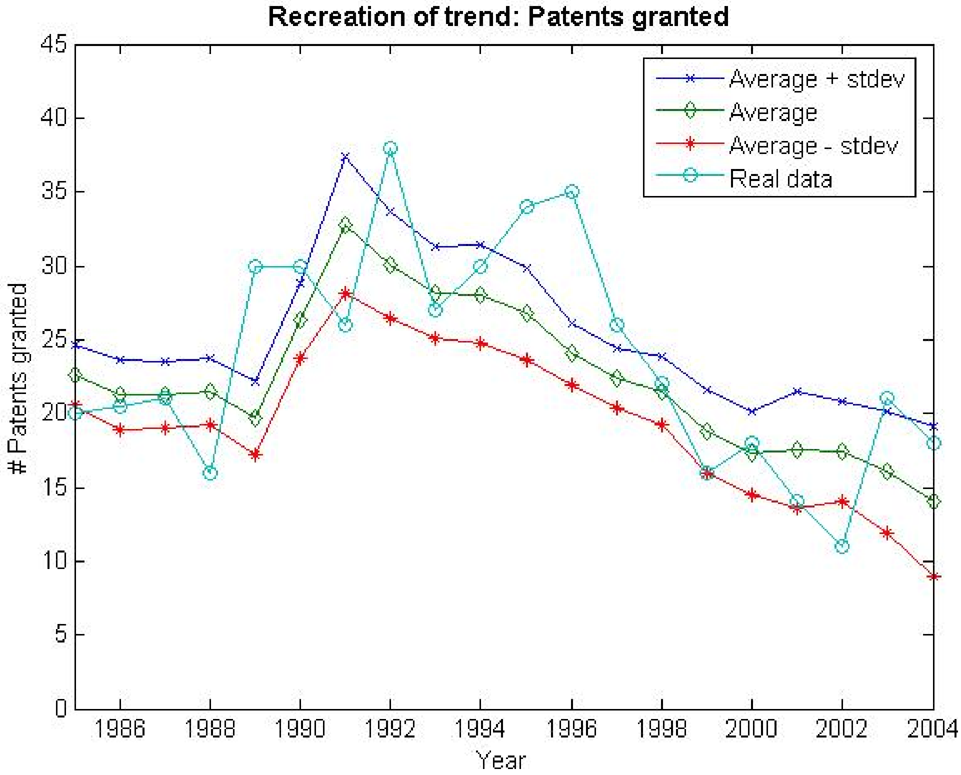


Figure 8-15: Model Recreation of the Creation of Knowledge Trend Data

The coefficient of the determination (R^2), the fraction of the variance in the data explained by the model, is computed to be 0.60, which indicates that the average of the model runs explains 60% of the variation in the actual data.

8.5 Model Simulation

This section documents scenario tests run on the model. These scenario tests were developed from the research questions as well as the Delphi study conducted. The Delphi study was instrumental in finding the foremost issues facing the public sector R&D system in South Africa. Using the Delphi study to develop the scenario tests ensured that the scenario tests developed are relevant in terms of the current concerns of experts working in the system.

The following table relates to the scenarios developed in the Delphi study (see section **Error! Reference source not found.**). The scenario tests run in this section were developed to answer the following questions as described in Table 8-18.

Table 8-18: The Scenario Tests Runs Executed on the Model

Base Case: How would a constant/unchanging investment in the South African public sector R&D system affect its ability to produce R&D output and absorb knowledge?

Scenario 1: How would a decreasing level of government investment in the South African public sector R&D system affect its ability to produce R&D output and absorb knowledge?

Scenario 2*:* How would moving away from the Framework autonomy policy influence the system?

Scenario 3: How would an increase/decreasing level of investment from government combined with a movement away from framework affect the system's ability to produce R&D output and absorb knowledge?

8.5.1 The base case

The base case of the model simulation run is aimed firstly at simulating the model behaviour, should as little as possible change. The following constants are selected for the base case scenario:

- the investment in the hiring of new staff members grow with 0% per year
- the external environment has a 3% increase in knowledge production per year
- the percentage spending from the state and contract funding remains constant; and
- the percentage distribution of funds between basic and applied and experimental R&D remain constant.

To test for the possible outcome in terms of the base case, 100 simulation runs were executed. This section presents output generated by the model of R&D in the public sector. In each figure, the average of the 100 runs as well as the trend lines for the standard deviations are indicated. The variability introduced into the model is a normal distribution for variability on the parameters of 30%.

For a normally distributed variability of 30% in parameter values, the model produces the following output from 100 separate simulation runs executed on the model. The following section describes the model output as well as the conclusions that can be drawn from the sensitivity analysis.

It is imperative that the robustness of conclusions on the uncertainty in the assumptions be tested for the model. The sensitivity analysis tests for changes in conclusions in ways important to the purpose of the model, should variables be varied over plausible ranges of uncertainty.

8.5.1.1 Base case: model output

The following figure represents the model output for patents granted to organisations in the public sector. The simulation is run for the years 1980 to 2030.

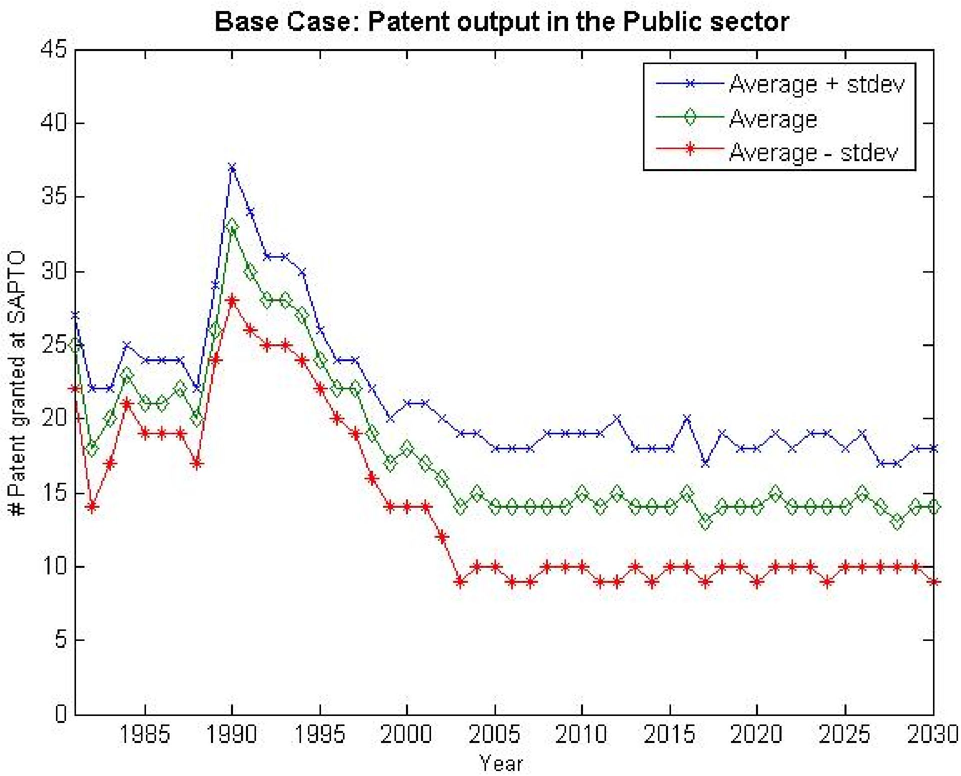


Figure 8-16: **Base Case: Patent Output in the Public Sector**

The Base Case reveals that little or no changes can be expected in the system, should the present situation continue in terms of the amount of FTE R&D staff employed in the system as well as the percentage funding sourced from the private sector, resulting in a constant percentage contract funding.

The model output for the base case scenario reveals the following result for the scientific output created in the system in Figure 8-17.

