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Using sensitivity analysis to construct a model for measuring sustainable development according to the Bellagio principles

Masters Research Report

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i. Declaration

I declare that this dissertation is my own unaided work. It is submitted for the degree of Master of Science (Statistics) in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination in any other University before. I also declare that this is my original work produced and submitted in accordance with all rules of professional academic standards and ethics.

ii. Abstract

The study investigates models and processes that could be used by decision-makers to influence policy. The objectives of the study are to illustrate the considerations in the use of information systems and modeling in the context of sustainable development in South Africa. The problem considered is that of measuring South Africa's progress toward sustainable development. The study is conducted at a national level. The design uses statistical indicators arranged into a model based information system using the Bellagio principles of 1996. The statistical indicators are assembled from the United Nations 1993 System of National Accounts, UN 1995 Driver-Pressure-State-Impact-Response framework, United Nations 2003 System of integrated Environmental and Economic Accounting, Basel Committee's 2004 Basel II framework, and South African Presidency 2010 Developmental indicators frameworks. The South African economy is conceptualised as a dynamic system composed of five types of capital. The fitted model is a vector autoregressive time series model of order p on a set of statistical factors that describe the South African economy. The robustness of the model to assumptions is evaluated using sensitivity and uncertainty analysis. The optimality of the model output for decision making is evaluated using decision theory. The study will facilitate an evidence based approach to managing South Africa's progress towards sustainable development.

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vii. Glossary

AIDS	Acquired Immunodeficiency Syndrome
AMPS	All Media Products Survey
ASGISA	Accelerated and Shared Growth Initiative for South Africa
ASSA	Actuarial Society of South Africa
BCBS	Basel Committee on Banking Supervision
BIS	Bank of International Settlements
BEE	Black Economic Empowerment
BPL	Business Partners Limited Group
Brundtland Report	United Nations Brundtland Commission report of 1987
Ca	Calcium
$CaCO_3$	Calcium Carbonate
CAI	Consultancy Africa Intelligence
c.f.i.	Cost, insurance, freight
Cl	Chloride
CPI	Consumer Price Index
DEAT	South African Department of Environmental Affairs and Tourism

DoE	South African Department of Education
DMS	Dissolved Major Salts
DoH	South African Department of Health
DPSIR	Driver-Pressure-State-Impact-Response
DSBB	Dissemination Standards Bulletin Board
DQAF	Data Quality Assessment Framework
DTI	Department of Trade and Industry
DWA	Department of Water Affairs
DWAF	South African Department of Water Affairs and Forestry
EMIS	Education Management Information System
EISA	Electoral Institute for the Sustainability of Democracy in Africa
EPWP	Extended Public Works Program
F	Flouride
fob	Free on board
FSAP	Financial Sector Assessment Program
GCIS	South African Government Information System
GDDS	General Data Dissemination System
GWM&E	Government-Wide-Monitoring and Evaluation
GDP	Gross Domestic Product
HIV	Human Immunodeficiency Virus
HST	Health Systems Trust
IDC	International Development Corporation
IEMP	Index of Exchange Market Pressure
IFES	International Foundation For Electoral Systems
IMF	International Monetary Fund
IISD	International Institute on Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
JIPSA	Joint Initiative for Priority Skills Acquisition
K	Potassium
MDG	Millennium Development Goals

Mg	Magnesium
M&A	Mergers and Acquisitions
NEPAD	New Partnership for Africa Development
N	Nitrogen
Na	Sodium
NH_4^+	Ammonium
NO_3^+	Nitrate
NO_2	Nitrite
NSSD	Statistics South Africa National Statistical System Division
OECD	Organisation for Economic Cooperation and Development
PH	Negative decimal logarithm of the hydrogen ion activity in a solution
PGM	Platinum Group of Metals
SA	South African
SADC	South African Development Community
SAR	Sodium Absorption Ratio
SARB	South African Reserve Bank
SASQAF	South African Statistical Quality Assessment Framework
SDDS	Special Data Dissemination Standard
SI	Statistical indicator
SIC	South Africa Standard Industrial classification of All Economic Activities, Version 5.
Stats SA	Statistics South Africa
UN	United Nations
UN 1993 SNA	1993 United Nations System of National Accounts
UN 1995 DPSIR	1995 United Nations Driver-Pressure-State-Impact-Response
UN 2003 SEEA	2003 United Nations System of integrated Environmental and Economic Accounting
UN 2004 SEEAF	UN 2004 Integrated Environmental and Economic Accounting for Fisheries

UN 2008 SNA	2008 United Nations System of National Accounts
UNESCO	United Nations Education, Scientific and Culture Organisation
USA	United States of America
3-D	three dimensional

1. Introduction

The aim of the study is to illustrate how to implement a Bellagio principle modeling approach to measuring sustainable development in South Africa using sensitivity and uncertainty analysis. This is achieved by defining sustainable development in Section 1.1 and a Bellagio principle modeling approach in the context of South Africa in Section 1.2. This approach uses statistical indicators, and the background to these and to statistical indicators and their models, is outlined in Section 1.3. The scope of the research will be outlined in Section 1.4, while Section 1.5 will outline the structure of the research report.

1.1. Sustainable development

The Brundtland Report (United Nations, 1987, p54) defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The Brundtland Report also encourages analysts to refine the definition based on a consensus and a broad strategic framework for achieving it. In this study each component of the definition is refined to include South African developments in the context of each component, namely, meeting needs and the ability of future generations to meet needs.

Meeting needs in the South African (SA) context is defined as the collection of all activities encapsulated in government programmes within the legislative framework of the 1996 Constitution of South Africa. The distinction between present and future generations uses the timeframe of 1998 to 2010 for the present generation and 2011 to 2015 for the [??] future generation.

The ability of future generations to meet their own needs is based on three approaches to sustainable development: three pillar, ecological and natural capital (United Nations, 2003). The simultaneous consideration of the three to measure sustainable development in this study is possible through the proposed sensitivity and uncertainty analysis approach to modeling within the United Nations (UN) System of integrated Environmental and Economic Accounting of 2003 (UN SEEA 2003) framework.

The three pillar approach, proposed by Robinson and Tinker (1998, cited in UN, 2003, p3), divides system needs into economic, social, and environmental, and requires that they be satisfied simultaneously through integrated decision-making. The ecological approach, proposed by Golley (1990, cited in UN, 2003, p3), requires robustness in the ecosystem to external perturbations and changes. The capital approach, proposed by Daly (1991) and Daly and Goodland (1996), requires that development be accompanied by a "non-declining per capita national wealth by replacing or conserving the sources of that wealth" (UN, 2003, p3).

The use of a modeling framework to consider the three approaches to simultaneous sustainability is considered in Bossel (1999) and De Groot, Erkins, Simon *et al.* (2003). In Bossel (1999), a collection of nine environment- and system-determined needs, called orientors, is defined. In the context of an economic system, the orientors require that economic, social, and environmental needs critical for ecosystem survival and its continued functioning be satisfied simultaneously. De Groot *et al*. (2003) consider integrated decision-making within a critical natural capital framework that covers the social, economic, and environmental spheres and whose resiliency must be maintained into the future.

The approach to sustainability used in this study is that of strong sustainability as defined by Turner, van den Bergh, Barendregt *et al.* (2000) and Daly and Goodland (1996), where manufactured capital is not a perfect substitute for natural capital.

1.2. Bellagio Principles

The Bellagio principles were formulated after the achievement of five international milestones to measure progress toward sustainable development (Rogers, Jalal and Boyd, 2008). The first two are the UN Conference on the Human Environment in 1972 and the Brundtland Report. The last three are the adoption of Agenda 21, the UN Framework Convention on Climate Change and the UN Convention on Biological Biodiversity in the Earth Summit of 1992 (UN, 1992a; UN1992b).

The 1983 UN General Assembly mandate to the World Commission on Environment and Development that led to the Brundtland Commission Report was to formulate a global agenda for change. Agenda 21 is a global partnership that describes the basis for action, objectives, activities and means of implementation for program areas on development and the environment in various countries (UN, 1993a). Included in the programs are sustainable development indicator programs in section 40.6(a) and 40.6(b) of Agenda 21 as part of the chapter on information for decision-making. The UN Convention on Biological Diversity and the UN Framework Convention on Climate Change outline sustainable development considerations in biodiversity and climate change, respectively.

In November 1996, a group of international measurement practitioners met in Bellagio, Italy, to review progress toward sustainable development and to synthesize insights from ongoing efforts toward its measurement. At the heart of the guidelines is an approach for the choice and design of indicators of sustainable development, their interpretation and communication of the results (Hardi and Zdan, 1997).

The 10 principles deal with four aspects of measuring progress toward sustainable development (Hardi and Zdan, 1997). The first, which is addressed by the first principle, is establishing a vision of sustainable development and clear goals that provide a practical definition of the vision in a manner that is meaningful for decision-making.

The second aspect, addressed by principles 2 through 5, is the content of assessments and the need to merge the overall system with a practical focus on current priority issues. The third aspect is the identification of the key issues of the assessment process, which is addressed by principles 6 to 8. The fourth aspect is the necessity of establishing and continuing capacity for assessment, which is addressed by principles 9 and 10.

This study addresses the 10 principles with an emphasis on the second, and partly on the third, aspect of measuring progress toward sustainable development. The Bellagio principles are listed in Table 1.

Bellagio principles of 1996
1. Guiding Vision and Goals
2. Holistic Perspective
3. Essential Elements
4. Adequate Scope
5. Practical Focus
6. Openness
7. Effective Communication
8. Broad Participation
9. Ongoing Assessment
10. Institutional Capacity

Table 1: The Bellagio principles of 1996.

Source: Hardi and Zdan (1997)

1.3. Background to statistical indicators and statistical indicator models

As society becomes more advanced, people are beginning to rely more on data to get information to solve problems. The issue is that although a large volume of data may be available, the method of converting it into information that can be used effectively is not always obvious. In addition, official statistical office publications, an important source of public information, tend to be outdated or describe what is in the past.

Practitioners in the fields of mathematical statistics, operations research and mathematics have developed a large number of techniques that can be used to visualise and analyse information.

Thus, data, as well as methods and techniques for processing the data, are available; however, there is a general mismatch between public needs and the information that can be used to generate knowledge that people can use. One aim of the present study is to analyse this problem and identify guidelines to alleviate it. The method involves using statistical indicators (and their implicit models) that represent statistical data (UN Statistical Commission, Economic Commission for Europe, 2000). Examples of statistical indicators are the Gross Domestic Product (GDP) and the Human Immunodeficiency Virus (HIV)/Acquired Immunodeficiency Syndrome (AIDS) infection rate, representing national economic production (or consumption or expenditure) and the rate of HIV/AIDS infection, respectively.

A model is a "formalized expression of theory or the causal situation which is regarded as having generated observed data" (International Statistical Institute, 2002). A statistical indicator (SI) model is an extension of the definition of a model to SIs. Models can be categorised as analytical, numerical and observational (Gershenfeld, 1999). The SI model used in this study is observational, but is subject to analytical national accounting balancing equations (UN, 1993b; UN, 2003).

The indicator model used in this study is a generalised version of the UN 1993 SNA statistical units model designed to cater to specifications of the 2003 United Nations System of Economic and Environmental Accounts (UN 2003 SEEA). The generalisation involved expanding the production frontier of the UN 1993 SNA to cater to the impact of the environment on economic production. The use of the statistical units' model in sustainability is partly reinforced by considerations in UN (1987, section 2.22) and UN (2003).

1.4. The scope of the research report

The model construction is in the context of the evolution of the South African economy between quarter one of 1997 to quarter 4 of 2007. This study is concerned with the creation and use of an economic model. The study of model creation methodologies is necessary (SA Government Communication Information System, 2010) to manage the SA economy by creating policy within the framework of Accelerated and Shared Growth Initiative for SA (ASGISA), which aims to accelerate growth from 4,5% in 2005-2009 to 6% from 2010- 2014. With the launch of various international indicator programs to combat global community problems (e.g. MDG, World Summit on Sustainable Development, Basel II Accord and global warming), an accurate set of economic indicators with which to influence policy can help the common effort to reduce adverse effects and control them currently as well as in the future.

This study outlines issues that contribute to the government's National Strategy for Small Business Development and the management of the National Empowerment Fund established by the SA Presidency (1998). The approach involved identifying a set of SIs (social, environmental and economic) and a model to predict a vector composed of seasonally adjusted annualised quarterly GDP values (constant or market prices) and a set of sustainable development composite indicators prospectively, coincidentally and retrospectively. The SIs are a set of ratios, indices, correlations and regressions of economic random variables from the Supply-Use tables of the UN 1993 SNA and a simplified version of the BCBS 2004 framework adapted for the SA economy.

These are complemented by and combined with SIs from the environmental and social dimensions. For the environmental dimension, variables were obtained from the SA Environmental Indicators database constructed according to the 1995 UN Driver-Pressure-State-Impact-Response (DPSIR) model (SA Department of Environmental Affairs and Tourism, 2006), UN 2003 SEEA and 2006 Intergovernmental Panel on Climate Change (IPCC) greenhouse gas emissions inventory guidelines. For the social dimension variables were obtained from the SA Presidency Developmental Indicators of 2010 and UN (2007).

Multivariate time series analysis is used to analyse and perform an integrated analysis of the data over time. The sensitivity and uncertainty analysis is used to evaluate the robustness of the results to model assumptions. The model is then used to forecast developmental and environmental conditions to 2015. The aim is to obtain insights into how to measure and provide tools that could assist in influencing the SA economy's progress toward sustainable development. The study also aims to investigate models that could be used to facilitate the movement of economic and environmental indicators toward the recommendations outlined in Hall (2005) and Cobb and Rixford (1998).

1.5. Summary

Chapter one gave a background to sustainable development and outlined the development of the concept of sustainable development. Chapter two will discuss the literature concerning SIs and SI models as well as using and developing economic models.

The third chapter gives the background to the UN1993 SNA, and the various components, such as the institutional units in the economy, the Open Leontief System and the Supply-Use tables, and the UN 2003 SEEA. Chapter four uses the definition of sustainable development to construct a context specific modeling framework with a scope that is adequate for its measurement. It also provides the characteristics of the scope and outlines how these were quantified in the context of the constructed model. Chapter five describes and discusses the results obtained, and Chapter six gives the conculsions and recommendations.

2. Literature study

Section 2.1 discusses the literature on SIs, Section 2.2 the literature concerning SI models and Section 2.3 the literature on the scope of sustainable development in South Africa. Section 2.4 summarises the findings of the literature study.

2.1 Literature on Statistical indicators

The need for statistical indicators has been growing with the many global economic, social and environmental issues raised in international conferences, task group meetings, summits, workshops, declarations, the establishment of programmes, and the launches of dissemination standards and systems up to the late eighties and nineties. Examples include the foundation of the Club of Rome and the UN Conference on the Human Environment in 1972; the publication of UN (1987); the creation of the International Institute on Sustainable Development (IISD) in 1990; the UN Earth Summit in 1992; the establishment of the UN Environment Programme in 1992, the Scope Scientific Workshop on indicators of sustainable development in 1995; the meeting of the Bellagio group in 1996; the launch of the International Monetary Fund's Special Data Dissemination Standard (SDDS) in 1996; and the launch of the International Monetary Fund's General Data Dissemination System (GDDS) in 1997.

Identifying this need for statistical indicators continued with the Millennium Declaration of 2000; the UN Education, Scientific and Culture Organisation (UNESCO) Universal Declaration on Cultural Diversity of 2001; World Summit on Sustainable Development in 2002; publication of the Basel Committee on Banking Supervision (BCBS) Basel II Accord in 2004; and 14th Commonwealth Statisticians Conference in 2005.

People want to be able to measure progress in developmental issues in the context of their countries as well as in the context of their surroundings (Organisation for Economic Cooperation and Development, 2008a). For example, national government structures are interested in measuring progress toward sustainable development in the face of the problem of climate change. In SA, the Eastern Cape, Kwa-Zulu Natal and the Western Cape, floods have led to loss of life, possessions and property in the last three years. Additionally, for many farming communities in these and other areas, over the same period there have been veld fires, cyclones and other natural hazards that have greatly reduced farming production (SA Government Communication Information System, 2010). Given these occurrences, the existence of the SA Presidency (2002) and schedule 4 of the SA Parliament (1996) on disaster management, it is important for the SA people to have at their disposal usable information to monitor government allocation of funding to protect them against the consequences of such adverse meteorological effects.

The big issue is how to decide on the best statistical indicators for a specific issue. This has become a discussion topic in many conferences and for task teams of international organisations such as the Organisation for Economic Cooperation and Development (OECD), International Monetary Fund (IMF), Eurostat and the UN. The problem is that indicators are used in a variety of disciplines, each with its own considerations, and establishing a consensus on a methodology is difficult. For example, in the case of economic indicators, headline indicators like the Consumer Price Index (CPI), the prime interest rate, the exchange rate and the unemployment rate have a user consensus on how their underlying methodologies summarise economic conditions. However, for topics such as sustainable development or the quality of life, an equivalent and widely accepted methodology for an equivalent set of headline indicators is still being formulated and, thus, the analysis of the resulting statistical indicators is different.

In addition, as the number of indicator efforts increase (each with its own set of indicator frameworks) distinguishing between indicator types is more difficult. For example, the Millennium Declaration of 2000 covers social, economic, cultural, environmental and sustainable development issues, each of which have individual government policy frameworks in the case of South Africa. With the advent of the UN 2003 SEEA, this trend of indicator efforts becoming multidisciplinary has also begun to become a feature of the 1993 UN System of National Accounts (UN 1993 SNA). The field of statistics provides the tools and methodologies for statistical indicators to meet the requirements from the various fields.

2.2. Literature on statistical indicator models

According to Hall (2005), the key issue for choosing indicators (and thus indicator models) is their usefulness to the public in driving or influencing policy, raising awareness and getting key messages across. Further, the correct indicators will achieve each of these requirements if they involve policy colleagues, have commitment in policy, are user-friendly in communication and are compact. These issues are also identified in other SI texts, including Cobb and Rixford (1998), David (1994), Evans, Leone, Gill and Hilbers (2000), Haining (2003), Hardi and Zdan (1997), Horn (1993), Meadows (2005), OECD (2007) and UN (1993a),.