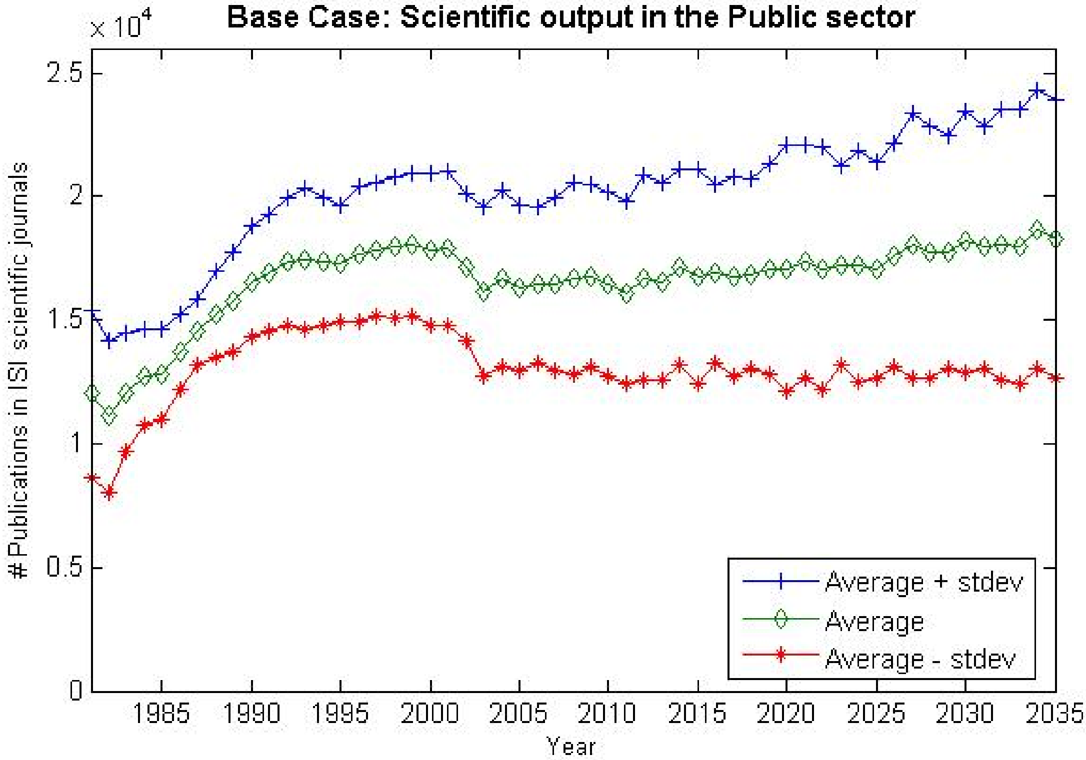


Figure 8-17: **Base Case: Scientific Output in the Public Sector**

The following figure represents the predicted rate at which the system will be absorbing knowledge from the external environment.

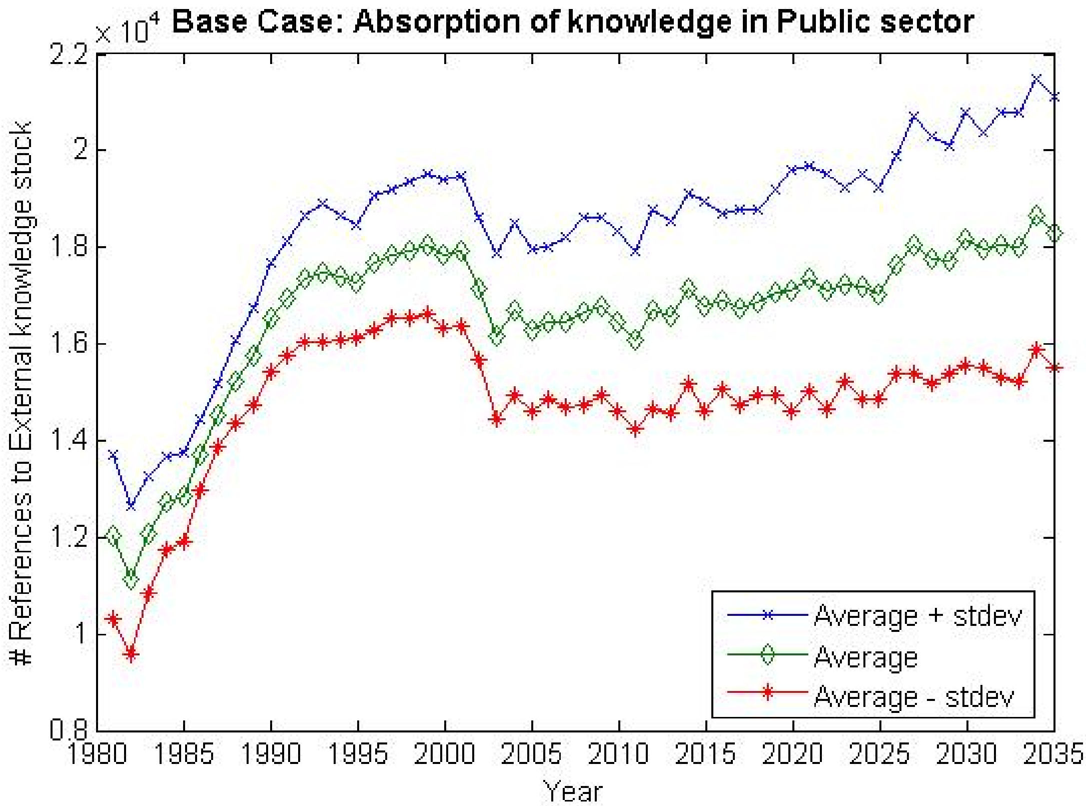


Figure 8-18: **Base Case: Absorption of Knowledge in the Public Sector**

The slight increase, which can also be seen in the rate at which the system is absorbing knowledge, can be attributed to knowledge spillovers from an external environment, which continues to produce an increasing amount of scientific output.

In the Delphi study executed in this research project, the experts cited poor prospects for the public sector R&D system to have appropriate funding for R&D in the next 20 years. Questions thus arise around the system's reaction to changing levels of R&D investment (decreasing as well as increasing levels of funding). A scenario is tested on the model to obtain satisfactory answers to these questions.

8.5.2 Scenario 1

Scenario 1 aims to run simulations for the predicted outcome, should the R&D expenditure in the system vary:

- the external environment has a 3% increase in knowledge production per year
- the percentage spending from the state and contract funding remains constant, thus 88% state funding and 12% contract funding
- salaries remain constant; and
- the R&D expenditure in the system changes with the following different percentages per year:

Table 8-19: Test Runs for Scenario 1

	Percentage Growth Rate in HES Investment
Run 1	-4 % per year
Run 2	-3 % per year
Run 3	-2 % per year
Run 4	-1 % per year
Run 5	0 % per year
Run 6	1 % per year
Run 7	2 % per year
Run 8	3 % per year
Run 9	4 % per year

The R&D survey for 2003 reported R&D expenditure in the public sector, i.e. science councils and government departments, of approximately R2 210 million. The following investment is the effective increase investment analysed in constant 2003 Rand[3].

[3] The effect of changes in the value of the Rand is ignored and the assumption is made that the ?????