It is also important to note that much work has been done in the past few decades on SIs, such as that of the Club of Rome in 1968, the World Bank International Comparison Program of 1968, Brundtland Report of 1987, BCBS Basel I Accord of 1988, Earth Summit on Sustainable Development of 1992, Bossel (1999), Millennium Declaration of 2000, the IMF Data Quality Assessment Framework (DQAF) of 2003, BCBS Basel II Accord of 2004, Eurostat (2005), 14th Commonwealth Statistician's Conference of 2005, OECD (2008a) and Statistics SA (2008b).

An important issue is how to decide on the best indicators within a statistical indicator framework for a specific issue. This has been a discussion topic in many statistical conferences and for task teams of international organizations. Because indicators and their models are used in a variety of disciplines, each with its own considerations, consensus on a common statistical indicator methodology has not yet been established.

An important consideration pertains to the increase in SI efforts that have frameworks that share common indicators but different concerns. For example, the Millennium Development Goals (MDG) of 2000 (UN, 2000) and the 1995 UN Driver-Pressure-State-Impact-Response model (UN 1995 DPSIR) frameworks share common indicators. The MDG of 2000 utilise the common SIs in the context of measuring social development (UN, 2000), while the UN 1995 DPSIR interprets the common SIs in the context of measuring progress toward sustainable development (SA Department of Environmental Affairs and Tourism, 2001).

With the development of the UN 2003 SEEA and the transition by official organisation national accounting frameworks to the 2008 UN System of National Accounts (UN 2008 SNA), this trend of frameworks sharing common SIs, has also begun to become a feature of the UN 1993 SNA. The field of statistics provides the tools and methodologies to meet the requirements of SIs (and their models) from the various fields. In the context of the current study of economic and environmental indicators in the form of the Supply-Use tables, the macroprudential indicators of financial soundness, the MDG of 2000, the UN 1995 DPSR environmental indicators and the UN 2003 SEEA, using a statistical units' model approach to indicators limits these the difficulties posed by SI frameworks having common SIs.

The main impact of the SI efforts is a build-up of theoretical issues around the choice and evaluation of indicators. For example, the adoption of Agenda 21 and its reinforcement in the World Summit on Sustainable Development in 1992 provided an opportunity for various countries to try and implement issues relating to sustainable development indicators based on their own experiences. This can be observed in the indicator program sessions in the 2005 Commonwealth conference, in papers like Meadows (2005), Scott (2005) and Kahimbaara (2005), where SIs are being integrated into planning policy and the activities of statistical organizations.

2.3. Literature on the creation and use of economic models

This study is concerned with the creation and use of an economic model. Use includes the management of economic growth and stability to the benefit of its stakeholders which in the case of SA are the 48.7 million inhabitants in mid-year 2008 (medium variant estimates) (Statistics SA, 2010f). South Africa is a new democracy battling high levels of poverty (headcount index of 22% using a poverty line of R283 in 2008); crime (4 309.7 per 100 000 of population in 2008/09); inequality (Gini coefficient of 0.679); unemployment (23.2% June to Sept 2008); HIV AIDS (HIV prevalence of 11% mid-year 2008); inflation (12.1% December 2008); environmental degradation (Ecological Footprint of 2.8 global hectares in 2001) and multiple deprivation (2001 Provincial Indicators of Multiple Deprivation, which has an average of 165.31 for Eastern Cape using Census 2001 data) (Statistics SA, 2006; SA Department of

Environmental Affairs, 2006; Statistics SA, 2010f; SA Presidency, 2010).The effective use of economic indicators (and their models) provides an opportunity to manage scarce resources to mitigate these problems faced by South Africa.

The study of model creation methodologies is necessary (SA Government Communication Information System, 2010) to manage the SA economy by creating policy within the framework of Accelerated and Shared Growth Initiative for SA (ASGISA), which aims to accelerate growth from 4.5% in 2005-2009 to 6% from 2010- 2014. Similarly, the study is necessary for the management of the economy within the framework of the Joint Initiative for Priority Skills Acquisition (JIPSA) launched in 2006 and the Extended Public Works Program (EPWP) launched in 2004. Economic models are used in the SA Reserve Bank's monetary policy in managing domestic output and expenditure, price inflation, exchange rate and foreign trade payments (SA Reserve Bank, 2010b). Similarly, these models provide information for the efforts of the SA National Treasury's fiscal policy and the SA Presidency's War on Poverty program launched in 2008. Econometric models are used by the Department of Trade and Industry (DTI) in its modeling of the SA economy (SA DTI, 2000; SA DTI, 2004). Model results are available from the DTI website (SA DTI, 2004). Economic models also fit within the framework of the SA Presidency Government-Wide-Monitoring and Evaluation (GWM&E) framework, which is available from the Statistics SA (Stats SA) National Statistical System Division (NSSD) website (Stats SA, 2005b; SA Presidency, 2007).

With the launch of various international indicator programs to combat global community problems (e.g. MDG, World Summit on Sustainable Development, Basel II Accord and global warming), an accurate set of economic indicators with which to influence policy can help the common effort to reduce adverse effects and control them currently as well as in the future. This can be done through managing trade relations like the New Partnership for Africa Development (NEPAD) and helping combat local and global problems as part of the Southern African Development Community (SADC). Economic indicators (and their models) will also help manage relationships with major trading partners like Europe, the United States of America (USA), Canada, Latin America, South Asia, South East-Asia, Australasia and East-Asia.

This study outlines issues that contribute to the government's National Strategy for Small Business Development and the management of the National Empowerment Fund established by the SA Presidency (1998). The information is useful in the context of local economic agencies and groups like the Industrial Development Corporation (IDC), Business Partners Limited Group (BPL) and the Department of Public Enterprises (SA Government Communication Information System, 2010).

The scope of this study is to construct a statistical model that assesses the progress of the SA economy toward sustainable development. Sustainable development in SI terms involves taking quantities, such as total mineral sales (R25 682 million in August 2010) associated with the harvesting of non-renewable resources (Statistics SA, 2010h); fisheries catches (131 000 tons of hake and 2 340 tons of west-coast rock lobster in 2008) for renewable resources (Statistics SA, 2010b); unemployment rates for socio-economic indicators; and GDP for economic indicators and analysing them within a developmental and environmental impact framework.

The approach involved identifying a set of SIs (social, environmental and economic) and a model to predict a vector composed of seasonally adjusted annualised quarterly GDP values (constant or market prices) and a set of sustainable development composite indicators prospectively, coincidentally and retrospectively. The SIs are a set of ratios, indices, correlations and regressions of economic random variables from the Supply-Use tables of the UN 1993 SNA and a simplified version of the BCBS 2004 framework adapted for the SA economy.

These are complemented by and combined with SIs from the environmental and social dimensions. For the environmental dimension, variables were obtained from the SA Environmental Indicators database constructed according to the 1995 UN Driver-Pressure-State-Impact-Response (DPSIR) model (SA Department of Environmental Affairs and Tourism, 2006), UN 2003 SEEA and 2006 Intergovernmental Panel on Climate Change (IPCC) greenhouse gas emissions inventory guidelines. For the social dimension variables were obtained from the SA Presidency Developmental Indicators of 2010 and UN (2007).

Multivariate time series analysis will be used to analyse and perform an integrated analysis of the data over time. The sensitivity and uncertainty analysis will be used to evaluate the robustness of the results to model assumptions. The model will then be used to forecast developmental and environmental conditions to 2015. The aim is to obtain insights into how to measure and evaluate indicators that could be used to influence the SA economy's progress toward sustainable development. The study also aims to facilitate the movement of economic and environmental indicators toward the recommendations outlined in Hall (2005) and Cobb and Rixford (1998).

2.4. Conclusions

The literature review indicates that SIs have the potential to be an information source for society's daily activities. The critical factor that determines how useful this information is, is determined by the consensus on the methodology of how the SIs are constructed for various purposes. SI models are an important operation for the analysis of SIs because they allow them to be grouped into frameworks that enhance the knowledge about specific topics. However, just as in the case of SIs their usefulness largely depends on the consensus concerning the methodology used. The literature review has shown that there are a variety of programs in place in the SA economy that make use of SIs and SI models and a study that addresses issues concerning a consensus in methodology could be useful to these programs

3. Concepts and definitions

3.1. Introduction

The chapter considers the concepts and definitions used in the modelling framework, and the analysis in Chapter 4. The chapter considers the components of the UN SNA 1993 system in Section 3.1, Section 3.2 considers the statistical units model of the UN SNA 1993 system, Section 3.3 considers the matrix accounts of the UN SNA 1993, Section 3.4 considers the satellite accounting system of the UN SNA 1993 and Section 3.5 considers the components of the UN 2003 SEEA satellite accounting system.

3.2. Background to the UN 1993 SNA

The UN 1993 SNA is a set of integrated and consistent set of macroeconomic accounts, balance sheets and tables based on internationally agreed concepts, definitions, classifications and accounting rules (UN, 1993a). The system is designed such that the articulation of the accounts can be done at the level of an individual institutional unit or economic agent, groups of institutional units or agents and at the level of the whole economy.

The system is composed of a sequence of interconnected flow accounts linked to the economic activities taking place over the study period (accounting period), and balance sheets that record stocks of assets and liabilities by institutional units at the beginning and at the end of the period. Each flow account presents information on a particular kind of economic activity like production or the generation, distribution and redistribution of income. Each flow account contains a balancing item which is defined residually as the difference between the total resources and their uses as recorded on the two sides of the account. The balancing item in one account is carried forward to be the first item of the following account, thereby creating an articulated sequence of accounts presenting different types of information about the economic activity over the study period.

The flow accounts are also linked to the balance sheets since all the changes occurring over the study period in one of the flow accounts will affect the assets or liabilities that are held by the institutional units or sector at that point in time. The net result is that the closing balance in the balance sheet accounts are fully determined by the opening balances and the flows recorded in the sequence of accounts during the study period.

3.2.1. Sequence of flow accounts

The different types of flow accounts are the current accounts and accumulation accounts.

3.2.1.1. Current accounts

The current accounts record the production of goods and services, the generation of incomes by production, the subsequent distribution and redistribution of incomes among the institutional units and the use of incomes for the purposes of consumption or saving.

3.2.1.1.1. Production account

The production account records the activity of producing goods and services as defined in the system. The balancing item of the production account is the gross value added, which is defined to be the residual difference between intermediate consumption and the value of total output that accompanies the intermediate consumption. The gross value added serves as a measure of the contribution to GDP of an individual producer, industry or sector. In terms of the sequence of accounts, the gross value added is the source from which primary incomes of the system are generated and is thus an item that is carried forward to the primary distribution of income account. The value added is also measured by adjusting the gross value added for the consumption of fixed capital to be net value added.

3.2.1.1.2. Distribution of income accounts

The distribution of income accounts consist of a set of articulated accounts showing how incomes are generated by production, distributed to institutional units, redistributed among the institutional units, and used by households, government units or non-profit institutions serving households. The balancing or residual item of the set of income accounts is saving. The saving is carried forward into the capital account which is the first account in the next sequence of accounts, namely, the accumulation accounts.

3.1.1.2. Accumulation accounts

The accumulation accounts record the acquisition and disposal of non-financial and financial assets, and liabilities by system institutional units through transactions or as a result of other events. The accumulation accounts are the capital accounts, financial accounts and the other changes in assets accounts.

3.1.1.2.1. Capital accounts

The capital account records the acquisitions and disposals of non-financial assets as a result of transactions with other institutional units or from internal bookkeeping transactions linked to production.

3.1.1.2.2. Financial accounts

The financial account records the acquisition and disposal of financial assets and liabilities through transactions

3.1.1.2.3 Other changes in assets accounts

The other changes in assets accounts consist of two sub-accounts. The first is called the other changes in volume of assets account and the second is called the revaluation account. The first account records the changes in the amounts of assets and liabilities as a result of events other than transactions. The second account records changes in the values of assets and liabilities as a result of changes in their prices.

The link between the accumulation accounts and the income accounts is provided by the property that saving, which is disposable income that is not spent on consumption of goods and services, must be used to acquire either financial or non-financial assets. When saving is negative then there is excess of consumption over disposable income and must be financed by disposing of assets or incurring liabilities. The financial account thus shows how funds are channelled from one group to another, especially through financial intermediaries.

3.1.1.2.4. Balance sheets

The balance sheet show the values of stocks of assets and liabilities held by the institutional units or sectors at the beginning and at the end of the study period. The values of the assets and liabilities will vary during the study period through transactions, price changes or other changes affecting the volume of assets or liabilities. These transactions and changes are recorded in the accumulation accounts so that the changes in the balance sheets from the beginning to the end of the study period are entirely contained within the system when certain criteria are met. The criteria include a consistent system of valuation of the transactions and other changes in current prices.

3.3. Activities and transactions

The sequence of accounts is designed to provide analytical information about the behaviour of institutional units and the activities in which they engage, including production, consumption and accumulation of assets. This is done by recording the values of goods, services or assets involved with these activities rather than trying to record the physical consumption of goods and services by households. The value of household expenditure on final consumption goods and services are measured in terms of the transactions they conduct with other institutional units, whether they include purchasing or not.

The data on transactions provide the source material from which the values of the various elements of the accounts can be derived. The first property of this approach is that the use of prices in transactions between sellers and buyers on markets allows for the valuing, directly or indirectly, of the items in the accounts. Also since a transaction that takes place between two different institutional units has to be recorded for both parties to the transaction it will always appear twice in the macroeconomic accounts. This provides information for tracing the flow of goods and services through the economic system from their producers to their eventual users. In the case of the transaction occurring within the same institutional unit the transaction also appears twice in the macroeconomic accounts. The approach thus also allows for the analysis of internal bookkeeping transactions when a single unit engages in two activities, such as production and consumption of the same good or service.

3.4. Institutional units in the economy

The main types of institutional units or transactors that are distinguished in the system are households and legal entities. The legal entities are either entities created for the purposes of production, mainly corporations and non-profit institutions or government units (including social security funds). Institutions in the system are defined to be "units that are capable of owning goods and assets, incurring liabilities and engaging in economic activities and transactions with other units in their own right" (SNA, 1993a).

Institutional units that are resident in the economy are grouped into five mutually exclusive sectors composed of the following types of units: non-financial corporations; financial corporations; government units; non-profit institutions serving households; and households.

The five sectors make up the make up the total economy in the system. Each sector is in turn divided into sub-sectors. For example the non-financial and financial corporations sectors are divided into corporations subject to control by governments or foreign units from other corporations. The system is sufficiently flexible so as to allow for the sequence of flow accounts, and balance sheets to be compiled for each sector and sub-sector.

3.5. Open Leontief System

An Input-Output system or model is said to be open “with respect to consumer demand if it does not contain equations describing the structural characteristics of the household sector or it is open with respect to investment demand which implies that the structural relationships determining all the individual sectors of the economy are not included in the system” (Barna, 1955).

3.6. Supply and Use tables

The Supply and Use tables are two tables in a type of matrix account, with the Supply table showing the supply of products and the Use table showing the use of products in the economy and the production and generation of income accounts of industries.

The Supply table shows that value of products in basic prices and in purchaser’s prices. The main part of the Supply table shows columns at basic prices but also contains supporting columns containing adjustments in order to arrive at the Supply table in purchaser’s prices.

The Supply table of the central system is essentially composed of composed of columns and rows that give three types of information about economic activity. The first is on the output of the various industries according to classified activities with aggregates broken down to distinguish between market output, output produced for own final use and other non-market output along the columns and the same three-way split for the products of each industry along the rows. The second piece of information provided by the Supply table is information on imports broken down into goods and services. The third piece of information is on adjustments, namely, trade and transport margins, taxes and subsidies and the cif (cost, insurance, freight)/fob (free-on-board) adjustment.

The Use table shows information on the uses of goods and services and thus on the cost structures of the economic activity of the industries (i.e. production functions) in an economic activity classification. The Use table is composed of three populated quadrants and one empty quadrant. The three populated quadrants are the intermediate use quadrant, the final use quadrant and the uses of value added quadrant, numbered sequentially as quadrants one, two or three in UN (1993a).

The intermediate use quadrant shows intermediate consumption at purchaser's prices by industries in the columns and by products in the rows in the Use table. The final use quadrant shows exports, final consumption and gross capital formation at purchaser's prices, each classified by products on the rows in the Use table. The use of value added quadrant shows the production costs of producers other than intermediate consumption. The main uses of value added depicted in the Use table are: the compensation of employees; taxes less subsidies on production and imports; consumption of fixed capital; and net mixed income and net operating surplus.

3.7. Symmetric Input-Output tables

The Symmetric Input-Output tables in the system are a type of matrix account. They facilitate a variety of analyses but three are highlighted in UN (1993a).The first is the decomposition of purchaser's prices into basic price, taxes, subsidies, and trade and transport margins, and the separate analysis of the decomposed components. The second is distinguishing the use of imported products from the use of products from resident producers. The third is the expression of the information in the rows and columns of the Supply and Use tables in the same classification of either products or industries.

The Symmetric Input-Output table (SIOT) has two important assumptions that underlie input-output analysis in their construction and analysis, namely, a single technique of production for each product and the linear fixed-coefficient production function. The symmetric table has the same dimensions in industries or products and can be expressed either as a product by product table or industry by industry table, with each table showing different information. The product-by-product table shows which products are used in the production of which other products, while the industry by industry table shows which industry uses the output of which other industry (UN, 1993a).

The format of the product by product table is similar to the Use table and is also composed of three quadrants. The upper-left part is the intermediate use quadrant and shows the intermediate consumption in product by product terms. The upper-right part called the final use quadrant and shows the same information as the final use quadrant in the use table but excludes imports (which are usually shown on a separate matrix table). The lower-left part is called the uses of value added quadrant, similar to the uses of value added quadrant table, and has the same classification in the rows but the classification of the columns is such that it shows homogenous activities. The industry by industry table can conceptualised to contain the same quadrants analogously.

3.8. Satellite Accounts

The satellite accounts mainly allow for five types of analyses in the system: the provision of additional information on particular social concerns of a functional or cross-sector nature; the use of complementary or alternative concepts to introduce additional dimensions to the conceptual framework of national accounts; the extended coverage of costs and benefits of human activities; additional indicators and aggregates to facilitate further analysis of data from the central framework; and the linkage of physical data sources and analyses to the monetary accounting system (UN, 1993a). The compilation of a functionally oriented satellite account begins with a satellite analysis.

The components of a satellite analysis involve supplementing the information of the central system of the following components: production and products; primary incomes and transfers; uses of goods and services; assets and liabilities; purposes; and aggregates.