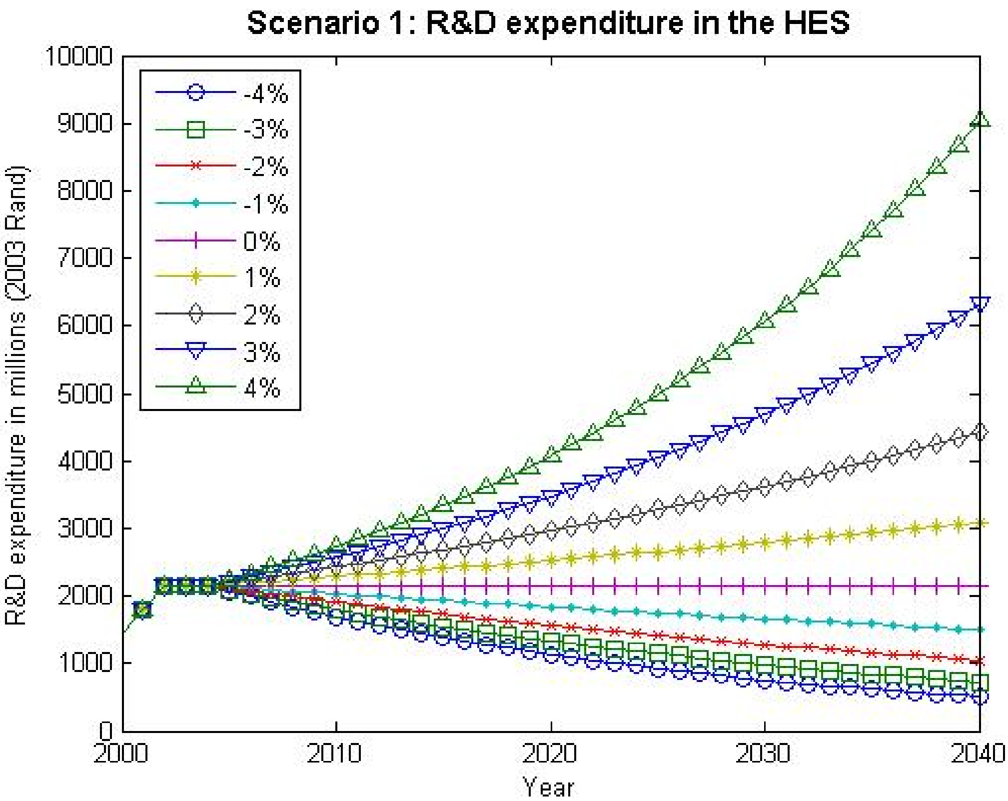


Figure 8-19: Scenario 1: R&D Expenditure

Figure 8-19 is a graphical representation of the effect of the percentage increase in terms of R&D expenditure in the public sector. The following figure is a graphical representation of the corresponding changes in terms of headcount of R&D staff in the public sector.

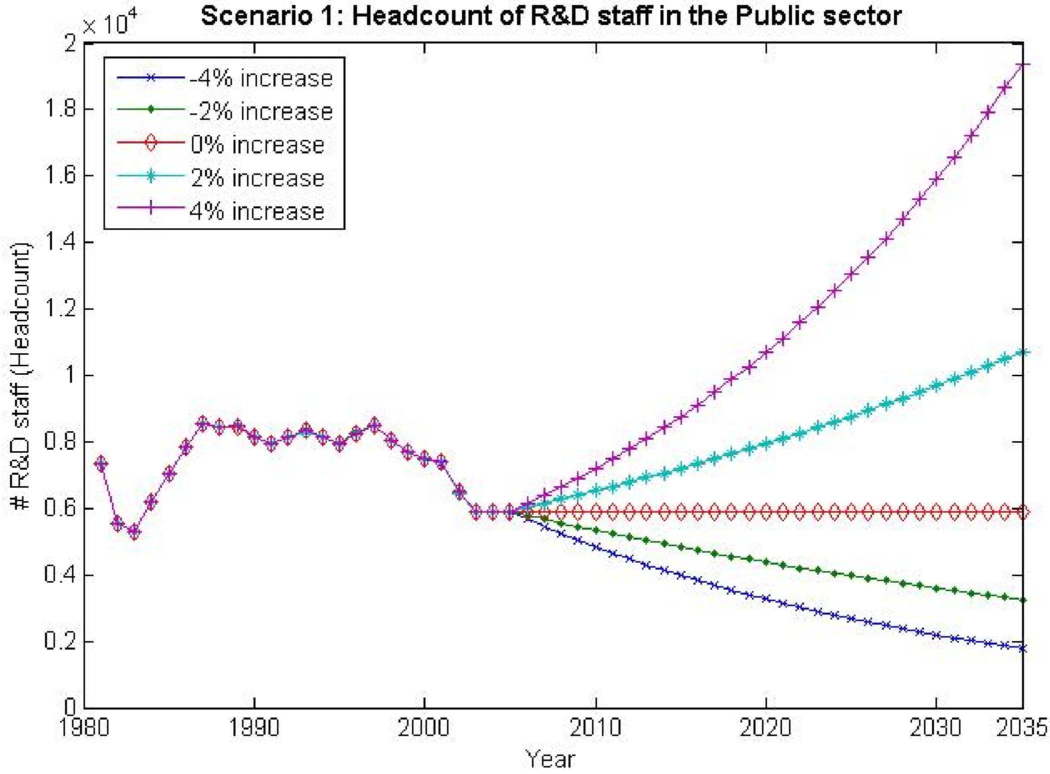


Figure 8-20 Headcount R&D Staff Employed in the Public Sector

As expected, an increase in the funding will result in a higher number of human resources employed in the system (Figure 8-20), resulting in a higher level of patents to be granted to organisations in the public sector (Figure 8-21).

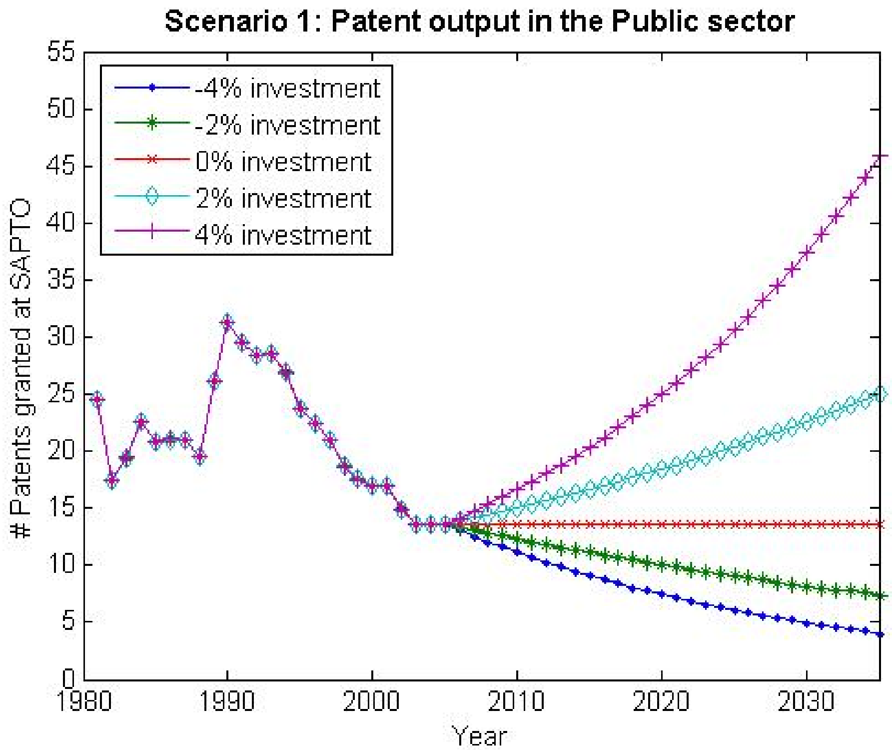


Figure 8-21 Patents Granted at the SAPTO to Organisations in the Public Sector

The following figures present the predicted effect that the different scenarios of change in R&D expenditure might have on the system's ability to produce scientific output in terms of ISI publications.