The process of supplementing information may involve the re-organisation of information within the central system using an alternative classification suited for the specific purpose. For example, the South African Standard Industrial classification of All Economic Activities, Version 5 (SIC) single digit aggregates may be supplemented with aggregates only including corresponding higher digit classification aggregates for the purposes being analysed, as would be in the case of environmental expenditure or water accounts. Other analyses may occur outside the production boundary of the central system, in which case if additional production aggregates are included, so must the income aggregates and the expenditure aggregates in line with the accounting principles of measuring GDP (UN, 1993a).

The scope of a functionally orientated satellite account begins with the analysis of the uses of products in the field or discipline (UN, 1993a). The main issues are the goods and services that can be associated with the specific field, the activities which correspond to capital formation in the field, and transfers that are considered specific to the field keeping in mind that each of the components might already be included in the central system of national accounts.

The design of the satellite account usually emphasises (UN, 1993a): a detailed analysis of production and uses of the specific goods and services of that field; a detailed analysis of the transfers; an analysis of production or uses and transfers equally; and the final uses of the products and services associated with the field.

The satellite account thus covers the analysis of uses or benefits out of national expenditure, production and its factors, transfers and other ways of financing the uses, both in value terms and in physical terms (UN, 1993a). Additionally, all the analyses must be linked to institutional or statistical units within the central framework or the satellite accounting framework.

3.9. UN 2003 integrated System of Environmental and Economic Accounts

The UN 2003 SEEA satellite account essentially amends central system 1993 SNA aggregates to treat natural resources as capital in the production of goods and services. This involves recording the cost of using natural resources and the implicit transfers needed to account for the imputed costs and capital items (UN, 1993a). In the compilation of the UN 2003 SEEA the important consideration is that relevant parts of the UN 1993 SNA take into account aspects of environmental accounting. For example, the cost and capital items of accounting for natural resources are identified separately in classifications and accounts that record stocks and other volume changes of assets in the sequence of accounts. However, several elements of the UN 1993 SNA still have to be made more detailed, reclassified and other elements have to be introduced in order to meet the specific purposes of environmental accounting.

An illustration of this property is that in the UN 1993 SNA only produced assets and inventories are explicitly taken into account for the calculation of the net value added, additionally, the cost of their use is also reflected in intermediate consumption and consumption of fixed capital. In the case of non-produced assets such as land and natural resources, they are only included in the UN 1993 SNA asset boundary insofar as they are under the effective control of institutional units. The cost of their use is also not explicitly accounted for in production cost, and as such the cost may or may not be included in the costs that are used in the calculation of net value added (UN, 1993a).

The UN 1993 SNA manual identifies five details on the amendments made by the UN 2003 SEEA framework on the UN 1993 SNA central system to accommodate environmental satellite analysis and accounting. These are: the introduction of alternative accounting frameworks suited for environmental accounting; adjustments to the asset boundary and its associated classifications; the recoding of environmental cost; the introduction of the concept of capital accumulation for non-produced assets as a complement to capital formation for produced assets; and valuation techniques suited for environmental accounting.

In this study the five amendments are implicit in the aggregates compiled according to the UN 2003 SEEA framework, namely, the El Serafy Resource Rent indicators, and to some extent in the UN 2004 Integrated Environmental and Economic Accounting for Fisheries (UN 2004 SEEAF) framework fisheries stock SIs. In the remainder of the aggregates the amendments are accommodated through the harmonised statistical units model outlined in Chapter 4 and the valuation techniques used in De Groot *et al*. (2003).

3.10. Conclusions

The chapter provided a background to the components of the UN 1993 SNA, namely, the sequence of accounts, balance sheets, matrix accounts, and satellite accounts (also a matrix account). It also provided a detailed specification of the UN 1993 SNA statistical units model and how it was generalised to a satellite accounting framework for the case of the UN 2003 SEEA. This study uses a generalised version of the UN 2003 SEEA satellite account in that the sustainable development analyses also include aggregates of human and social capital (Meadows, 1998). In the UN (1993a) this generalised version of the satellite account is used in a SAM-based environmental analysis (UN, 1993, p 639).

4. Methodology

4.1. Introduction

The chapter considers the methodology used in the study. The chapter begins with an overview of the modeling used in the analysis, including the key aims of the modeling excercise. This is followed by a section on the methodology for the selection of the source data used in the analysis in section 4.3., section 4.4. for the compilation of the source data, section 4.5. for fitting a statistical factor model to the source data, 4.6. for sensitivity and uncertainty analysis on the fitted model, and section 4.7. for decision theory on the model output.

4.2. Overview of the modeling methodology

The SI model fitted in the analysis was an observational model (Gershenfeld, 1999). The methodology applied in Broomhead, King and Jones (1987) also shows that the model is equivalent to a numerical model (Gershenfeld, 1999), also called macro-econometric (Boulanger and Brechet, 2005). The numerical model approach is also supported by the Open Leontief system multiplier production function assumption, which links economic, social and environmental SIs to the UN 2003 SEEA framework.

The first step in constructing the SI model was to identify a set of SIs that covered all aspects of sustainability in a policy-making-based decision theoretical framework. Fitting the model to the data provided the foundation for this procedure to be performed iteratively by analysing recommendations from official and academic texts and possible decision theory frameworks.

The methodology used in this study considered four aspects of model creation that facilitate integrated decision-making for a collection of SIs. The first is a SI harmonisation procedure, and the second is the use of a surrogate model to characterise the evolution of a real-life process that generates the SIs over time. The third is the evaluation of the robustness of the results to the assumptions made to construct the surrogate model using sensitivity and uncertainty analysis.

Interpretability of statistical information is defined as the ease with which users can understand statistical information emanating from measurement and estimation activities through the provision of metadata (Statistics SA, 2008b). Statistics coherence is “their adequacy to be reliably combined in different ways and for various uses” (Eurostat 2003). An interpretability and coherence analysis combines the two operations to study how the source statistics can be combined with other information to create statistics. The harmonisation procedure uses an interpretability and coherence analysis to harmonise the SIs generated by the process.

The fourth component of model creation in the study is the use of decision theory to evaluate the utility of the model output for addressing the problems that underlie its design. In this study, decision theory is defined as the analysis of decision-making in the face of uncertainty. The components of a decision-making problem were arranged into six general categories (Chernoff and Moses, 1959): available actions, states of nature, a loss table, an experiment with an empirical distribution, available strategies, and an average loss table for evaluating a consequence of the strategies.

The limitation of the construction involved not addressing issues concerned with the available budget. This factor of SI production was not considered; hence, the study illustrates procedures for available statistical data. However, a limited cost-based analysis was conducted using decision theory by constructing loss functions.

4.3. Identifying the source data relevant for sustainable development policies

Analysing sustainable development in this study began with the analysis of national SIs from South Africa. This involved analysing government policies and programmes contained in all (2001-2010) yearbooks from the SA Government Communication Information System (GCIS), data from the national treasury, monetary policy statements from the SA Reserve Bank (SARB), the SA Parliament (1996) and national statistical data relating key government programmes identified in the GCIS yearbooks.

In this study, the first set of academic and official texts used to provide guidelines for choosing the initial set of SIs to cover all aspects of sustainability were UN (1987); UN (1993a); UN (1993b); Atkinson, Dubourg, Hamilton *et al.* (1997); Meadows (1998); SA Department of Environmental Affairs and Tourism (2001); UN (2000); UN (2002); UN (2003); and Bank of International Settlements (2004) and Rogers, Jalal and Boyd (2008).

The analysis of sustainable development policies provided the basis for selecting SIs that facilitated the measurement of sustainable development in SA using the SI model. The policies identified in the texts were arranged into a dynamic systems modeling framework outlined in Meadows (1998). The modeling framework is composed of five types of capital, Daly's Triangle and a sustainable development SI information system. The five types of capital are natural capital, built capital, human capital, social capital and well-being. The SIs of that provide measures of the five types of capital can be arranged into three dimensions, namely, economic, social and environmental.

Natural capital (ultimate means in Daly's triangle) consists of stocks and flows in nature from which the human economy obtains its raw materials and energy (i.e. sources) and in which it disposes of these when their use is complete (i.e. sinks). Built capital (intermediate means in Daly's triangle) is human-built long term physical capacity in the form of factories, tools, machines that produce economic output. The built capital integrates natural capital with human capital in that it determines the demand for human capital. Built capital can be used with throughput to generate more built capital which determines the rate of economic growth. Human capital (ultimate means/ ultimate ends), is the productive wealth embodied in labour skills and knowledge (OECD glossary of terms)

Social capital (intermediate ends in Daly's triangle) is a stock of attributes (knowledge, trust, efficiency, honesty) that inheres not to a single individual but to human collectivity. Well-being (ultimate ends in Daly’s triangle), this is defined to be human happiness, fulfillment, purpose, satisfaction or quality of life.

4.4. Methodology used in collecting source data

The overarching framework for the methodology of the compiled data for the analysis was UN 2003 SEEA. The UN 2003 SEEA is suitable for compiling the data because it adheres to the data requirements for the three schools of approaches to sustainable development measurement (UN, 2003); is based on the UN 1993 SNA statistics units model (UN, 2003); and facilitates matching costs and benefits of economy resource usage in sustainability analyses (UN, 1987).

The sample surveys used to construct the data table (columns are the variable names and the row entries are the variable values at a point in time) are economic, social and environmental in nature. The data table base frequency for the analysis is quarterly.

The SIs were sourced from data compiled according to the 2004 Basel II Accord, 2009 SA Developmental Indicators, UN (2007), UN 1993 SNA, UN 1995 DPSIR and UN 2003 SEEA. The capital approach to strong sustainability was used as the basis for building the model. The economic dimension of sustainability was quantified using SIs from the Basel II Accord of 2004, UN 1993 SNA and UN 2003 SEEA. The social dimension was quantified using the SA Presidency Developmental indicators of 2009 and UN (2007). The environmental dimension was quantified using the UN 1995 DPSIR and UN 2003 SEEA.

The three pillar approach to sustainability was incorporated into the study through interactions among the three dimensions that were quantified by the model and interpreted within the context of the UN 2003 SEEA. The ecological approach to measuring sustainability was conducted by analysing the interactions measured by the model within the context of the UN 2003 SEEA, and the feedback from the environmental dimension was quantified within the UN 1995 DPSIR framework.

The economic dimension was introduced into the model through the broad theme of economic growth and economic macroprudential stability (Evans, Leone, Gill et al., 2000). Economic growth was quantified using the seasonally adjusted annualized quarterly GDP growth rate, which was compiled according to the UN 1993 SNA manual. The Basel II accord indicators were compiled using methodology in SARB (2010a), Evans, Leone, Gill et al. (2000), UN (2003) and IMF (2006). The Basel II Accord indicators were the net qualifying capital and reserves to total risk-weighted assets, return on assets, return on equity, interest margin to gross income, noninterest expense to gross income, and liquid assets to short-term liabilities for the banking sector. Other financial stability indicators were mortgage debt as a percentage of the market value of housing, household income gearing and household debt as a percentage of disposable income. Additional macroprudential indicators were the Open Leontief System multiplier proxies, aggregate civil cases issued for debt for enterprises and private persons, and aggregate company liquidations. The SIs under the economic dimension mentioned measure social capital in the capital approach to sustainability, with the exception of the Open Leontief System multiplier proxies, which measure built capital.

The social dimension was introduced into the model using the poverty headcount index, poverty gap ratio, Gini coefficient and percentage of total income of the poorest 20% compiled from the All Media Product Survey (AMPS) by the SA Presidency and Van der Berg, Louw and du Toit (2009). The socio-economic effect was introduced into the model using population growth (mid-year population estimates) compiled by the Stats SA, the Black Economic Empowerment (BEE) transactions as a percentage of all merger and acquisition (M&A) transactions compiled from the Ernst and Young handbooks for M&A, the total number employed–total population calculated from Stats SA data (Statistics SA, 2000; Statistics SA, 2003a; Statistics SA 2005a; Statistics SA, 2010f; Statistics SA, 2010j; Statistics SA 2010k).

The health component in the social dimension of the population was introduced in four parts. The first used the under 5 mortality rate, the under 1 mortality rate and total AIDS orphans from the Actuarial Society of South Africa (ASSA) 2003 model ASSA (2005) and Statistics South Africa (2010f). The second part, health services, was introduced using immunisation coverage, malaria incidence, malaria deaths, TB incidence and the TB cure rate from the Department of

Health Malaria Notification System, SA Department of Health National TB Control Programme, SA Department of Health (DoH) SA Health Review and the World Health Organisation (Health Systems Trust, 2010; SA Presidency, 2010). The third, HIV prevalence and its impact, was introduced using the HIV prevalence of mothers attending antenatal clinics from the SA DoH annual HIV and Syphilis Sero-prevalence Surveys between 1997 and 2009 (SA DoH, 2010). The fourth part, life expectancy, used life expectancy estimates from the ASSA 2003 model and Stats SA data (ASSA, 2005; Stats SA, 2010f).

The education component was introduced using the matric pass rate, gross enrolment ration for girls, gross enrolment ratio for boys and the adult literacy rate (SA Department of Education, 2010). The gender parity effect component was introduced using the overall Gender Parity index (GPI) in primary and secondary schools, and the number of women in parliamentary and provincial legislatures (SA Department of Education, 2010; Independent Electoral Commission, 1999; Independent Electoral Commission, 2001; Independent Electoral Commission, 2003; Independent Electoral Commission, 2004; Independent Electoral Commission, 2009).

The human settlement component of the social dimension was introduced using the number of households in informal dwellings with access to electricity and potable water, from the Stats SA October Household Survey (OHS) 1997-1999, Census of 2001, General Household Survey 2002-2006, Community Survey of 2007 and GHS of 2008 (Stats SA, 1999; Stats SA 2003b; Stats SA, 2008a; Stats SA, 2010c). The security component used the murder and the burglary rates from the SA Police Service (SAPS) annual reports and crime statistics (SA Police Service, 2010a; SA Police Service, 2010b).

The social dimension of global community was introduced using democratically elected governments in Africa, the real GDP growth in Sub-Saharan Africa and the Index of Exchange Market Pressure. The SIs for the democratically elected governments in Africa were obtained from the SA Presidency (SA Presidency, 2010), Electoral Institute for the Sustainability of Democracy in Africa (EISA), Consultancy of Africa intelligence (CAI) and International Foundation for Electoral Systems (IFES)Election Guide data (CAI, 2010; CAI 2011; EISA, 2004; IFES, 2011). The real GDP growth in Sub-Saharan Africa was obtained from the SA

Presidency 2010 developmental indicators (SA Presidency, 2010) and the IMF Word Economic Outlook (IMF, 2010c) database for April 2010. The Index of Exchange Market Pressure (IEMP) was obtained from SARB (2010c). The SIs included under the social dimension measure human capital, except for the SIs; percentage of all merger and acquisition (M&A) transactions; the human settlement SIs; and the global community SIs. The percentage of all merger and acquisition (M&A) transactions and the global community SIs measure social capital. The human settlement SIs measure built capital in the context of household production but social capital in the context of consumer goods.

The environmental dimension was introduced into the model using the El Serafy gold income resource rent, platinum group of metals income resource rent and coal income resource compiled using Stats SA Environmental Economic Accounts data compiled according to the UN 2003 SEEA (Stats SA, 2010g). The aquatic biodiversity capital was introduced into the model using total fishery stock harvest rate compiled using Stats SA (2010b). Environmental Economic Accounts data were compiled according to the UN 2003 SEEA. The climate change indicator was introduced using an average rainfall index for South Africa compiled using Department of Water Affairs (DWA) meteorological data (SA Department of Water Affairs and Forestry, 2000).

The aquatic ecosystems change effect was introduced into the model using DWA flow data for water properties: PH (dissolved measured in water (units of PH)); PH cal content (PH at saturation with respect to $CaCO_3$, dissolved measured in water (none)); F content (flouride, dissolved measured in water (milligram per litre)); DMS content (dissolved major salts, total-water measured in water (milligram per litre)); Nitrates (NO_3^+, NO_2, N) (nitrate $^+$ nitrite nitrogen, dissolved measured in water (milligram per litre)); NH_4 content (ammonium nitrogen, dissolved measured in water (milligram per litre)); Na content (sodium, dissolved measured in water (milligram per litre)); Mg content (magnesium, dissolved measured in water (milligram per litre)); SO_4 content (sulphate, dissolved measured in water (milligram per litre)); Cl content(chloride, dissolved measured in water (milligram per litre)); K content (potassium, dissolved measured in water (milligram per litre)); Ca content (calcium, dissolved measured in water (milligram per litre)); electric conductivity (electrical conductivity, physical measurements measured in water)); and SAR content (sodium absorption ratio, dissolved measured in water) (SA Department of Water Affairs and Forestry, 2000).

The air pollution effect was included in the model using 2006 Intergovernmental Panel on Climate Change (IPCC) methodology and the seasonally adjusted physical production indices for basic precious, non-ferrous metal products; machinery and equipment; basic chemicals; plastic products; wood and wood products; paper and paper products; publishing and printing; food and beverages; motor vehicles, parts and accessories and other transport equipment; textiles; leather and leather products; non-metallic mineral products; coke, petroleum products and nuclear fuel; basic iron and steel products; electricity generated; and the production of building materials from Stats SA (IPCC,2006; Stats SA, 2010a; Stats SA, 2010d; Stats SA, 2010e).

The first part of the effect of agriculture, fisheries, forestry and mining on terrestrial degradation was introduced using seasonally adjusted physical volume production indices for iron ore, chromium, copper, manganese, nickel, other metallic minerals, diamonds, building materials, other non-metallic minerals and seasonally adjusted annualised quarterly GDP for Agriculture, Fisheries and Forestry data from Stats SA (IPCC, 2006; Stats SA, 2010d; Stats SA, 2010h). The second part of the effect of agriculture, fisheries, forestry and mining on terrestrial degradation was introduced by the El Serafy resource rent indicators (UN 2003; IPCC, 2006; Stats SA, 2010g). All of the SIs in the environmental dimension measure natural capital.

The proportion below the poverty line of R388 per month was calculated from annual AMPS (R388 per month) data using methodology outlined in Van der Berg, Louw and du Toit (2009). The methodology for the AMPS aggregates was outlined in the AMPS methodology reports found on the South African Advertising Research Foundation (SAARF) website. The Gini coefficient and poverty gap were calculated from annual AMPS data for 1998-2008 using methodology outlined in Van der Berg, Louw and du Toit (2009). The percentage of total income (2008 constant prices) of the poorest 20 percent from annual APMS data used methodology outlined in Van der Berg, Louw and du Toit (2009).