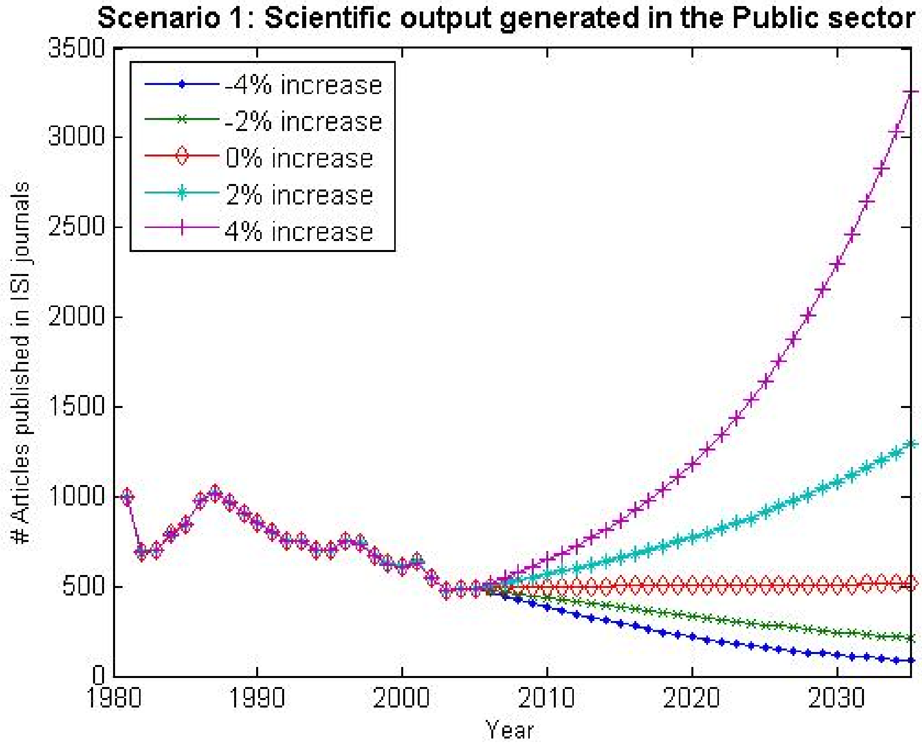


Figure 8-22: Scientific Output Generated in the Public Sector

Figure 8-22 presents the model output for the development of scientific knowledge in the system. The following figure presents the system's absorptive capacity due to the implementation of the different scenarios.

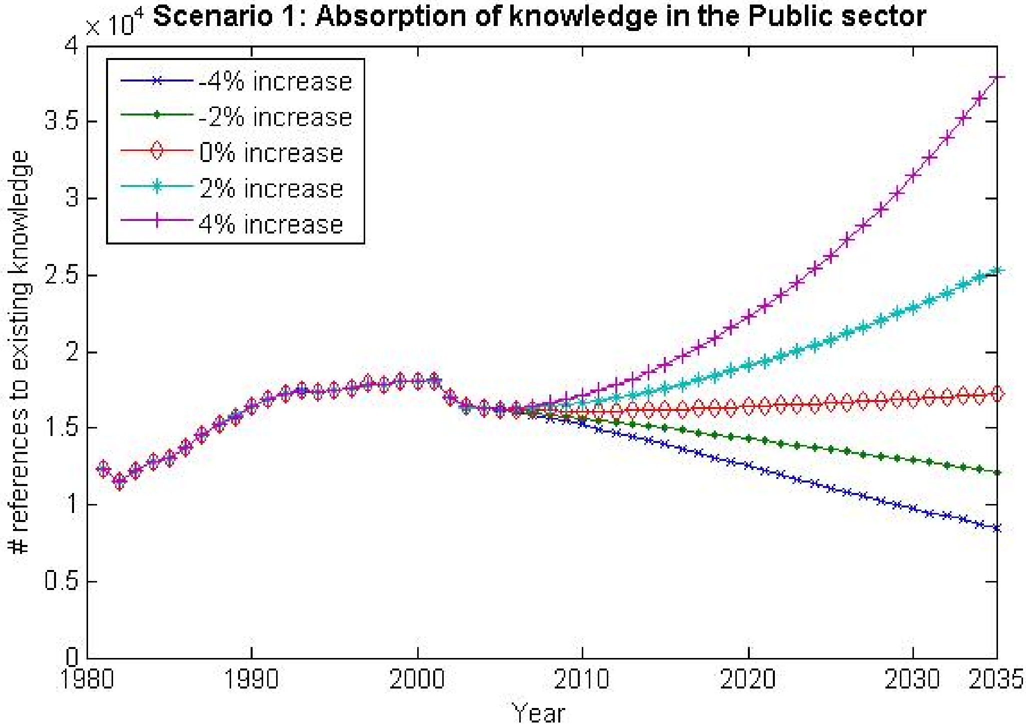


Figure 8-23 **Rate of Knowledge Absorption in the Public Sector**

As expected, higher levels of R&D expenditure should result in more people employed in the system, which would ultimately lead to higher levels of output.

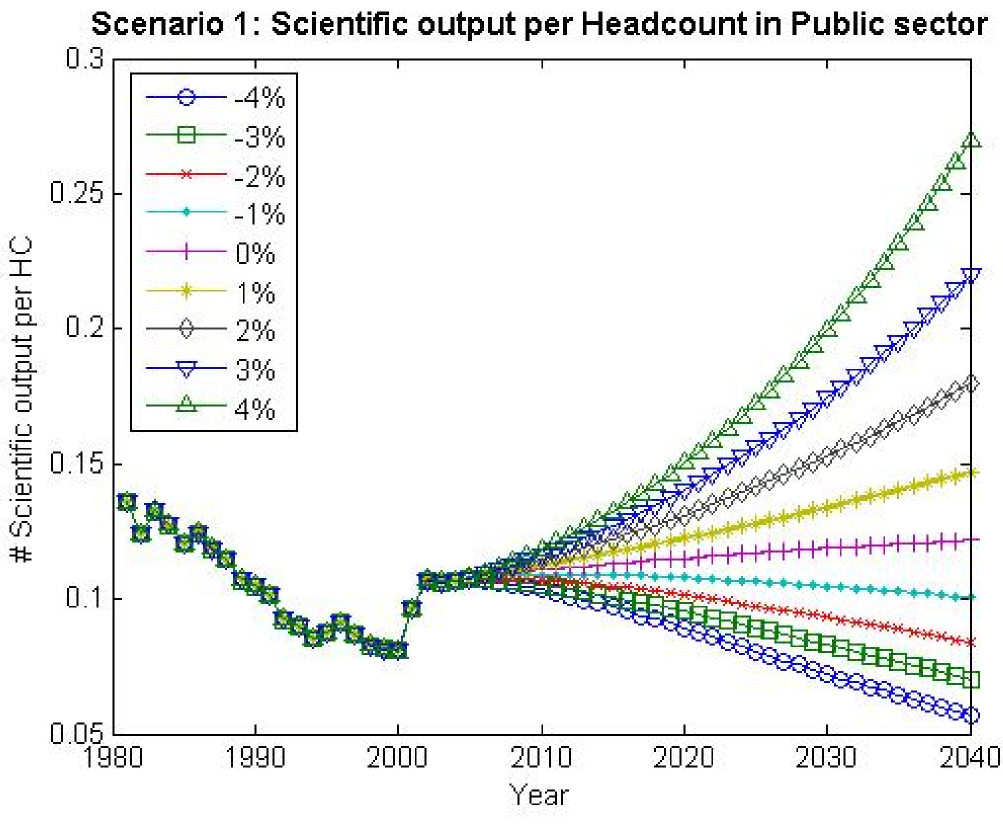


Figure 8-24: Scenario 1: Papers Produced per Headcount in the System

It can thus be concluded that through a larger investment, R&D capacity will be developed. It is also evident that an increase in investment will result in an increase in the R&D output generated per worker in the system.