The methodology for the mid-year population estimates (1998-2009) from Statistics SA is outlined in Stats SA (2010f). The BEE M&A transactions as a percentage of all M&A transactions were calculated using methodology outlined in Ernst and Young (2009). The employment to population ratio was calculated using Stats SA data in the form of the mid-year population estimates for the numerator and employment estimates for the denominator (Stats SA, 2000; Stats SA, 2003a; Stats SA, 2005; Stats SA, 2009; Stats SA, 2010f; Stats SA, 2010j; Stats SA, 2010k). The methodology for combining the numerator and denominator datasets to obtain a ratio is outlined in Kamakura and Wedel (1996) and Statistics Canada (2000).

The methodology for the calculation of the under 1 mortality rate (which is included the life expectancy at birth) under 5 mortality rate (which is included in life expectancy at birth), life expectancy at birth and total AIDS orphans, is outlined in ASSA (2005) and Stats SA (2010f). This data, as well as the assumptions and spreadsheets, were obtained from the ASSA website. The methodology for the TB incidence, TB cure rate, and immunisation coverage variable is outlined in Health Systems Trust (2010). The respective methodology for the malaria incidence and malaria death rate variables is contained in SA DoH (2008). The respective methodologies for the calculation of the matric pass rate and gender parity index (school) methodology are outlined in the SA Department of Education (DOE) publication “Education at a Glance” for 1999 to 2010, found on the Education Management Information System (EMIS) website (DOE, 2010). The methodology for the number of women members in parliament and provincial legislatures is outlined in Independent Electoral Commission (1999), Independent Electoral Commission (2001), Independent Electoral Commission (2003), Independent Electoral Commission (2004) and Independent Electoral Commission (2009).

The number of households in informal dwellings with access to portable water and electricity was calculated using methodology outlined in publications Stats SA (2000), Stats SA (2003b), Stats SA (2008a), Stats SA (2008a) and Stats SA (2010c). The respective methodologies for the calculation of the murder and burglary rates are outlined in SA Police Service (2010a) and SA Police Service (2010a) (SA Presidency, 2010). The methodology for calculating democratically elected governments in Africa is found in Adejumobi (2000), EISA (2004), CAI (2010), CAI (2011) and (IFES, 2011). The methodology for calculating the real GDP growth rate of SADC countries is found in the IMF World Economic Outlook reports (IMF, 2010c) and the methodology country sections in the Dissemination Standards Bulletin Board (DSBB) (IMF, 2010c). The methodology for the IEMP is found in Knedlik (2006) and SARB (2010c).

The methodology for calculating the seasonally adjusted quarterly GDP is outlined on the DSBB SA web page (Stats SA, 2010d; IMF, 2011). The net qualifying capital and reserves to total risk-weighted assets, return on assets, return on equity, interest margin to gross income, liquid assets to total assets, liquid assets to short-term liabilities, mortgage debt as a percentage of housing for banks and the household income gearing, household debt as a percentage of disposable income and mortgage debt as a percentage of market value of housing were calculated using methodology outlined in IMF (2006) and IMF (2010b).

The source data methodology for calculating the Open Leontief System multiplier proxies is outlined in Stats SA (2010d) for the 1997-2009 Supply-Use tables and ten Raa and Rueda-Cantuche (2007), for calculating the Open Leontief System multipliers from the Supply-Use tables. The multiplier proxies were calculated from Stats SA (Stats SA) official Supply-Use tables for 1998-2008 using Stats SA Standard Industrial Classification (SIC) (Stats SA, 1993) 1 to 9 and quarterly compensation of employment aggregates from the Stats SA publication series (Stats SA, 2010d; UN, 1993a; UN, 2003).

The proxy employment indices were further investigated using correlation over time with quarterly employment estimates in the October Household Surveys (1998,1999), Survey of Total Employment and Earnings (2000-2002), Census 2001, Survey of Employment and Earnings (2003-2004), Stats SA Labour Force Survey (2000-2007), Quarterly Employment Statistics (2005-2009), Community Survey of 2007 and the Quarterly Labour Force Survey (2008-2010) (UN, 1993b; Stats SA, 2000; Stats SA, 2003a; UN, 2003; Stats SA, 2003b; Stats SA, 2005a; Stats SA, 2008a; Stats SA, 2009; Stats SA, 2010j; Stats SA, 2010k). The methodology for bivariate time series cross-correlation analyses is outlined in Tsay (2005). The quarterly multiplier proxies measured the structural fragility in the economy.

The company liquidations and the civil cases issued for debt for enterprises and private persons variable calculation methodology is outlined in Stats SA (2010m) for cases issued for debt for enterprises and private persons aggregates and in Stats SA (2010n) for corporate company liquidations aggregates.

The methodology for calculating the gold income resource rent, Platinum Group of Metals (PGM) income resource rent and coal resource rent is outlined in Stats SA (2010g) and in UN 2003) for the calculation of the mineral resource accounts and in El Serafy (1997) for the calculation of income resource rent. The fisheries accounts for the calculation of the fisheries stock harvest rate is found in UN (2004) and Stats SA (2010b). The methodology for the collection of the rainfall data in DWA meteorological stations and water quality properties is outlined in SA Department of Water Affairs and Forestry (2000).

The methodology for calculating the seasonally adjusted volume of physical production of basic precious, non-ferrous metal products; machinery and equipment; basic chemicals; plastic products; wood and wood products; paper and paper products; publishing and printing; food and beverages; motor vehicles, parts and accessories and other transport equipment; textiles; leather and leather products; non-metallic mineral products; coke, petroleum products and nuclear fuel; basic iron and steel products was obtained from Stats SA (2010e). The methodology for calculating the seasonally adjusted volume of physical production of iron ore, chromium, copper, manganese, nickel, other metallic minerals, diamonds, and building materials was obtained from Stats SA (2010h). The methodology for calculating electricity generated for distribution in SA was obtained from Stats SA (2010a).

The data used to construct the decision theoretic framework was the SA National Treasury budgetary information for 1997 to 2010, government program performance data for the years 1997 to 2010 (SA National Treasury, 2010), SARB monetary policy statements and SARB monetary reviews (SA GCIS, 2010; SARB, 2010b; SARB, 2011; Granger and Pesaran, 2000). The methodology for the compilation of the National Treasury budgetary data is found in the SA Parliament (1996) for the years 1997 to 1999 and the SA Treasury (1999) for the years 2000 to 2010. The data and the texts facilitated the creation of a sustainable development policy monetary and fiscal strategy profile of the SA government for the period between 1997 and 2010 and its performance (as measured by government programme performance).

The non-decision theoretical framework source data will be incorporated into a statistical units' model using the UN 2003 SEEA framework (UN, 2003). The model was used to create a harmonised modeling framework to allow statistical methods to be used to create data that represent statistical outputs from the SA economy real-life processes. The representation methods used set theory to associate data types, domain values and units of measurement (or character sets) of data to statistical data (UN, 2000).

The harmonised data representation using the model will then be used to analyse model decision recommendations and all government policy decisions over the period 1997-2010. The measures of cost and gains of the decisions were used to construct a loss table for the decision theory framework (Granger and Pesaran, 1999). The cost measures of policy decisions in the loss tables used valuation methodology outlined in UN (1993), UN (2003), De Groot, d'Arge, Constanza *et al* (1998) and De Groot *et al.* (2003). The SA sustainability policy formulations within the decision theory framework used sustainability recommendations outlined in the UN (1987), UN (1993a), UN (1993b), Atkinson *et al.* (1997), Hardi and Zdan (1997), Meadows (1998), Bossel (1999), UN (2003), and Rogers, Jalal and Boyd (2008).

The source data, once processed, will facilitate two types of analyses: baseline and model-based. In the baseline analysis the scope is a quarterly level using available data at its specified frequency (i.e., this also includes auxiliary, complementary and proxy validation data at their given frequencies). The model-based analysis is performed at a quarterly level using model-based imputation and data fusion. The sensitivity and uncertainty analyses are used to determine (quantify) the robustness of the results to the assumptions in the imputation, data fusion and model creation exercise.

4.5. Fitting the model to the data

Fitting the model to the data begins with a model harmonisation procedure where the reference population is defined and aligned for all available source data sets. The reference population for the model is the SA population within the SA sovereignty. The source data defines the survey population and weighted estimates to a reference population.

4.5.1. Data harmonisation

The statistical units model as outlined in UN (1993b), UN (1999) and UN (2003) is used in the analysis. The model is expressed mathematically as containing a target population that can be denoted as a set of statistical units with a set of constant parameters and a set of random variables.

For $N \in \mathbb{N}$, sample space **S,** variable scale **V** and covariate space **Ω** the statistical units population will be depicted as (McCullagh, 2002);

$U_N(\boldsymbol{\theta}, \mathbf{X}, \mathbf{P})=\{u_1(\boldsymbol{\theta_1}, \mathbf{X_1}, \mathbf{P}) ,\ldots, u_N(\boldsymbol{\theta_N}, \mathbf{X_N}, \mathbf{P})\}$ for i=1,…, N,

where, $u_i(\boldsymbol{\theta_i}, \mathbf{X_i}, \mathbf{P})$ is the i'th population unit, $\boldsymbol{\theta_i} \in \mathbb{R}^a$ is an a*1 column parameter vector for the i'th population unit, $\mathbf{X_i} \in \mathbb{R}^b$ is a b*1 column vector of random variables for the i'th population unit, $\boldsymbol{\theta}=(\boldsymbol{\theta_1},\ldots\ldots, \boldsymbol{\theta_N})$ is a b*N matrix of parameters associated with the statistical population U_N, $\mathbf{X}=(\mathbf{X_1} ,\ldots, \mathbf{X_N})$ is an a*N matrix of statistical population variables and **P** is a probability distribution on $\mathbf{S=V^U}$ that the model associates with parameter vector $\boldsymbol{\theta_i}$ of the i'th unit. The dimension a is chosen to be equal to those of the statistical population unit with the most parameters and the dimension b is chosen to be equal to the number of random variables of the statistical population unit with the most random variables. In the statistical population units with a smaller parameter dimension the additional parameter values are set to missing. The procedure is applied analogously for the additional random variables in the statistical population units that have a smaller random variable dimension.

The source data of the model will be assumed to be generated by a collection of sample surveys on subsets of the statistical units of the population. Let $p_s \in \mathbb{N}$, for $U_{ps}(\boldsymbol{\theta}_{ps}, \mathbf{X}_{ps}, \mathbf{P})=\{u_1(\boldsymbol{\theta}_{1,ps}, \mathbf{X}_{1,ps}, \mathbf{P}), \ldots, u_{ps}(\boldsymbol{\theta}_{ps,ps}, \mathbf{X}_{ps,ps}, \mathbf{P})\} \subset U_N(\boldsymbol{\theta}, \mathbf{X}, \mathbf{P})$, denote p_s subpopulation units of the N target population units for s=1,….,q and for $q \in \mathbb{N}$, where $\boldsymbol{\theta}_{ps}=(\boldsymbol{\theta}_{1,ps},\ldots, \boldsymbol{\theta}_{ps,ps})$ and $\mathbf{X}_{ps}=(\mathbf{X}_{1,ps},\ldots, \mathbf{X}_{ps,ps})$. The sample survey operation $s_j(p_j, m_j, U_{pj}(\boldsymbol{\theta}_{pj}, \mathbf{X}_{pj}, \mathbf{P}), \Omega)$ for a given methodology m_j for j=1,….,z, for $z \in \mathbb{N}$, is assumed to be a function (or a design) that generates an observation vector $\mathbf{x}_{ji} \in \mathbf{V}$ for each population unit $u_{ji}(\boldsymbol{\theta}_{ji}, \mathbf{X}_{ji}, \mathbf{P})$ for i=1,…,p_s, where $\mathbf{x}_{ji}$ is a b*1 column vector of observations of $\mathbf{X}_{ji}$ for the given methodology m_j (associated with covariate space Ω) that generate an estimate of the a*1 parameter vector $\boldsymbol{\theta}_i$ from survey s_j. Then let $\mathbf{x}_j=(\mathbf{x}_{j1},..., \mathbf{x}_{jps})$ be a p_s*b sample survey observation matrix for sample survey j on population p_s.

In the coherence and interpretability method the inputs into the model will be the observed data from a set of surveys, $\mathbf{x}=\{s_1(p_1, m_1,U_{p1}(\boldsymbol{\theta}_{p1}, \mathbf{X}_{p1}, \mathbf{P}), \Omega),\ldots, s_z(p_s, m_z, U(\boldsymbol{\theta}_{ps}, \mathbf{X}_{ps}, \mathbf{P}), \Omega)\}$ for s=1,…,M for $M \in \mathbb{N}$, where $\mathbf{x}$ is a $(p_1+\ldots+p_s)$*b sample survey observation matrix that contains observations from each of the population units in the sample surveys. The harmonization procedure defines a set of pseudo statistical population units $Z(\boldsymbol{\theta}_f, \mathbf{X}_f, \mathbf{P})$ for f=1,…..,g, for $g \in [1,N]$, a pseudo sample survey s_h for $h=(M+1) \in \mathbb{N}$ and a pseudo-sample survey methodology m_h such that $\{Z(\boldsymbol{\theta}_f, \mathbf{X}_f, \mathbf{P})\}_{f=1}^{g} = U_g(\boldsymbol{\theta}_g, \mathbf{X}_g, \mathbf{P})=\{u_1(\boldsymbol{\theta}_{1,g}, \mathbf{X}_{1,g}, \mathbf{P}), \ldots, u_g(\boldsymbol{\theta}_{g,g}, \mathbf{X}_{g,g}, \mathbf{P})\} \subset U_N(\boldsymbol{\theta}, \mathbf{X}, \mathbf{P})$, where $\boldsymbol{\theta}_g=(\boldsymbol{\theta}_{1,g},\ldots, \boldsymbol{\theta}_{g,g})$ and $\mathbf{X}_g=(\mathbf{X}_{1,g},\ldots, \mathbf{X}_{g,g})$, for $s_h(g, m_h, U_g(\boldsymbol{\theta}_f, \mathbf{X}_f, \mathbf{P}), \Omega)=\mathbf{x}_h \in \mathbf{V}$. The pseudo population, sample survey and methodology are designed to combine, using data fusion, all the source data from the surveys that belong to the pseudo population using methodology outlined in Kamakura and Wedel (1996) and Statistics Canada (2000). The final values for the random variables in the observed vectors of the pseudo population units are chosen to be those of the sample survey and methodology that have the maximum statistical data quality. The final parameters in the vectors of the pseudo population units are all the parameters that have been defined in the sample surveys.

The pseudo survey approach was implemented iteratively for the whole population such that the pseudo population coincides with each of the sub populations in the original population, $U_N(\boldsymbol{\theta}, \mathbf{X}, \mathbf{P})$. The result of the harmonisation was that each statistical unit subpopulation had a pseudo sample survey, a pseudo methodology and its observation matrix based on data fusion for any two surveys that have the same subpopulation as their target population. The procedure generated a set of harmonised SIs for each subpopulation such that each element set contained all observations of its random variables from the source data for its statistical unit parameters. The statistical units' model was used to derive population parameter estimates for all population parameters required for the analysis, and could be calculated from the source data using data fusion. The harmonisation was repeated independently for each time value t=1,……,T (March 1998-December 2010) to generate the multivariate time series data matrix.

The source data from environmental surveys were included into the model using methodology outlined in the UN 1993 SNA manual; UN 2003 SEEA manual; De Groot *et al.* (1998); De Groot, Wilson and Boumans (2002); and De Groot *et al.* (2003) for valuing ecosystem services and incorporating their effect as a statistical units population variable and parameter values in the UN 1993 SNA statistical units model. Including the Open Leontief System multiplier proxies incorporated a fixed Statistics SA (Stats SA) Standard Industrial Classification (SIC) product aggregate production function assumption in the operation of the economy (Statistics SA, 1993; UN, 1993b). The assumption extended to the production of greenhouse gases, terrestrial ecosystem degradation, aquatic ecosystem change, renewable resource harvesting and non-renewable resource harvesting. The robustness of the model results to the data fusion and the assumption was evaluated using sensitivity and uncertainty analysis.

Before the data were processed, the Stats SA (2008b) was used to evaluate the statistical quality of each variable for all the time series values. The South African Statistical Quality Assessment Framework (SASQAF) scores were arranged into a matrix. The statistical quality of the source data was used in the analysis to derive the statistical quality of the model output.

4.5.2. Statistical quality assessment

The data were assessed for statistical quality using (Stats SA, 2008b).The framework was applied on all data and their respective institutions to be able to understand the statistical quality that can be attached to the results when decisions from the model fitting were analysed.

In Stats SA (2008b) the statistics are assessed using a collection of indicators and assessment levels. The indicators cover a variety of aspects divided into nine dimensions: prerequisites to quality, timeliness, relevance, accessibility, accuracy, coherence, methodological soundness, interpretability and integrity. These nine dimensions provide a framework that enables the data user to evaluate the statistical quality of data according to the fitness for use definition.

The assessment level grades the statistics into four levels: level four for quality statistics, level three for acceptable statistics, level two for questionable statistics and level one for poor statistics.

In the present study the data quality measures provided with the source data were complemented with a SASQAF grading. The grading results in the present study were judgmental in the sense that they focused only on the requirements of the model fitting process.

In some of the source data the assessment of the statistical quality using Stats SA (2008b) was not possible without consultation with the producing agencies. In such a case, Stats SA (2008b) was used as a framework for compiling statistical quality metadata. The source data quality reports were based on Stats SA (2008b) statistical quality indicators that could be compiled using available quality information. The scores that required consultation were considered to be outside the scope of this study.

4.5.3. Imputation

The social indicator data (excluding employment) was of an annual frequency and in some cases contained missing values. The data were converted into a quarterly frequency using deductive imputation. The deductive imputation method used is a linear trend between two observations.

The analyses of the trend of each of the social indicators showed that in most of the variables for which they will be conducted (social variables), small percentage changes are observed in the values from year to year. For example, the Gini coefficient decreased by 1.2% from 1996-2008. The deductive imputation was implemented using an imputation algorithm in the Statistical Analysis System (SAS) version 9.2.

The indicators imputed using the algorithm were the fisheries harvest rate, all indicators from the SA Presidency (2010) and the ASSA 2003 model. The employment variable used was of an annual, bi-annual and quarterly frequency. The employment was first converted into an annual frequency then converted into quarterly using a linear trend using imputation.

The water quality and meteorological data contained missing values. The water quality data had missing values that were imputed using stochastic imputation methodology outlined in (OECD, 2008b) and (Kalton and Kasprzyk, 1982). In most cases the meteorological data from a station had auxiliary data from adjacent meteorological stations and, in these cases a deductive imputation method was used.

The annual resource rent calculations for the three mineral resources were converted into quarterly aggregates by adjusting El Serafy's formula for the discount period for the mineral resource life expectancy by a=t*0.25 for each quarter (i.e., 0.25 for Q1, 0.5 for Q2, 0.75 for Q3 and 1 for Q4). The formulae are as follows (El Serafy, 1997; UN, 2003; Stats SA, 2010g):

$X = R(1 - \frac{1}{(1+r)^{n+1-t*a}})$ and $R - X = (\frac{R}{(1+r)^{n+1-t*a}})$, where R is the revenue from the extraction in any one year (Total Resource Rent), X is the estimated Income Resource, r is the interest rate, and n is the expected life expectancy of the resource.

The Open-Leontief System multipliers were converted into quarterly data by assuming that the structure of production over the year remains constant.

4.5.4. Mathematical construction of statistical indicators

Mathematical model indicators in the form of the proxy open system Leontief Multipliers were calculated from the UN 1993 SNA Input-Output Table manual. The tables were calculated using the commodity technology assumption coefficients matrix and labour multiplier coefficient, given by $\mathbf{A}=\mathbf{U}(\mathbf{V}')^{-1}$ and $\mathbf{l}=\mathbf{L}(\mathbf{V}')^{-1}$, respectively, where **L** represents an m by one row vector of employment, A is the Symmetric Input-output coefficient table, l is the n by one row vector of labour coefficients and $\mathbf{V}'$ is the transposed make matrix in the supply table (ten Raa and Jansen, 2007).

The employment multipliers are $\boldsymbol{\lambda}=\mathbf{L}(\mathbf{V}'-\mathbf{U})^{-1}$, where $\boldsymbol{\lambda}$ is an n by one row vector and U is the use matrix in the use table (ten Raa and Jansen, 2007). These were used because, in the case of SA, the nine by nine condensed SA SUTs the matrices V and U are square nine by nine matrices (number of commodities equals number of activities).

The Use and Make transactions were adjusted not to include imports (with f.o.b adjustment) and valued at basic prices. Net commodity taxes and non-deductible Value Added Tax (VAT), and trade and transport margins were initially excluded from the Use data by deducting them proportionally to the use values at purchaser's prices from the non-trade and transport industries. The trade and transport margins were then reallocated proportionally to the trade and transport industries (ten Raa and Jansen, 2007).

The Open System Leontief multipliers were, however, proxy multipliers since a quarterly compensation vector of employees was used instead of the vector, **L,** for employment. The compensation vector was compared with the South African Labour Force vector for 2001 to 2007 and the Quarterly Labour force Survey vector for 2008 Q1 to 2010 Q1 and found to have stable conversion factors, thus establishing a basis of correlation for the proxy relationship.

The average rainfall for SA used a sample of one meteorological station from each of the 19 of the 22 water management areas of SA and calculating an average quarterly rainfall figure. An average rainfall figure was obtained by aggregating the monthly rainfall figures in each station for one quarter and then averaging the aggregate across the 19 water management areas.

4.5.5. Variable scaling

The scaling of the variables involved converting the data values into simple returns using the formula (Tsay, 2005)

$$R_t = \frac{x_{t+1} - x_t}{x_t} \text{ for t=1, ..., T.}$$

The life expectancy variable at birth exhibited an exponential trend which was adjusted to stationarity by subtracting the quadratic function $0.1*t^2-0.05*t+0.1$ before calculating the simple returns.

4.5.6. Statistical indicator aggregation and centering

The disaggregated data table contained 82 variables aiming to cover the full scope of the sustainability considerations in SA from 1997 to 2010. The considerations were poverty and inequality, BEE, employment, health, security, economic growth and stability, climate change, air pollution, terrestrial degradation and the quality of aquatic ecosystems.

The statistical units' model was constructed such that structure was not expected to be receptive to small changes in the variables and was thus used for exploratory purposes in its first implementation. The modeling approach aimed to limit its function to identifying macroeconomic relationships on aggregates of the variables that would provide directions for further micro-economic model analysis. The scaled source variables were aggregated into composite indices with equal weighting on the variables using methodology in (OECD, 2008b). The limitation of this approach was the possible difficulty in interpreting the aggregates;

however, this allowed for the model to better perform its function of flagging aggregate themes that impact the macro economy.

A second consideration in selecting the equal weight aggregation methodology was to preserve the normality of the aggregates' probability distributions. The weighting system was also such that all the sustainability topics carry an equal weight after the significant sustainability macroeconomic relationships in the economy have been identified.

The proportion of the population below the R388 poverty line variable was aggregated with the poverty gap ratio, Gini coefficient and percentage of total income of the bottom 20 percent of the population variables. The aggregate aimed to measure the structure of poverty and inequality. The BEE M&A transactions as a percentage of total M&A and the population growth variables were not aggregated. The net enrolment ratio variable will be aggregated with the matric pass rate and the gender parity index (for schools) variable into an education index. The under 5 mortality rate, life expectancy at birth, immunisation coverage and TB cure rate variables will be aggregated into a health services index. The HIV prevalence of mothers attending antenatal clinics and AIDS orphans' variables will be aggregated into an epidemic index. The murder and burglary rate variables will be aggregated into a security index.

The banking sector indices, net qualifying capital and reserved to total risk-weighted assets, return on assets, return on equity, interest margin to gross income, liquid assets to total assets, liquid assets to short-term liabilities, net overdues as a percentage of net qualifying assets, and mortgage debt as a percentage of the market value of housing will be aggregated into a banking prudential index. The variables household income gearing and household debt as a percentage of disposable income will be aggregated into a household prudential index. The nine Open Leontief system multiplier proxies will be aggregated into an economic structure prudential index. The civil summonses and cases issued for debt for enterprises and private persons and the company liquidations variables will be aggregated into an economic condition prudential index.

The income resource rent El Serafy indicators for gold, PGM and coal variables will be aggregated with the seasonally adjusted physical volume indices for iron ore, copper, chromium, copper, manganese, nickel, diamonds and other metallic minerals. The mining indicators will then be aggregated with the seasonally adjusted and annualised GDP to obtain an aggregate index. The aggregate index will represent terrestrial degradation of mining, agriculture and forestry activities on terrestrial ecosystems. The income resource rents account for environmental degradation directly, while the remaining mining production sectors and the seasonally adjusted agricultural, fisheries and forestry GDP can be expected to positively correlate with terrestrial ecosystem degradation.

The seasonally adjusted volume of physical production of basic precious, non-ferrous metal products; machinery and equipment; basic chemicals; plastic products; wood and wood products; paper and paper products; publishing and printing; food and beverages; motor vehicles, parts and accessories and other transport equipment; textiles; leather and leather products; non-metallic mineral products; coke, petroleum products and nuclear fuel; basic iron and steel products and building materials will be aggregated into a air quality index because of their expected positive correlation with air pollution (IPCC 2006 guidelines).

The aggregation formula for a theme is given by (OECD, 2008b):

$$I_t = \sum_{i=1}^{n} x_{ti} \text{ ,}$$

where x_{ti} is the value of variable i in the thematic index at time t=1,…,T (1998 to 2010) and i=1,2,….,n.

After the variables were aggregated, they were then centered by subtracting their sample means in preparation for the principal components procedure.

4.5.7. Fitting a statistical factor model

The methodology for the statistical factor model fitted to multivariate time series data using principal components and the fitting of a Vector Autoregressive Integrated Moving Average Model to the factors is outlined in Tsay (2005).

For a given set of k time series for T time periods, let r_{it} be the simple return of series i at time period t. The factor model is given by

$r_{it} = \alpha_i + \beta_{i1} f_{1t} + \ldots\ldots\ldots + \beta_{im} f_{mt} + \varepsilon_{it}$, t=1,2,…..,T; i=1,….,k, where α_i is a constant representing the intercept, $\{f_{jt} | j=1,\ldots,m\}$ are m common factors, β_{ij} is the factor loading of process i on the jth factor and ε_{it} is the specific random error associated with series i.

Next, $\mathbf{f_t} = (f_{1t},\ldots,f_{mt})'$ was assumed to be an m-dimensional stationary process with $E(\mathbf{f_t}) = \mu_f$ and $Cov(\mathbf{f_t}) = \mathbf{\Sigma_f}$ is an m*m matrix. The specific factor ε_{it} was assumed to be a white noise series and uncorrelated with the common factors f_{jt} and other specific factors, such that

$E(\varepsilon_{it})=0$ for all i and t,

$Cov(f_{jt}, \varepsilon_{is})=0$ for all j, i, t and s,

$$Cov(\varepsilon_{it}, \varepsilon_{js}) = \begin{cases} \sigma_i^2, & \text{if } i = j \text{ and } t = s, \\ 0, & \text{otherwise.} \end{cases}$$

To identify the factors, principal components were used.

In principal components, $\mathbf{r}=(r_1,\ldots,r_k)'$ is assumed to be a k-dimensional random variable and Σ_r be its covariance matrix and ρ_r its correlation matrix and $\boldsymbol{\omega_i} = (\omega_{i1},\ldots,\omega_{ik})'$ to be a standardized k dimensional vector where i=1,….,k such that $\boldsymbol{\omega_i}' \boldsymbol{\omega_{i}}=1$. Then $y_i = \boldsymbol{\omega_i}'\mathbf{r} = \sum_{j=1}^{k} \omega_{ij} r_j$ is a linear combination of the random vector **r**.

Then $Var(x_i) = \boldsymbol{\omega_i}' \Sigma_r \boldsymbol{\omega_i}$, i=1,…..,k, $Cov(x_i,x_j) = \boldsymbol{\omega_i}' \Sigma_r \boldsymbol{\omega_j}$, i,j=1,…,k. Let $(\lambda_1,\mathbf{e_1}),\ldots,(\lambda_k, \mathbf{e_k})$ be the eigenvalue-eigenvector pairs of Σ_r, where $\lambda_1 \geq \ldots \geq \lambda_k \geq 0$, then the ith principal component of **r** is $y_i = \mathbf{e_i}'\mathbf{r} = \sum_{j=1}^{k} e_{ij} r_j$ for i=1,2,…,k. Also;

$Var(y_i) = \mathbf{e_i}' \Sigma_r \mathbf{e_i} = \lambda_i$, i=1,2,….,k,

$\mathrm{Cov}(y_i, y_j) = \mathbf{e_i}' \Sigma_r \mathbf{e_j} = 0, i \neq j$,

$\mathrm{Var}(r_i) = \mathrm{tr}(\Sigma_r) = \sum_{i=1}^{k} \lambda_i = \sum_{i=1}^{k} \mathrm{Var}(x_i)$ so that $\frac{\mathrm{Var}(x_i)}{\sum_{i=1}^{k} \mathrm{Var}(r_i)} = \frac{\lambda_i}{\lambda_1 + ... + \lambda_k}$.

4.5.8. Fitting a vector autoregressive moving average model

Using a formulation in Tsay (2005), $\mathbf{Z}_t' = (Z_{1t}, Z_{2t}, \ldots\ldots\ldots, Z_{mt})$ denotes an (m*1) vector of random variables, called multivariate white noise, with zero mean vector, **0**, and $\mathbf{Z}_t$ at different times are uncorrelated. The covariance matrix of $\mathbf{Z}_t$ is given by

$\Gamma(k) = \begin{cases} \Gamma_0 & k = 0 \\ 0_m & k \neq 0 \end{cases}$, where Γ_0 denotes an (m*m) symmetric positive-definite matrix and 0_m denotes an (m*m) matrix of zeros.

The model fitted was a Vector Autoregressive (VAR) model. The VAR(1) model fitted to the statistical factors, f_{jt}, (for j=1,….,m) is given by $\mathbf{X}_t = \mathbf{\Phi_1} \mathbf{X}_{t-1} + \mathbf{Z}_t$ where $\mathbf{\Phi_1}$ is a 6*6 matrix, for $\mathbf{X}_t' = (X_{1t}, X_{2t}, \ldots\ldots, X_{6t})$ and $\mathbf{Z}_t$ denotes multivariate white noise, for t=1,….,T.

4.6. Sensitivity and uncertainty analysis

The sensitivity and uncertainty analysis was used to study how model variation in the output can be apportioned to sources of variation and source data (Saltelli, Chan and Scott, 2000). The analysis facilitated an investigation of how well the model structure can generate output that can replicate components of the real-life processes. The sensitivity and uncertainty analysis allowed exploration of the general aspects of the real-life process (the probability of the observed trajectory of the fitted series) above that which can be observed from a single trajectory of the process. This included an exploration of the output statistical space, the input variable statistical space and the properties of mapping inputs to outputs.

The sensitivity and uncertainty analysis also facilitated quantifying the impact of the imputation and data fusion of the source data on the model output. The methods used to explore the model were factor screening and Monte Carlo global sensitivity and uncertainty analysis. The sensitivity and uncertainty analysis were used to implement an iterative procedure that facilitated the inclusion of SIs from the frameworks, UN 1995 DPSIR sustainable development indicators, 2000 MDG, UN 1993 SNA, SA Development Indicators of 2010 and the UN 2003 SEEA into the model.

The methods were implemented using the relation $f(\mathbf{x})=f(x_{11},\ldots,x_{it},\ldots..,x_{nT})$, where x_{it} is such that $t=1,2,\ldots..T$ and $i=1,2,\ldots.,n$. The parameterisation of the model used the direct method to sensitivity and uncertainty analysis of models outlined in Koda, Dogru and Sienfeld (1979). The parameterisation had the advantage of simplifying the analytical equations for model evaluation but the disadvantage of increasing the number of evaluations required to assess the model using sensitivity and uncertainty analysis methods. The alternative was to use the variational or the Fourier Amplitude Sensitivity test (FAST) methods outlined in Koda, Dogru and Sienfeld (1979), which are more complex. The second consideration was the property that the alternative methods for the different model parameterisations could use the same generated samples in the input variables. The methods differed only in how the results of the sensitivity and uncertainty analysis were analysed.

In factor screening, an Iterated Fractional Factorial Design (IFFD) was implemented in the second stage model fit (fitting the multivariate time series model on the principal component scores) input parameters to identify the most influential on the model output. The factor screening used the methodology outlined in Saltelli, Ardes and Homma (1995).

The global uncertainty analysis used a Monte Carlo analysis with random sampling for the input variables only. The global uncertainty analysis used methodology outlined in Helton (1993) and Saltelli, Chan and Scott (2000). The method was chosen because of the large number of input factors in the model and the complex nature of the model structure.

The limitation of the sensitivity and uncertainty analysis in the study is that it does not consider all input factors (variables and parameters) of the model in a single sensitivity and uncertainty analysis method. The results of the analysis are, however, useful in providing insights into the considerations involved in analysing the model using sensitivity and uncertainty analysis. The insights involve identifying techniques for conducting sensitivity and uncertainty analyses for a large number of input variables and an output variable with a dimension greater than 1.

4.7. Decision Theory

The model output (forecasts) used in measuring South Africa's progress toward sustainable development was evaluated by comparing model output to observed data using a decision theory framework. Included were the data from the variables that had high factor loadings in the principal components for quarters in 2008 and 2009 used as a validation dataset for the model.

Decision theory requires a payoff matrix and a contingency realisations matrix and forecasts or actions (Granger and Pesaran, 1999). In model decision theory, for time t=1,…,T, $U_{bn}(t)$ was defined to be the utility when a bad event occurs and the model prediction is no for taking an action; $U_{gn}(t)$ is when a good event occurs and the model prediction is no for an action; $U_{gy}(t)$ is when a good event occurs and the model prediction is yes for the action; $U_{gn}(t)$ is when a good event occurs and the model prediction is no for the action; for event type (good, bad) and model prediction(yes, no), respectively.

The decision theory analysis is conducted for the evolution of each variable and interpreted holistically in the context of the evolution of all the variables. The definition of the utility entries in the payoff matrix used methodology outlined in Berger (1985) and Parmigiani, and Inoue (2009).

In the contingency realisations matrix the matrix entries are defined as follows; $T_{bn}(t)$ is defined to be the number of times during the study period a bad event occurs and the model prediction is no for taking an action; $T_{gn}(t)$ is the number of times a good event occurs during the study period and the model prediction is no for an action; $T_{gy}(t)$ is the number of times a good event occurs and the model prediction is yes for the action; $T_{gn}(t)$ is the number of times a good event occurs and the model prediction is no for the action; for event type (good, bad) and model prediction(yes, no), respectively.

4.7.1 Payoff and contingency realisations and forecasts/actions matrices

States

Decisions

	Bad (s_t=1)	**Good (s_t=0)**
Yes (d_t=1)	$U_{by}(t)$	$U_{gy}(t)$
No (d_t=0)	$U_{bn}(t)$	$U_{gn}(t)$

Table 2: Payoff matrix

The assumptions for the derivation of the total utility cells of the payoff matrix shown in Table 2 are included in Appendix one. They are based on utility formulations of the evolutions in the underlying variables of the principal components and the costs associated with a 1% movement in the variables toward an adverse direction. For example, the impact or cost in GDP terms of a decrease in the national life expectancy of SAs of 1% is the GDP per capita for the whole population for the years lost.

Realisations

Forecasts/Actions

	Bad (z_t=1)	**Good (z_t=0)**
Yes ($\hat{\pi} \rangle q_t$)	T_{by}	T_{gy}
No ($\hat{\pi} \leq q_t$)	T_{bn}	T_{gn}

Table 3: Contingency matrix for forecasts/actions and realisations

The realisations matrix uses the observed data of the variables that had high factor loadings for the principal components over the period 1 January 2008 to 31 December 2009.

4.7.2 The forecast probability

The forecast density of predictions, π, using a white noise normal density is given by

$$\pi = \int_{-\infty}^{u} f(\overrightarrow{x_i})\,d\overrightarrow{x_i}$$

where $\overrightarrow{x_i}$ is the error term for the ith variable and u is a realisation of the process. The forecast probability of the errors was derived using methodology outlined in Pesaran, Lee and Shi (2001). The method is outlined in Appendix two.