8.5.3 Scenario 2

Scenario 2 aims to simulate model behaviour for changes in the total percentage of contract and state funding in the system:

- the R&D expenditure in the sector grows with 0% per year
- the external environment has a 3% increase in knowledge production per year
- salaries remain constant; and
- the distribution of the R&D expenditure sourced from players in the private sector is varied as follows:

Table 8-20: Test runs for Scenario 2

	Percentage Change in R&D Expenditure Sourced for Non-contract Funding
Run 1	-2 % per year
Run 2	-1.5 % per year
Run 3	-1% per year
Run 4	-0.5% % per year
Run 5	0 % per year
Run 6	0.5 % per year
Run 7	1 % per year
Run 8	1.5 % per year
Run 6	2 % per year

Different scenarios were run for the distribution of the percentage of funding sourced for non-contract research. The model produced the following output.

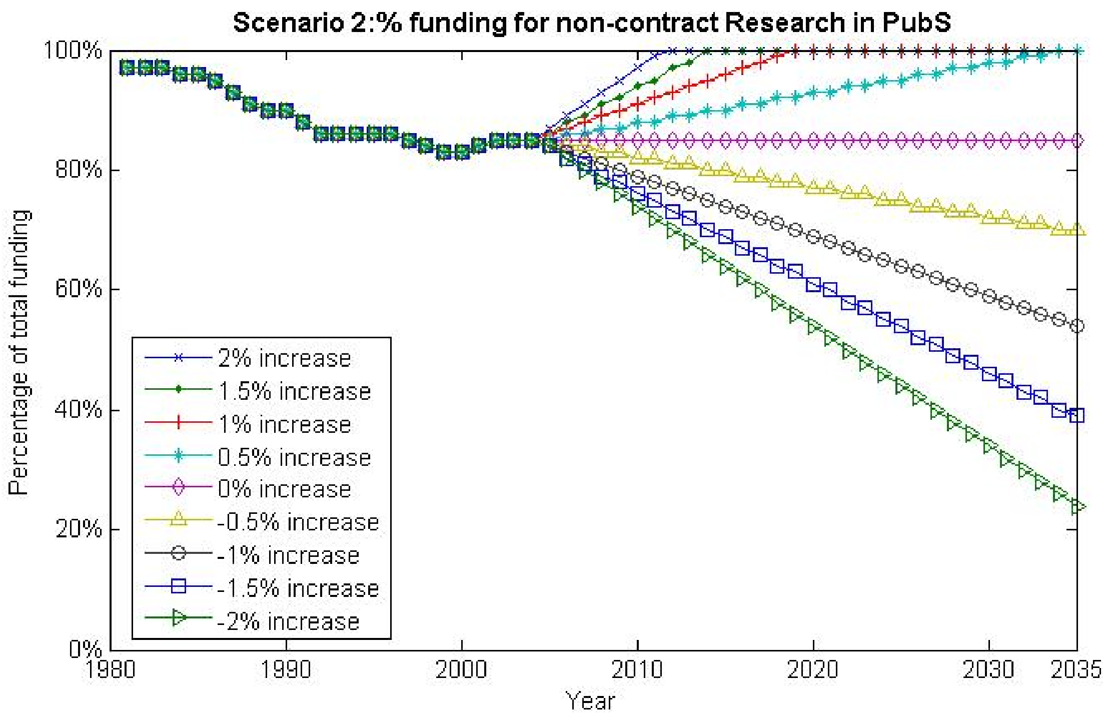


Figure 8-25: R&D Expenditure from Contact Funding

The model's reaction on changes of the type of research being conducted is observed. The following graphs represent model output for the different scenarios tested in Scenario 2.

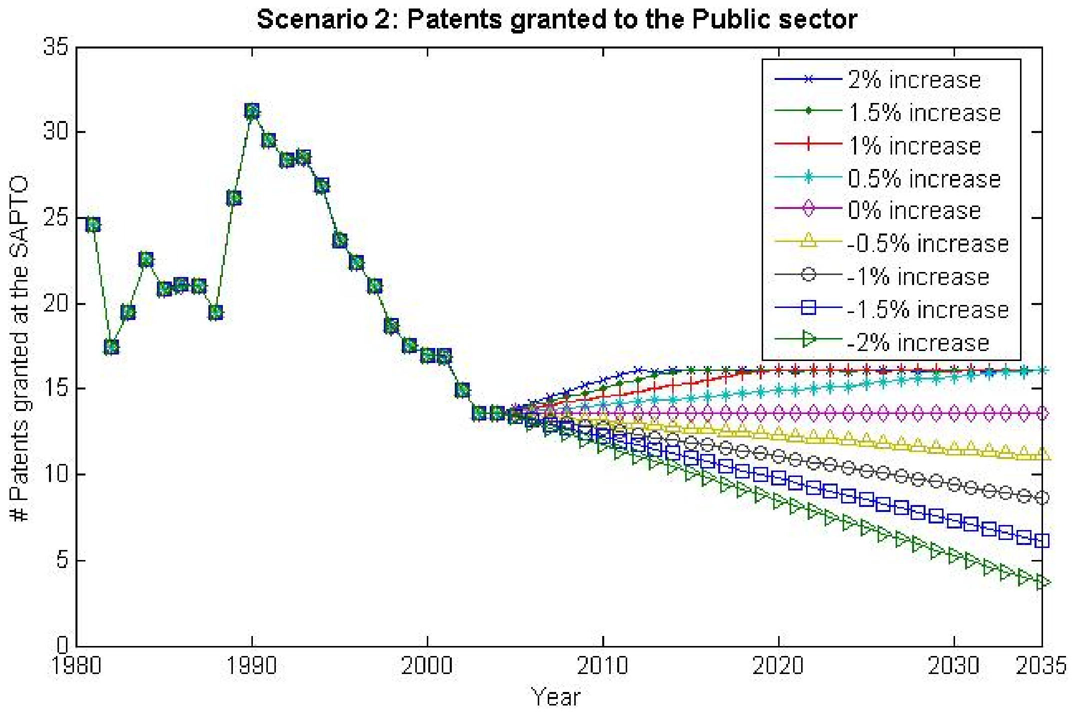


Figure 8-26: **Scenario 2 Model Output for the Patents Generated in the Public Sector**

Figure 8-26 presents the predicted model output for Scenario 2. As expected, a shift in research funding towards more contract research will result in a shift away from the development of patents and scientific output. For the scenario where 100% of all funding is directed toward non-contract research, the system reaches a maximum level for the production of knowledge in its predicted value for the production of new patents. This, in fact, can be contributed to modelled production function that fails to take the absorption of knowledge from the external environment into account, since references to prior knowledge are not included in filed South African patents.

This however is not the case for the production of scientific output in the public sector. Figure 8-27 presents the modelled rate of the absorption of scientific publication knowledge in the public sector.