4.7.3. Measures of forecast accuracy

The $\mathbf{z}_t = (z_{1t},..., z_{6t})$'s, t=1,...,T, are realisations of the multidimensional process (the economy) at time t. The z_{it}'s, i=1,..., 6, were obtained for the variables for the period Q1 2008 and Q4 2009. The following measures of forecasting accuracy were used in the decision theoretic evaluation: Brier score, economic value of decisions, Kuipers score, Mean Absolute error, mean absolute percentage error, median absolute percentage error and root mean square percentage error (Granger and Pesaran, 1999; Hyndmann and Koehler, 2006).

4.7.3.1. Brier score

$B=\frac{1}{T}\sum_{t=1}^{T}(z_t - \hat{\pi}_t)^2$, t=1,..., T.

4.7.3.2. Economic value of decisions

$\nu_t(\hat{\pi}_t) = a_t + b_t(z_t - q_t)I(\hat{\pi}_t - q_t)$, where $c_t = \frac{U_{gn}(t) - U_{gy}(t)}{U_{by}(t) - U_{bn}(t)}$ ›0, for all t=1,...,T,

$q_t = \frac{c_t}{1+c_t}$, $a_t = z_t U_{bn}(t) + (1-z_t) U_{gn}(t)$ and $b_t = U_{by}(t) - U_{bn}(t) + U_{gn}(t) - U_{gy}(t) > 0$ and

$\mathbf{a}_t = \frac{1}{T}\sum_{t=1}^{T} a_t$. In the formulation $\mathbf{a}_t$ is normalised to 0 in the calculation of the economic value of decisions from the model over the period 1 January 2008 to December 2009 (Granger and Pesaran, 1999).

4.7.3.3. Kuiper score

KS=H(**q**)-F(**q**), where H(**q**)= $\frac{T_{by}}{T_{by}+T_{bn}}$ and F(**q**)= $\frac{T_{gy}}{T_{gy}+T_{gn}}$, where T_{bn} is the number of times when a bad event occurs and the model prediction is no, $T_{gn}(t)$ is good and no, $T_{gy}(t)$ is good and yes, $T_{gn}(t)$ is good and no, for event type (good, bad) and model prediction(yes, no), respectively.

4.7.3.4. Mean Absolute Error

Mean Absolute Error (MAE) $= \frac{1}{n}\sum_{i=1}^{n}\left|F_t - Y_t\right|$ where F_t is the forecasted value and Y_t is the true value, for t=1,..., T.

4.7.3.5. Mean Percentage Error

Mean Percentage Error (MPE) $= \frac{1}{n}\sum_{t=1}^{n}\left(\frac{Y_t - F_t}{Y_t}\right) * 100$ where F_t is the forecasted value and Y_t is the true value, for t=1,..., T.

4.7.3.6. Mean Absolute Percentage Error

Mean Absolute Percentage Error (MAPE) = $\frac{1}{n}\sum_{t=1}^{n}\left|\frac{Y_t - F_t}{Y_t}\right|$ where Y_t is the actual value and F_t

is the forecast value, for t=1,..., T.

4.7.3.7. Median Absolute Percentage Error

Median Absolute Percentage Error (MedAPE) = $Median\left|\frac{Y_t - F_t}{Y_t}\right|$ where Y_t is the actual value and F_t is the forecast value, for t=1,..., T.

4.8. Conclusions

The overview of the modeling methodology outlined the key aims of the modeling process. The methodology of the modeling process involved: identifying the source data; reviewing the methodology used in the compilation of the source data; fitting the model to a harmonised dataset; conducting a sensitivity and uncertainty analysis on the fitted model; and a decision theory analysis on the model output.

5. Fitting the statistical units model to measure sustainable development

5.1. Introduction

The chapter analyses the results from the model fitting exercise. The results from the statistical quality assessment of the source data are analysed in section 5.2., the fit of the statistical factor model in 5.3. the vector autoregressive model fit section 5.4., the decision theory in 5.5, the sensitivity and uncertainty analysis in section 5.5., the model forecasts to quarter 4 of the year 2015 in section 5.7., and gives conclusions in section 5.8.

5.2. Statistical quality assessment of the aggregates

The input data were assessed for statistical quality. The framework that was used for compiling the statistical quality metadata was Stats SA (2008b). The SARB, Stats SA GDP data and National Treasury data were scored using information from IMF (2001), IMF (2008), IMF (2009), IMF (2010b), IMF (2011) and judgmental methods. The DWA data quality assessment used the DWA internal raw data assessment which is disseminated with all from DWA hydrology information system.

The data from the South African Reserve Bank yielded a judgmental score of 118 out of 120 based on IMF (2010b); from Water Affairs (DWA), a judgmental score of 108 out of 108; from the National Treasury, a judgmental score of 120 out of 120; and from Statistics South Africa GDP score of 120 out of 120. The reason the indicator totals from the various departments have different totals is because of the indicators and standards in the Stats SA (2008b) which are not applicable for the scoring of the data from the specific department. The SARB, National Treasury and Stats SA GDP data are part of the IMF SDDS and have thus benefited from SDDS recommendations since 1997.

An uncertainty analysis and sensitivity analysis on the ASSA 2002 which is relevant for the output and statistical quality of the ASSA 2003 can found in Johnson, Dorrington, Bradshaw and Daniel (2006). The methodology for the ASSA 2003 data is documented in ASSA (2005) and the data is referenced in local and international texts like Kaiser Foundation (2007) and Nattras (2006). The ASSA 2003 estimates are compared with the HIV/AIDS and demographic estimates in Stats SA (2008a) and Stats SA (2010f). A comparison is also made with the HSRC 2005 household HIV prevalence and behaviour survey in ASSA (2006). The source data of the ASSA (2003) was also assessed using Stats SA (2008b) as part of compiling a statistical quality report of the ASSA 2003 data.

The DWA data benefits from a 3 dimensional (3-D) hydrological model and database, which are disseminated to the public through the internet. The data from DWA contains measures of quality, specifying the percentage missing values in each time series of observations as well as flagging incomplete or problematic observations. The measures were included in the judgmental Stats SA (2008b) quality measures for the DWA data.

In the scoring of the South African 2010 QLFS for quarter one and GHS for year 2009 data, a cut-off of 10% for non-sampling errors as the standard requirement for official statistics (United States Office for Management and Budget, 2006) was used. The assessment of the 2009 General Household Survey showed that the survey is of good overall statistical quality, satisfying more than 83 % of the statistical quality requirements in each dimension. The statistical quality assessment of the 2010 quarter one Quarterly Labour Force Survey showed that overall the survey was of good statistical quality, scoring more than 84% for all dimensions.

For the remainder of the source data an overall Stats SA (2008b) score could not be obtained as the accuracy dimension could not be scored completely without further consultation with the data producers. In this case the proxy accuracy measures disseminated with the source data were used. The source data satisfied the remainder of the dimensions with a judgemental score of more than 3.5 (out of 4) for each SI. The statistical quality metadata compiled for each of the source data with a brief description of the statistical quality information is contained in Appendix four.

In the Appendix four statistical quality metadata, with the exception of the Stats SA GDP, Open Leontief System multipliers, SARB Basel II data and DWA source data, SASQAF indicates that the source data was assessed using Stats SA (2008b) dimensions excluding accuracy (and an average score of 3.5 out 4 was obtained for each dimension).

5.3. Statistical factor model identification using principal component analysis

The eigenvalue plot in Figure 1 shows that the proportion of the variance explained by the first principal component is 15.72% while the cumulative of the first seven principal components is 69.55%. The principal components fit yielded the pattern profile given in Figure 2 below.

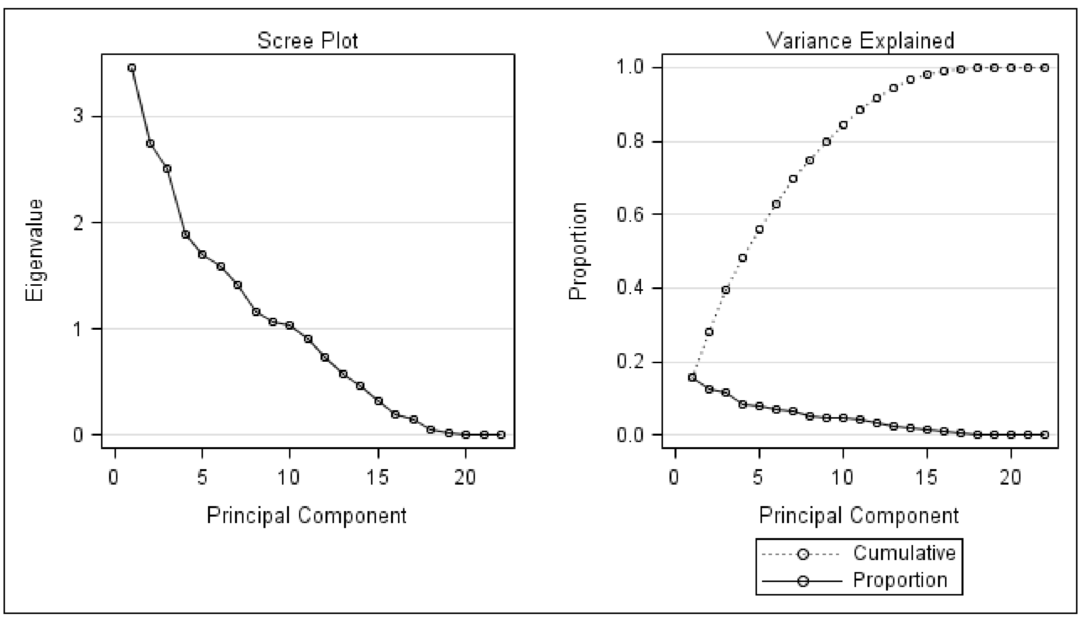

Figure 1: Eigenvalue plot

The cut-off for variables that had high loadings in the principal component was 30%. In the case of a resource like water, which can influence many physical processes simultaneously, the restriction of a single variable not being allowed to feature in more than one component was relaxed because of the large number of variables involved in the statistical factor model fitting exercise. In addition, the aim of the exercise was to reduce the dimensionality of the problem without discarding information.

Principal component 1 had a high positive factor loading for BEE transactions as a percentage of M&A transactions (0.35) and gender parity index (0.34). The first principal component had high negative factor loadings for the GDP growth in Sub-Saharan Africa (-0.32), the epidemic index (-0.40) and the structure of poverty index (-0.37). Principal component 2 had high positive factor loadings for the employment to population ratio (0.31), health index (0.4) and the epidemic index (0.35). Principal component 2 had a high negative factor loading for GDP growth in Sub-Saharan Africa (-0.35).

Principal component 3 had high negative factor loadings for the household prudential index (-0.43), employment to population ratio (-0.31)and the economic structure prudential index (-0.41). Principal component 3 had a high positive factor loading for the education index (0.36). Principal component 4 had high positive factor loadings for the household prudential index (0.48), economic structure prudential index (0.49) and the education index (0.32). Principal component 4 had a high negative factor loading for life expectancy at birth (-0.33).

Principal component 5 had a high positive factor loading for the aquatic ecosystems index (0.39). Principal component 5 had high negative factor loadings for the household index (-0.44) and the health index (-0.37). Principal component 6 had high positive factor loadings for the banking prudential (0.39), the rainfall (0.35), the IEMP (0.31) and the air quality (0.38) indices. Principal component 7 had high positive factor loadings for the aquatic ecosystems (0.45), terrestrial degradation (0.30), economic conditions (0.345) and security (0.52) indices. Principal component 7 had a high negative factor loading for the IEMP (-0.35). The principal component factor loadings are included in Appendix five.

The schematic of the principal component profiles of the principal components is shown in Figure 1. The scatterplot of the first two principal components principal components is shown in Figure 3. The scatterplot shows that the first two principal components explain roughly the same amount of variation in the data, namely, 15.72% and 12.49%, respectively.

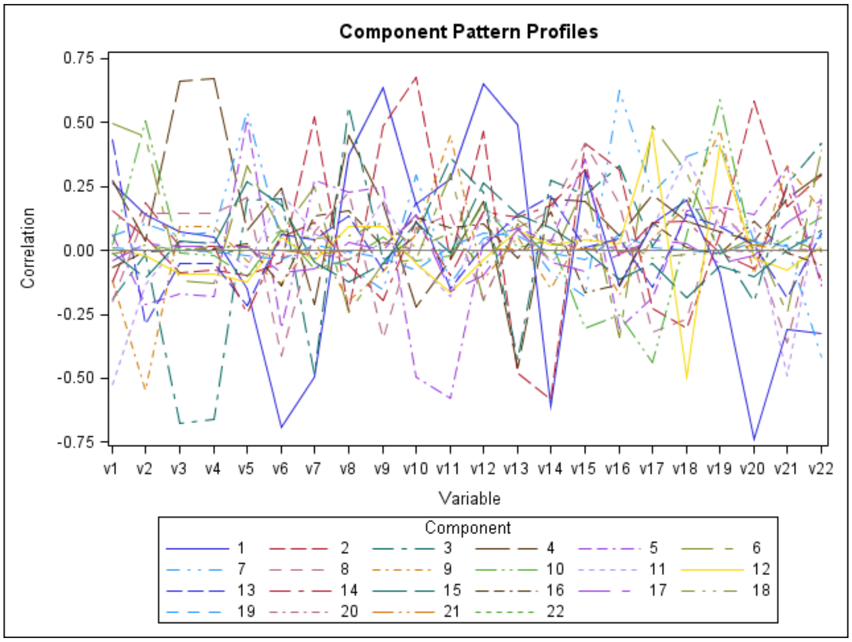

Figure 2: Component profile plot

The scatterplot of the first two principal components, shown in Figure 3, shows that the first two principal components explain roughly the same amount of variation in the data, namely, 15.72% and 12.49%, respectively.

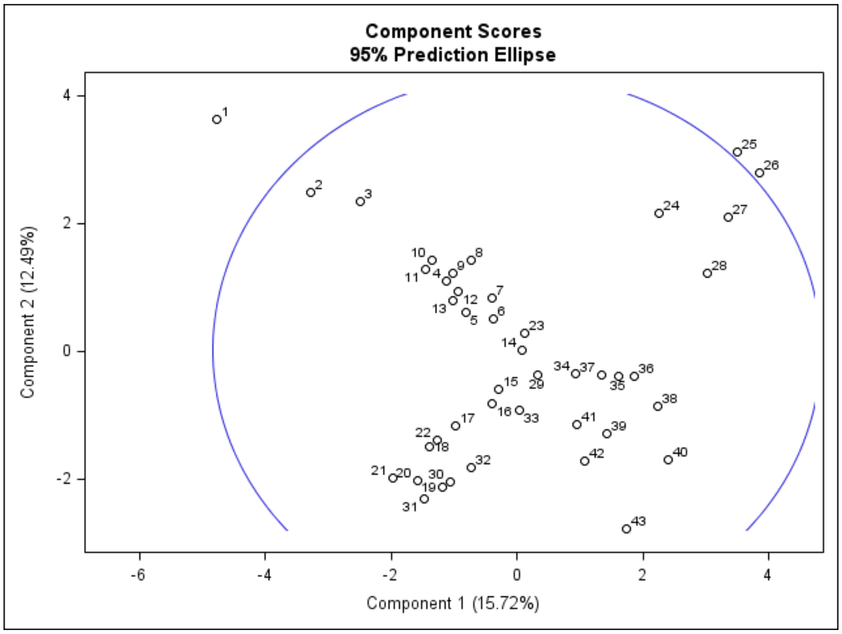

Figure 3: Scatterplot of the component scores for the first two principal components

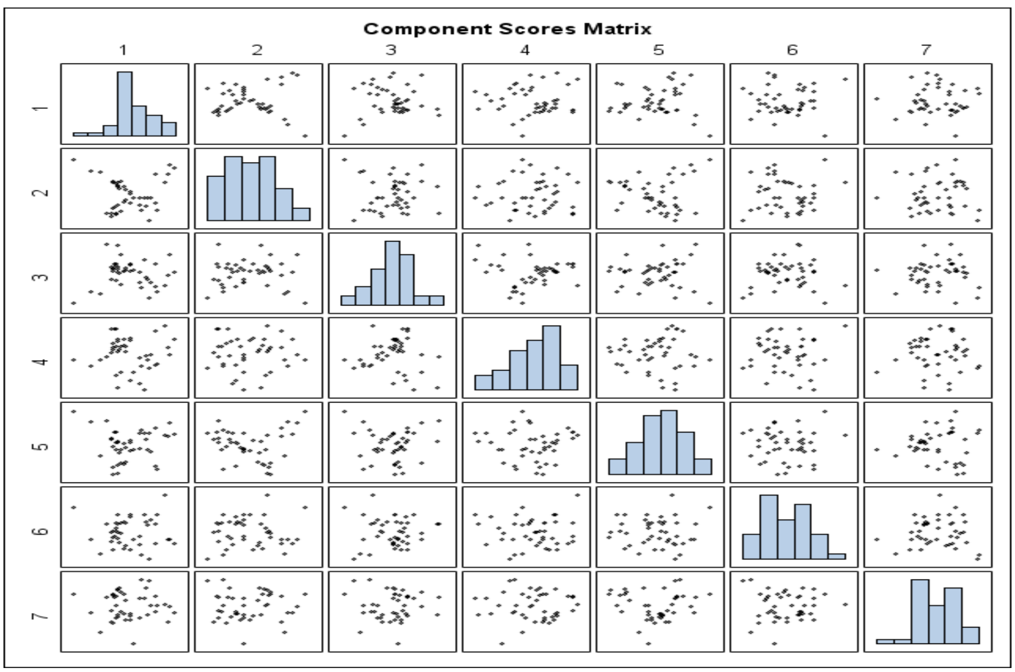

Figure 4: Matrix plot of the component scores of the first seven principal components

The scatterplot matrix in Figure 4 indicates that the principal component scores of the first principal component are skewed to the left and those of the second appear bimodal and skewed slightly to the right. The principal component scores of the third and sixth are skewed to the right. The principal component scores of the fourth, fifth and seventh principal components are skewed to the right.

5.4. Vector autoregressive model fit

The first seven principal components were fitted to a VAR(1) model with the log return of the seasonally adjusted annualised GDP. Principal component 4 and 5 were aggregated into a single component, and principal component 6 and 7 were aggregated into a single component. The aggregation was such that the aggregated components explained a similar amount of variation as principal component 3. Principal component 3 explained 11.38% of the variation in the data, the principal component 4 and 5 aggregate explained 16.31%, and the principal component 6 and 7 aggregate explained 13.65%.