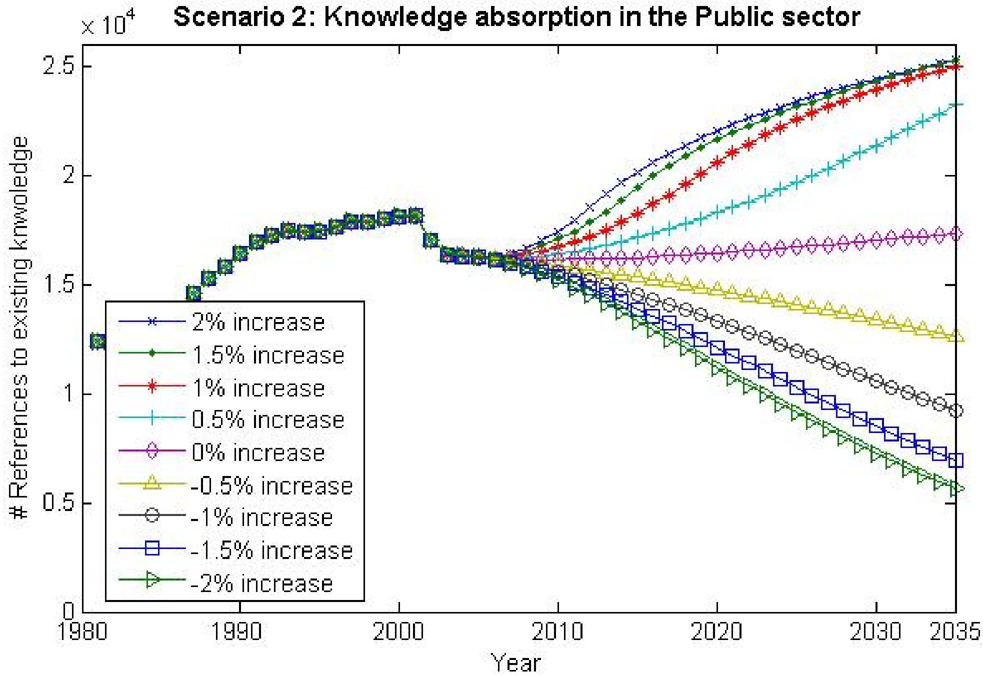


Figure 8-27: Scenario 2: Absorption of Knowledge in the Public Sector

Figure 8-27 is a graphic representation of absorptive capacity of the system due to the implementation of the different scenarios. The system's behaviour towards an increased level of contract funding is once again that of a decreasing trend of scientific knowledge absorption. This trend in conjunction with human resources spending a smaller portion of their time on non-contract research also contributes to the resulting decreasing trend in terms of the generation of scientific output from the public sector in Figure 8-28.

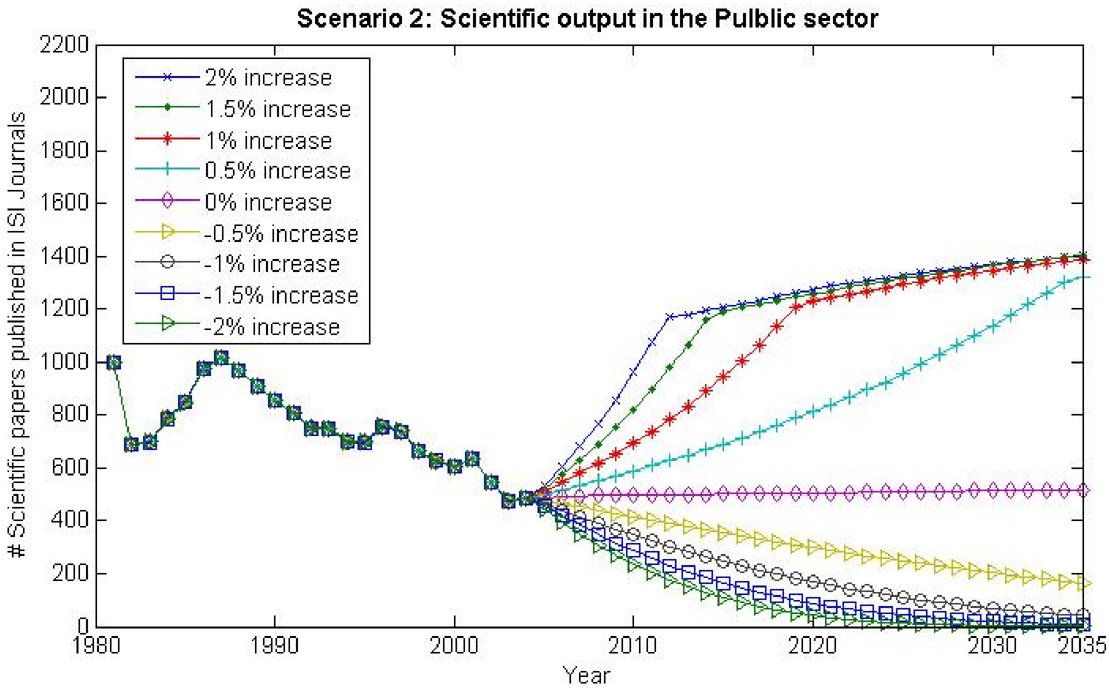


Figure 8-28: Scenario 2: Scientific Output in the Public Sector

8.5.4 Scenario 3

The analysis executed on the public sector is based on the assumption that R&D expenditure in this sector sourced from the private sector funding is approximated to be an indication of the amount of contract research being done in the public sector.

Scenario 3 aims to examine the model's predicted output for conditions in the system arising from the combination of Scenarios 1 and 2. The effect of changes in the system is tested along two axes:

- Axis 1: change in the R&D expenditure in the system, i.e. change ranges with an increase ranging from -4% to 4% of current expenditure; and
- Axis 2: change in the percentage funding directed towards non-contract funding. (Change in the investment sources ranges from -2% to 2% per annum). The system's reaction to change in the shift of funding towards and away from contract funding is tested.

Table 8-21: Scenario 3: Changes in System Constants Along Two Axes

	-2%	-1.5%	-1%	0.5%	0%	0.5%	1%	1.5%	2%
-4%									
-3%									
-2%									
-1%									
0%									
1%									
2%									
3%									
4%									

Each cell in Table 8-21 represents a specific scenario tested for. A total of 100 simulation runs were executed for each of these scenarios (cells) in Table 8-21. This means that for each of the cells in the grid, 100 simulation outputs were created for the period 1980 to 2030. To obtain a convenient measure of comparing the different scenarios, the average of these 100 runs is calculated for each cell by computing the average value of the trend from the years 2010 to 2030. This calculation results in a single value that can be represented in the matrix.

The following is a graphical representation of the model output for scenarios run on the grid, where the z-axis represents the human resources in the system working on non-contract R&D in the public sector.

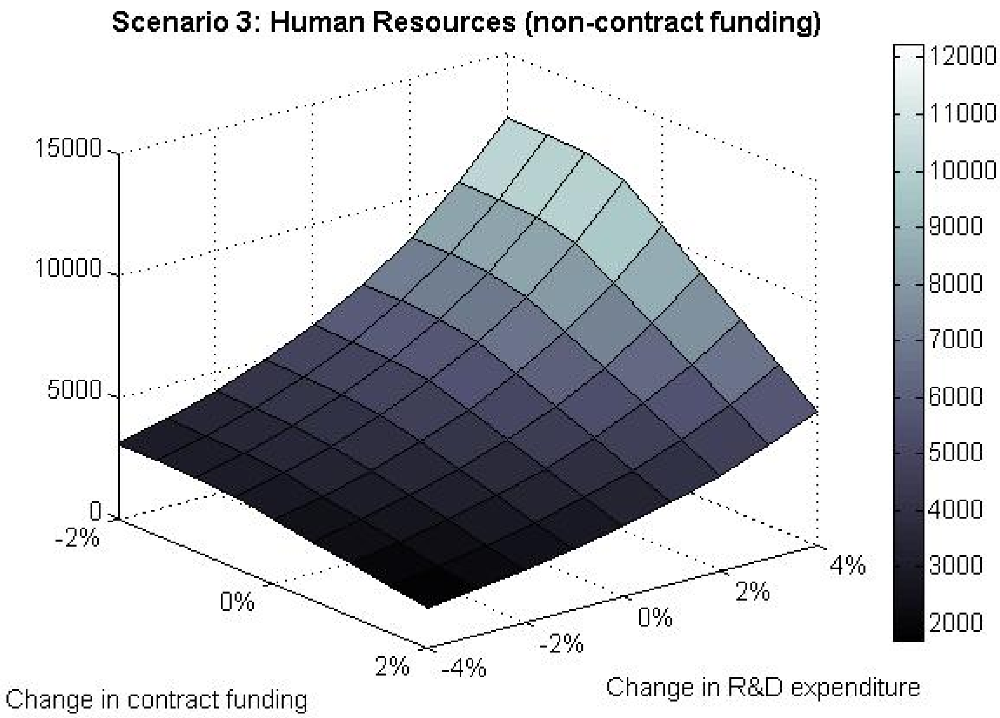


Figure 8-29: Scenario 3: HR Focusing on Non-contract Funding - Public Sector

To obtain an expression of the amount of human resources focussing on non-contract funding, the human resources stock in the system is multiplied with the percentage of R&D expenditure sourced for non-contract funding.