The model re-parameterisation is such that: index 1 corresponds to principal component 1; index 2 to principal component 2; index 3 to principal component 3; index 4 the aggregate of principal component 4 and 5; index 5 to the aggregate of principal component 6 and 7; and index 6 to the percentage change in the annualised seasonally adjusted GDP growth.

The purpose of the model was to facilitate a holistic approach to understanding the sustainable development indicators in the context of the SA economy. The model thus facilitated linking the frameworks to the GDP in a structured model.

The model parameters are given by

$$X_t = \begin{pmatrix} 0.795168 & 0.0099144 & 0.091618 & 0.04698 & -0.08283 & 15.09876 \\ -0.02103 & 0.85442 & 0.1201016 & 0.053547 & 0.038464 & -18.11329 \\ -0.088789 & 0.0082279 & 0.3674236 & 0.135064 & -0.00500383 & -1.1355733 \\ 0.0081309 & -0.1184547 & 0.4067200 & 0.5535959 & -0.3991179 & -3.59173 \\ 0.0847153 & -0.12739 & 0.09183 & -0.39088 & -0.03464 & -7.749856 \\ 0.0003287527 & -6.8*10^{-6} & 0.0000928 & -0.000123 & -0.0006165 & 0.9598954 \end{pmatrix} X_{t-1} + Z_t$$

for t=1 to 44.

The Information Criteria diagnostic measures of the model were -10.3471 for the Corrected Akaike Information Criterion, -10.08369 for the Hannan-Quinn Criterion, -10.6328 for the

Akaike Information Criterion, -9.1335 for the Schwarz Criterion and 0.000024 for the Final Prediction Error Criterion.

The significant parameters at the 5% level of significance in the AR(1) matrix were 0.795168, the (1,1)th matrix entry; 0.85442, the (2,2)th matrix entry; 0.3674236, the (3,3) th matrix entry; 0.40672, the (4,3)th matrix entry, 0.5535959, the (4.4)th matrix entry; 0.128222, the (5,4) th matrix entry and 0.9598954, the (6,6)th matrix entry.

The univariate ANOVA diagnostics showed significant F statistics at the 1% level except for principal component 3 (p-value of 0.1939) and index 5 (p-value of 0.0841). The R^2 's were 0.79 for index 1, 0.82 for index 2, 0.18 for index 3, 0.59 for index 4, 0.23 for index 5 and 0.5 for index 6.

The univariate Jarque-Bera tests for normality show that index 6 deviates from normality at the 5% level but not at the 1% level with a p-value of 0.036. The remainder of the indices are not significantly different from normality at the univariate level when using the Jarque_Bera test. The ARCH (1) disturbances are only significant for index 2 with a p-value of 0.0092. The AR(1), AR(2), AR(3) and AR(4) tests for disturbances are significant for index 1 and index 2. The Portmantau tests for cross-correlation between residuals are significant at the 5% level, up to lag 12 The tests indicate that the model residuals have some correlation and heteroscedasticity.

The model diagnostic texts indicate some limitations in the applicability of the model results to the data.

5.5. Decision theory

States

Decisions

	Bad (s_t=1)	Good (s_t=0)
Yes (d_t=1)	127 195 265 408.58	-418 941 687.50
No (d_t=0)	-254 390 530 817.15	44 099 125.00

Table 4: Estimated Payoff matrix

The payoff matrix satisfies the requirement that the utility of acting to mitigate a bad event as forecasted by the model leads to a higher utility than the model predicting no action when an adverse event is observed. Also the utility of a model forecast for action when a good event occurs is lower than not acting when a good event occurs.

Realisations

		Bad (z_t=1)	Good (z_t=0)
Forecasts/Actions	**Yes ($\hat{\pi}\rangle q_t$)**	0	0
	No ($\hat{\pi} \leq q_t$)	1	7

Table 5: Estimated Contingency and forecasts/actions matrix

There was one adverse event in the period which corresponded to the true value of index five dropping below 3.5. The model prediction for index five was 0.213511607, which was very far from the threshold of 3.5. Index five corresponded to the banking prudential index, rainfall, air quality, IEMP, water quality, security, terrestrial and economic conditions indices which are very important sustainability indices because of their link to the three types of capital, social, economic and environmental capitals. The rainfall index is an exogenous variable as it cannot be usually controlled directly through fiscal and monetary policy. A possible explanation is the large unexpected change in economic conditions over the period because of the global economic crisis. In the remainder of the periods the model forecasts suggested no mitigation and no bad event occurred.

The forecasts for the six indices are given in Table 6. Index one and index four cross the origin (i.e. change from negative to positive or from positive to negative), which indicates a possible reversal in the underlying variables of the index. The analysis of the model forecasts needs to be accompanied by model probability forecasts of a bad event, the government fiscal and monetary stance, and government programme performance. The probability forecasts are shown in Table 8 below. The evolution of the economy in the face of government fiscal and monetary stance are summarised by the economic evolution of the variables in Table 7, the realised values of the six indices. The realisations also act as indicators of performance of government programs.

Date	Index One	Index Two	Index Three	Index Four	Index Five	Quarterly seasonally adjusted annualised GDP
31-Mar-08	1.04651	-3.06186	-1.35025	-0.99106	0.21351	1.04651
30-Jun-08	0.54967	-3.09595	-0.76487	-0.86561	0.62741	0.54967
30-Sep-08	0.17154	-3.01580	-0.49072	-0.72035	0.58256	0.17154
31-Dec-08	-0.09597	-2.88785	-0.33512	-0.51980	0.51563	-0.09597
31-Mar-09	-0.27815	-2.73240	-0.22487	-0.33293	0.42072	-0.27815
30-Jun-09	-0.39266	-2.56200	-0.14030	-0.16352	0.33191	-0.39266
30-Sep-09	-0.45531	-2.38433	-0.07347	-0.01801	0.25105	-0.45531
31-Dec-09	-0.47889	-2.20524	-0.02100	0.10327	0.18084	-0.47889

Table 6: Model forecasts for the six variables

Date	Index One	Index Two	Index Three	Index Four	Index Five	Quarterly seasonally adjusted annualised GDP
31-Mar-08	-0.09077	-0.16315	0.063999	-0.224890022	3.186113794	-0.09077
30-Jun-08	0.050606	0.298324	-0.245	0.221030784	0.361910311	0.050606
30-Sep-08	0.072976	0.248112	-0.18159	0.172182767	-0.254236788	0.072976
31-Dec-08	0.055885	0.108453	-0.25597	0.236993025	-0.392276221	0.055885
31-Mar-09	-0.03272	-0.02898	0.309879	-0.356001858	0.879089613	-0.03272
30-Sep-09	0.177973	0.052493	-0.07108	0.123549871	0.207737628	0.177973
1-Jul-09	0.189048	0.065285	-0.11467	0.176484973	0.193682691	0.189048
31-Dec-09	0.233396	0.000216	-0.19383	0.279545866	0.152237121	0.233396

Table 7: Realised values for the six variables

The forecast probability estimates boot-strap simulations of the bad event are shown in Table 8 below. The usefulness of the probability forecasts depend on how the evolution of the economy in the context of the bad event can add information about SA progress toward sustainable development. In this study the bad event was $\mathbf{a}_l$ = (-0.2, -4.6, -1.5, -2.5, -1.5, -0.05) for the following functions on the variable forecast (z_{1T+h}, z_{2T+h}, $-z_{3T+h}$, z_{4T+h},$-z_{5T+h}$, z_{6T+h}).

Date	P(Bad)	P(Good)
31-Mar-08	0.361179361	0.638820639
30-Jun-08	0.447174447	0.552825553
30-Sep-08	0.4004914	0.5995086
31-Dec-08	0.398034398	0.601965602
31-Mar-09	0.353808354	0.646191646
30-Sep-09	0.398034398	0.601965602
1-Jul-09	0.393120393	0.606879607
31-Dec-09	0.353808354	0.646191646

Table 8: Forecast probabilities associated with each forecast

MAE(z1)	MAE(z2)	MAE(z3)	MAE(z4)	MAE(z5)	MAE(z6)
0.50743	2.81577	0.39255	0.52288	0.98887	0.02823
ME(z1)	**ME(z2)**	**ME(z3)**	**ME(z4)**	**ME(z5)**	**ME(z6)**
-0.07371	-2.81577	-0.33904	-0.51711	-0.22626	-0.00813
MPE(z1)	**MPE(z2)**	**MPE(z3)**	**MPE(z4)**	**MPE(z5)**	**MPE(z6)**
77.48823	128249.87098	249.58708	175.09104	30.61934	76.61378
MAPE(z1)	**MAPE(z2)**	**MAPE(z3)**	**MAPE(z4)**	**MAPE(z5)**	**MAPE(z6)**
545.35057	131026.12598	377.27453	260.26245	115.23816	238.27341
MedAPE(z1)	**MedAPE(z2)**	**MedAPE(z3)**	**MedAPE(z4)**	**MedAPE(z5)**	**MedAPE(z6)**
3.30735	32.57474	1.33820	2.75841	0.92799	2.02668
RMSE(z1)	**RMSE(z2)**	**RMSE(z3)**	**RMSE(z4)**	**RMSE(z5)**	**RMSE(z6)**
6.62334	3617.64084	7.91092	3.15948	1.35605	3.31015

Table 9: Measures of forecast accuracy for the variables

The statistical forecast measures show the model forecasts for index 2 were particularly poor. In the model index 2 corresponded to the employment to population ratio, health index, GDP growth in Sub-Saharan Africa and the epidemic index. The poor forecasts can be partially explained by the exogenous nature of the Sub-Saharan Africa percentage GDP growth variable. The poor performance is a problem because the epidemic, employment and health variables are particularly important social capital variables for making decisions about sustainable development. The approach used in the model to mitigate this problem was to make use of available data on these variables over the model validation period, quarter 1 2008 to quarter 4 2009, to make sustainable development decisions in conjunction with the model forecasts.

The Brier Score for the model is 0.22282507 and the Kuiper Score is 0. The economic value of forecasts was calculated for an artificial utility and loss function formulation of the SA economy. The utility values are based on the gain in the variables that have high factor loadings in the principal components. The utility associated with an improvement in each of the variables is specified in GDP equivalent terms. For example, terrestrial degradation utility was calculated using the relationship of the SA terrestrial ecosystem to tourism and the tourism contribution to GDP of 0.093. The economic value of forecasts is R 29 738 818 543 when valuing utility in GDP equivalent terms (i.e. 2000 constant prices) after **a** is normalized to 0.

5.6. Sensitivity and uncertainty analysis

The principal component plot in Figure 5 shows the scores of the simulated output variable values in the Monte Carlo analysis in principal component space. The results are for 101 simulations of the input vector for an uncorrelated normal distribution with standard deviations equal to those of the observed data.

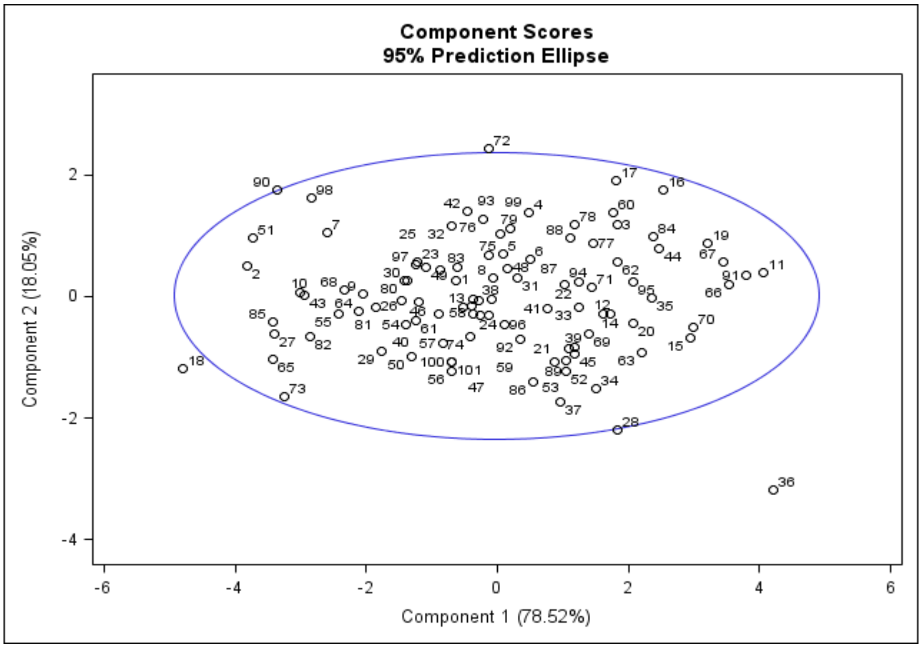

Figure 5: Plot of the output variable for the Monte Carlo uncertainty analysis

The global uncertainty results yielded the following estimated mean vector and variance covariance matrix of the output:

$$\hat{y} = (0.030263828, 0.06786961, 0.026905488, -0.191410876, -0.061345543, 0.005493866)$$

and

$$\hat{\Sigma} = \begin{pmatrix} 2.155527 & -1.46397 & -0.05576 & -0.01066 & -0.67051 & 0.081061 \\ -1.46397 & 2.542065 & 0.187575 & 0.398781 & 0.561071 & -0.09591 \\ -0.05576 & 0.187575 & 0.185398 & 0.364115 & -0.05117 & -1.00584 \\ -0.01066 & 0.398781 & 0.364115 & 1.481313 & -0.29643 & -0.03995 \\ -0.67051 & 0.561071 & -0.05117 & -0.29643 & 0.77126 & -0.03995 \\ 0.081061 & -0.09591 & -0.00584 & -0.02059 & -0.03995 & 0.005004 \end{pmatrix}.$$

A matrix of the linear effects and quadratic effects associated with each parameter in the IFFD are included in Appendix Three. The design used a Hadamard matrix of order 32 where parameters 1 to 4 share columns with parameters 33 to 36. The linear and quadratic effects of the parameters that share columns are confounded and hence, cannot be interpreted in the same manner as the other parameters.

A possibility might be to interpret their results by making assumptions. In the VAR(1) coefficient matrix the parameters are numbered across the rows: with (1,1)th entry being parameter 1; the (1,6)th entry being parameter 6; and the (2,1)th entry being parameter 7; and the proceeding sequentially to parameter 36 being the (6,6) th entry of the coefficient matrix.

The IFFD parameter linear and quadratic effects were plotted in principal component space in order visualise their characteristics. The first three principal components of the linear effects of the parameters explained 60.88% of the variance in the linear effects of the parameters. The first two principal components of the quadratic effects of the parameters explained 71.19% of the variation in the quadratic effects of the parameters. A principal component plot of principal component 1 and 2 for the linear effects is shown in Figure 6.

A principal component plot of principal component 1 and 3 for the linear effects is shown in Figure 7. A principal component plot of the first two principal components of the quadratic effects of the parameters is shown in Figure 8.

The linear effects of the parameters are bunched close to the origin of the component axes while those of the confounded parameters (parameters 1 to 4 and 33 to 36) are further away from the rest, as could be expected. The figure shows that the linear effect of parameter 32, the (6, 2) th entry of the coefficient matrix ($-6*10^{-6}$), has a large negative effect as compared to the other parameters while parameter 31, the (6, 1) th entry of the coefficient matrix (0.0003287527), has a large positive linear effect on the output.

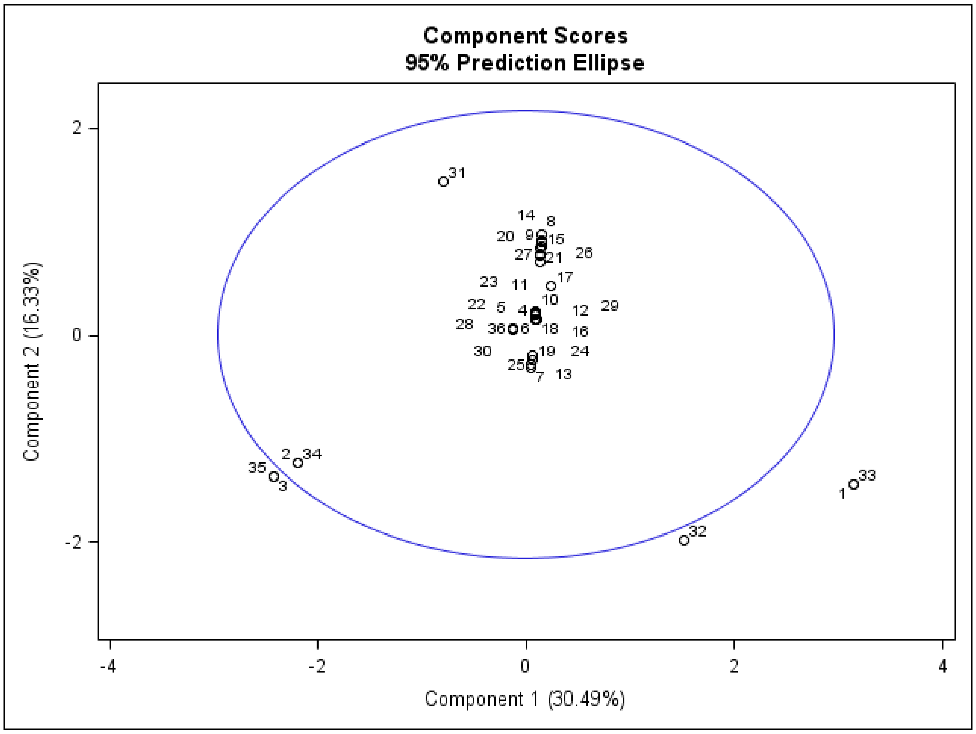

Figure 6: A principal component plot of the linear effect vectors from the IFFD on principal component 1 and 2 axes

The principal component plot on the axes of principal components 1, 2 and 3, shows that parameters 26 and 27, have a large positive effect on the output. Parameters 26 and 27 correspond to the (5, 2) th entry of (-0.12739) and (0.09183) in the VAR (1) coefficient matrix, respectively. A possible explanation of a positive linear effect from a negative parameter could be because each coefficient influences the output as part of a linear combination with other matrix coefficients.