This can also be interpreted as the average amount of human resources from 2010 to 2030 which will have to be funded from funds made available to the public sector by the state. The trend in Figure 8-29 therefore indicates that where the sector should move towards a policy of decreasing funding from contract income, it will have to obtain increased government backing to allow the system to continue employing the current levels of human resources in the system.

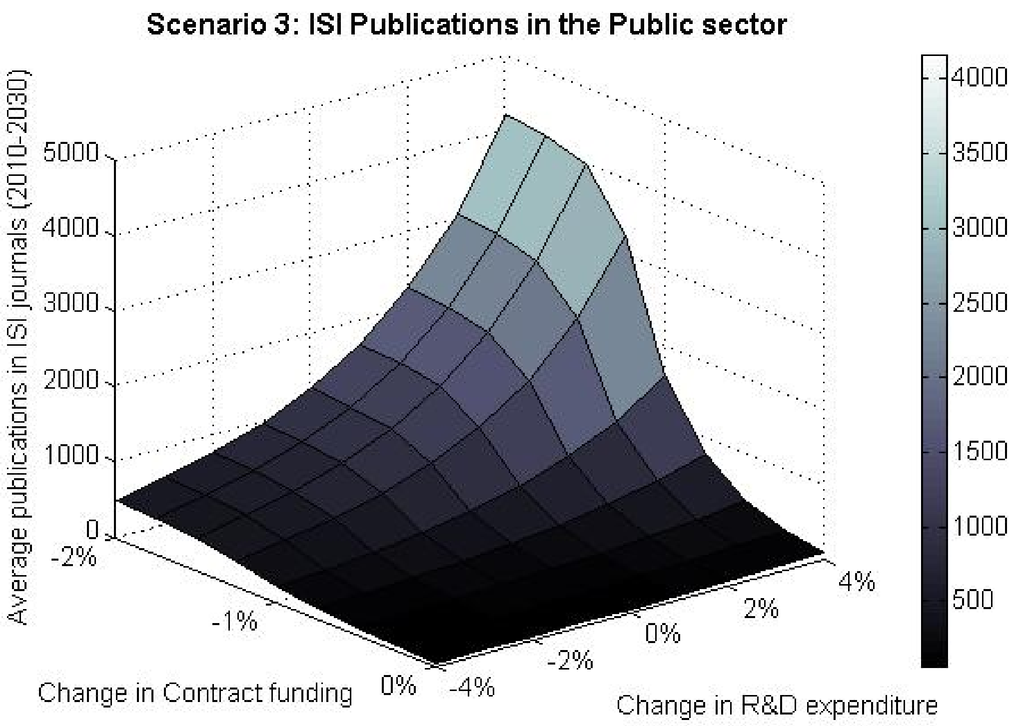


Figure 8-30: **Scenario 3: Avg. Publications in the Public Sector (2010 to 2030)**

Figure 8-30 is the graphic representation of the output from simulation runs from different constant values for Scenario 3. As expected, the highest level of ISI publications generated in the public sector could be achieved by increasing the R&D expenditure and by shifting the focus from contract research towards a system where all research is focussed on developing R&D output.

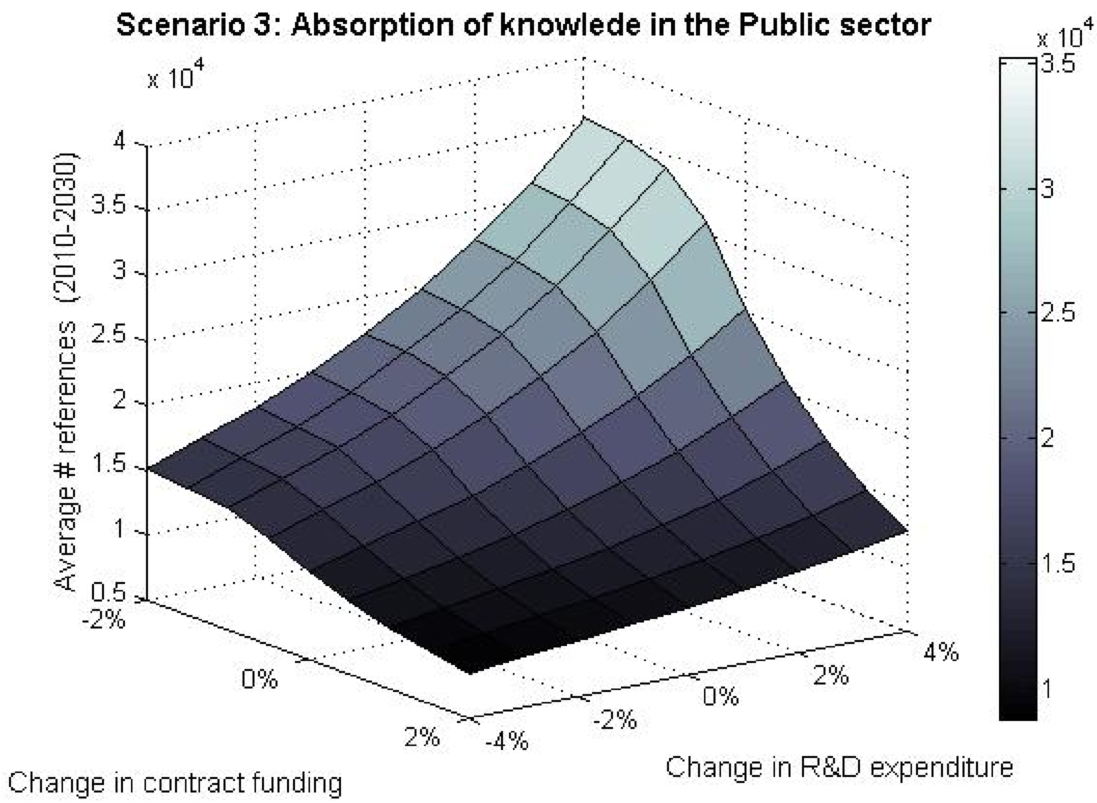


Figure 8-31: **Scenario 3: Absorption of Knowledge in the Public Sector (2010 to 2030)**

A similar trend can be observed for the output from the absorption rate of knowledge in the system.

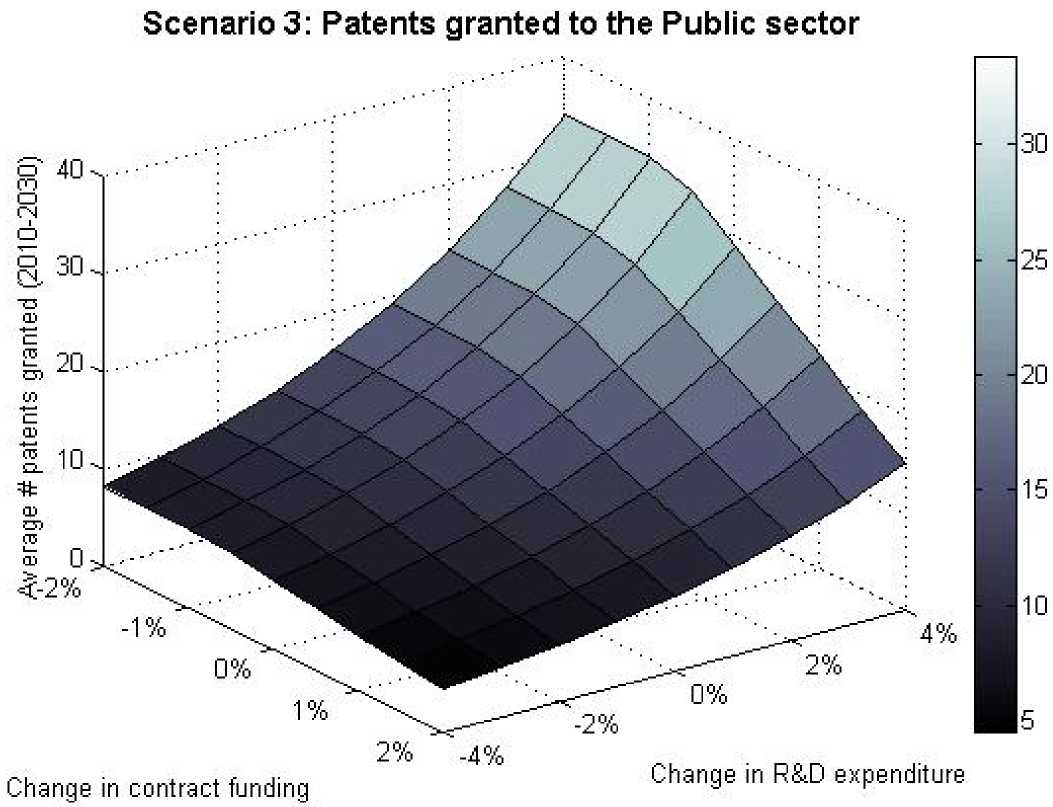


Figure 8-32: **Scenario 3: Patents Granted in the Public Sector for (2010 to 2030)**

The model's predicted levels of patent output generated in the public sector reveals that the highest output in the system will be gained through an increase in expenditure and by decreasing the outsourcing of R&D capabilities. It must however be noted that the model's predicted output of the patents granted to the public sector remains low.

The model simulates the dynamic that where government funding increases, the need for contract income will also decrease, resulting in higher tangible R&D outputs. The following figure is a graphic representation of the average funding that will have to be sourced from government for non-contract funding.

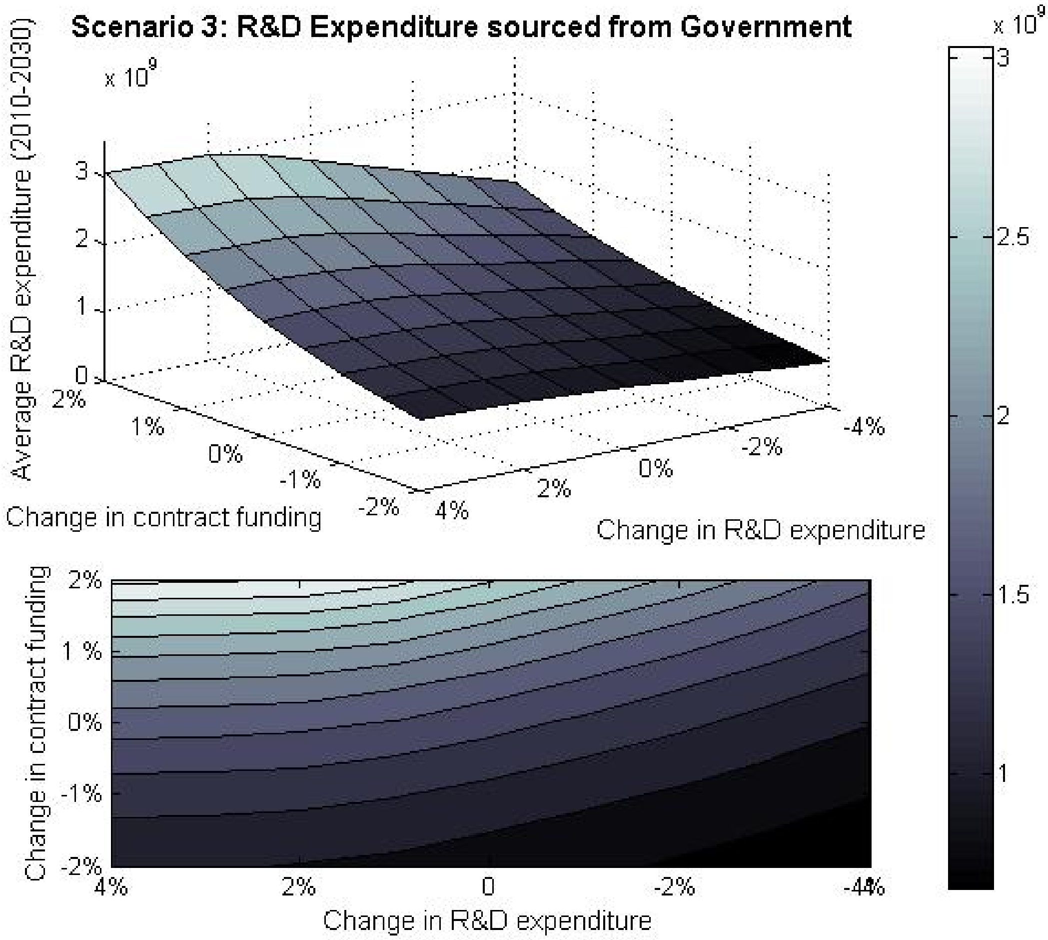


Figure 8-33: Scenario 3: R&D Expenditure Sourced from Government

Figure 8-33 thus indicates that as the system R&D expenditure is increased and as the percentage of the funding sourced from contract income is decreased, the funding will have to be sourced from government.

8.6 Chapter Summary

This chapter documents the data gathering and application of a conceptual model of an R&D performing sector to the South African public sector R&D system.

A regression analysis was performed to estimation parameters and to produce functions of the absorption and creation of knowledge. The explanatory variables included in the model were confirmed to be statistically significant to the explanation of the dependent variables. The following table summarises the coefficients of determination (R^2) of the various regressions in the dynamic model:

Dependent Variables	Regression R-square
Patent creation rate	59.0%
Paper creation rate	47.9%
Knowledge absorption rate	54.0%

It can thus be concluded that although the coefficients of determination do not have high values, the predictive ability of the model seems to follow the most important trends of the actual data.

Another factor playing a role in the low coefficient of determination achieved for the paper creation rate in the public sector model is the indicator used to measure the applied and basic research output in the public sector. As revealed in the Delphi study, experts did not find scientific output to be a suitable measure of R&D output in the public sector. Given the lack of any better measure available, the author decided to use this measure.

After establishing the model's ability to recreate the historical trend satisfactorily, the model was used to run scenario tests to investigate possible behaviours of the system under conditions specified in the scenario tests.

The base case scenario reveals that should the system be left unchanged in terms of the distribution of the funding as well as the R&D expenditure (in 2003 Rand), the knowledge creation output will remain relatively constant.

Scenario 1 tested the influence of increasing or decreasing R&D expenditure. It is evident that should an increasing number of research staff be employed in the system and should the knowledge stocks in the system increase, the knowledge creation output rate is also bound to increase. As the distribution of funding remains consistent, an increasing R&D expenditure also implies that the system should receive an increasing amount of funding from the state.

Scenario 2 assumes a constant total R&D expenditure in the system. Different scenarios were run on the system to test for the possible effect that the shift in funding towards or away from contract funding might have on the system.

Scenario 3 is run as a combination of Scenarios 1 and 2. Constants in the model are changed along two axes:

- Axis 1: change in the R&D expenditure in the system, i.e. change from -4% to 4% in current expenditure per annum; and
- Axis 2: change in the percentage funding directed towards non-contract funding (change in the investment sources ranging from -2% to 2% per annum). The system's reaction to change in the shift of funding towards and away from contract funding is tested.

The output gained from the model concluded that as the system moves away from framework autonomy and the outsourcing of R&D, R&D outputs are likely to increase. This must however be seen in the light of the fact that the system will then have to receive increasing support from the state.

The following chapter investigates the application of the model to the South African private sector.