The principal component plot on the axis of the first two principal components shows that parameter 20 and parameter 21 have a positive score on the principal component axis of principal component 2, while parameter 15 has a large positive score on the principal component axis of principal component 1. The parameters, 15, 20 and 21, correspond to entries, (3, 3), (4, 2) and (4, 3), with values, 0.3674236, -0.1184548, and 0.4067200 in the VAR (1) coefficient matrix, respectively.

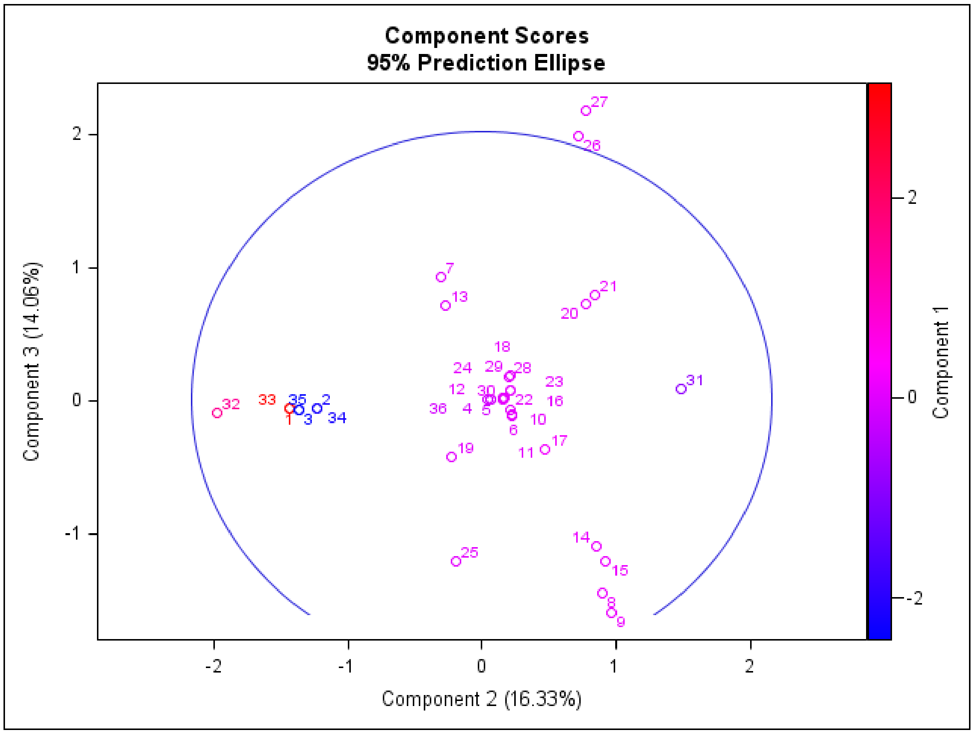

Figure 7: A principal component plot of the linear effect vectors from the IFFD on principal component 1 and 3 axes

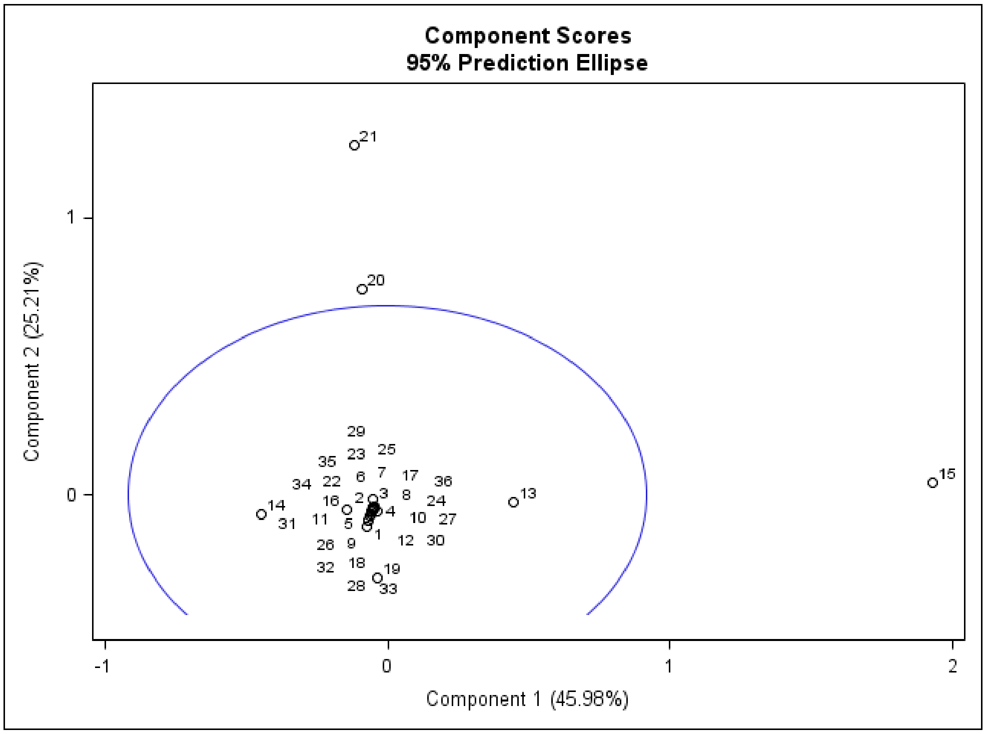

Figure 8: A principal component plot of the quadratic effect vectors from the IFFD on principal component 1 and 2 axes

5.7. Forecasts to 2015

The model forecasts were analysed to 2015 in order to provide recommendations for a government fiscal and monetary stance on issues of sustainable development. The analysis assumes that data is only available until December 2007 and hence, an accurate prediction of the conditions in December 2015 given all available data at present (i.e. until 31 December 2010) is beyond the scope of the study. The texts used to summarise the global and local economic conditions with respect to the SA government fiscal stance for the period 1997 to 2007 were SARB (2010a), SARB (2010b), SA National Treasury (2010), SA Presidency (2010) and IMF (2010a).

The model forecasts a decrease in index 1 (Figure 9) from December 2007 to a minimum of -0.47889 in 31 December 2009 and then an upward increase to 0.071341 in 31 December 2015. This corresponds to an increase in poverty, a decrease in gender equality, a decrease in the value of BEE M&A transactions, an increase in percentage change in Sub-Saharan GDP and an increase in the epidemic index up to 31 December 2009. This is reasonable in the face of the global financial crisis. The index then predicts a reversal of conditions until 31 March 2015 after which conditions will deteriorate slightly.

From a monetary and fiscal stance point of view, the important consideration in the interpretation of the forecasts is that they are based a process image of what has transpired between January 1997 and December 2007. The key issue is thus the macro-economic policies on the domestic variables that have been implemented over the period and their success until 31 December 2007. The key domestic variables are the structure of poverty, gender parity index, value of BEE M&A transactions and the HIV/AIDS epidemic.

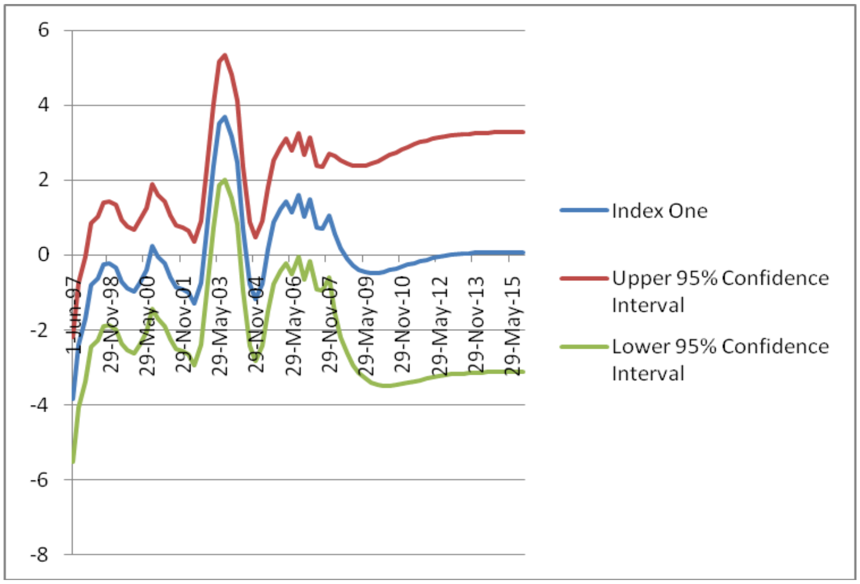

Figure 9: Index one forecasts from January 1998 December 2015

The forecasts for index 2 in Figure 10 show an increase employment to population ratio, the health index and the epidemic index and a decrease in the GDP percentage growth rate in Sub-Saharan Africa. The forecasted decrease in the percentage GDP growth rate in Sub-Saharan Africa contradicts the forecast of index 1. In the formulation of a fiscal and monetary policy strategy a more pessimistic view of the evolution of the exogenous variables might be preferred. In the present context the forecast measures of index 2 are poor as compared to those of index 1 and the actual realisations correspond to the forecasts associated with index 1. Thus a better interpretation might be that the observed effect in the index 2 forecasts can be attributed to the impact of the other variables underlying the index rather than the percentage GDP growth rate in Sub-Saharan Africa.

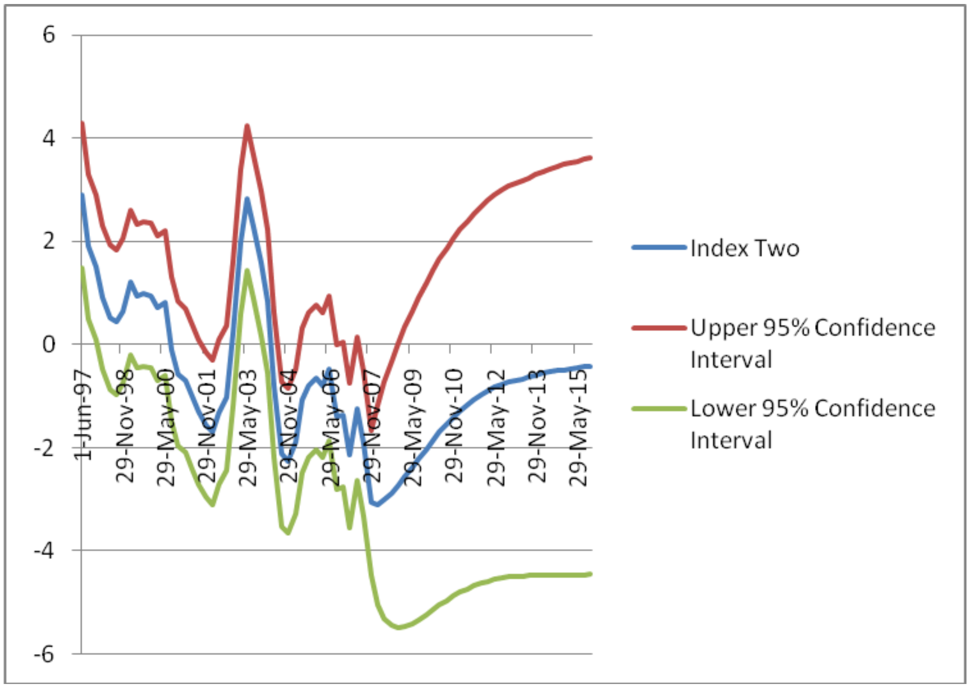

Figure 10: Index two forecasts from January 1998 December 2015

The forecasts for index 3 show an increase until 30 June 2011 followed by a smooth decrease to a value just above 0 in 31 December 2015. The index corresponds to the household prudential index, the economic structure index, the employment to population ratio and the education index, where the first three variables have negative factor loadings and the last index has a positive factor loading.

An increase in the index corresponds to a decrease in each of the underlying indices with negative factor loadings. The decrease in the household index corresponds to a decrease in access of basic services associated with housing, which is an important social capital component of sustainability. The employment to population ratio and the economic structure prudential indices are closely linked to employment, which is forecasted to decrease. The increase in the education in the face of lack of access to employment and basic housing services will create a problem in sustainability terms.

The forecast in increase in the employment to population ratio in the second index is contradictory to that which is forecasted for index 3, shown in Figure 11. A possible fiscal and monetary stance would be to assume a pessimistic view which corresponds to the forecasts for index 3 and to plan for the prudential aspects of a decrease in employment and access to basic services.

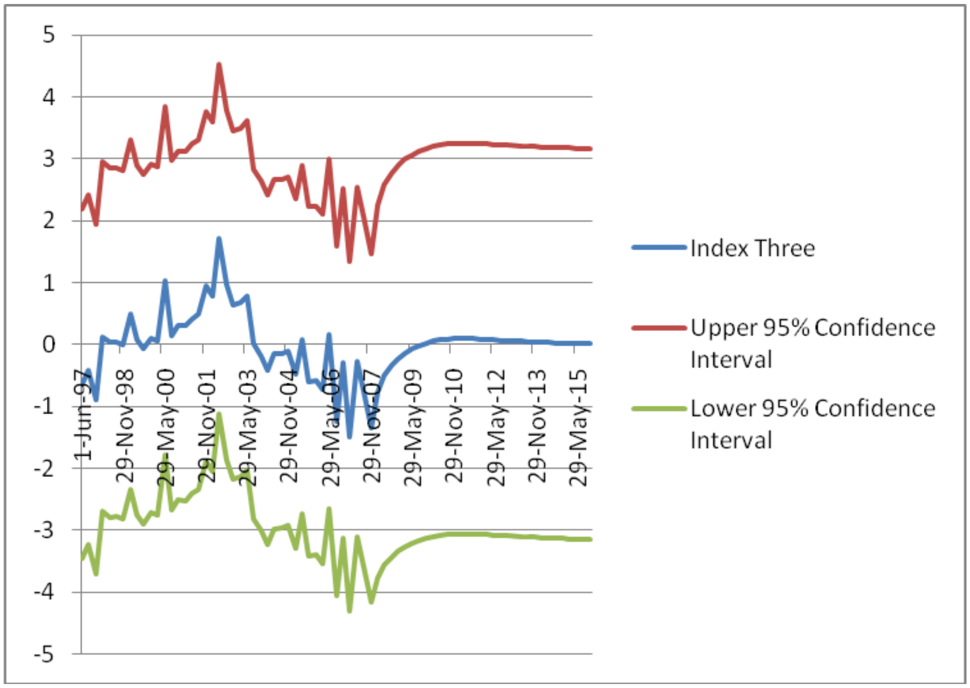

Figure 11: Index three forecasts from January 1998 December 2015

The forecasts for index 4, shown in Figure 12, indicate an initial smooth increase up to a maximum of 0.411289 in 30 September 2011 followed by a smooth decrease to 0.133165 in December 2015. The index has high factor loadings for indicators of household prudentiality, economic structure, education, life expectancy, aquatic ecosystem quality, health and household access to services. The forecast corresponds to a decrease in life expectancy, an improvement in overall mortality associated with health services, a decrease in household prudentiality, a decrease in access to education, a deterioration in aquatic ecosystems and an increase in household access to services.

The forecast is in line with the developments of the global economic crisis in 2007-2009, and the government fiscal stance over the periods. In the forecasts the adverse effects could be attributed to the global economic crisis and the advantageous impacts to the government's fiscal stance.

The reversal in 2010 can also be fitted within this framework, as the global economic crisis began to ease and the advantageous impact of the fiscal stance began to take shape.

The forecasts for index 5 are shown in Figure 13. Index 5 began with an initial increase to a figure of 0.627409 in 30 June 2008, followed by a decrease to -0.01621 in 31 December 2015. The index corresponds to banking prudentiality, rainfall, air quality, IEMP, water quality, security, economic conditions and terrestrial degradation.

The forecasts correspond to an improvement in banking prudentiality, an increase in rainfall, a deterioration in air quality, a deterioration in prudentiality associated with foreign exchange, a deterioration or change in aquatic ecosystems, a deterioration in security, a deterioration in economic conditions, and an increase in terrestrial degradation. The forecasted conditions are especially close to the developments associated with the global economic crisis. For example, a deterioration in economic conditions during times of economic crisis can be signalled or indicated by an increase in the number of company liquidations and civil cases for debt.

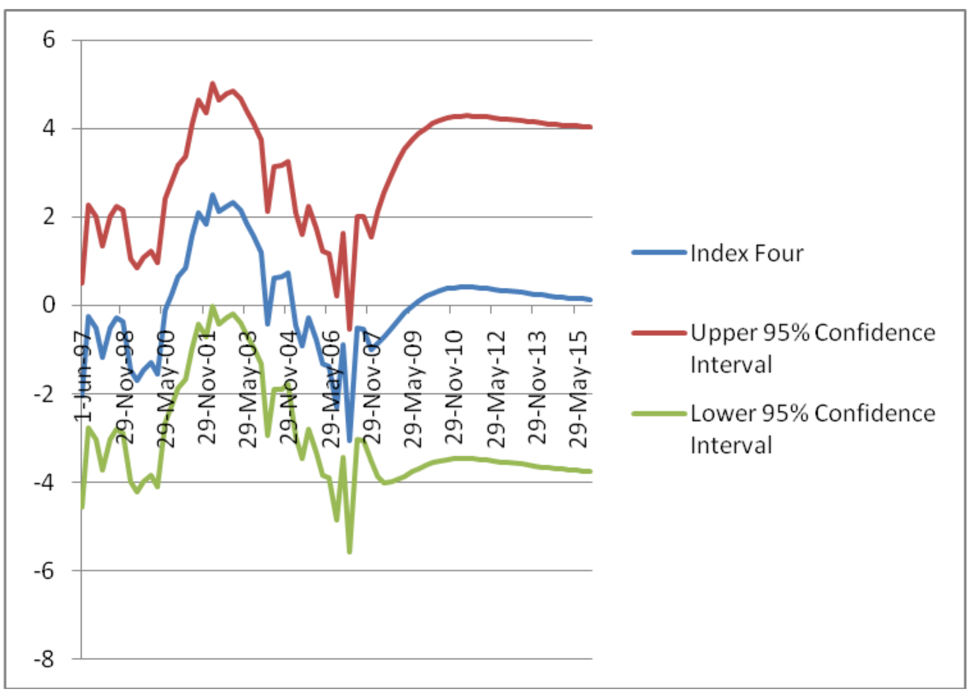

Figure 12: Index four forecasts from January 1998 December 2015

The forecasts for index six are shown in Figure 14. Index 6, the annualised seasonally adjusted percentage GDP growth, is forecasted to increase to a maximum growth value of 1.38 % in 31 March 2008 which will then begin to decrease to a value of 0.29% in December 2015.

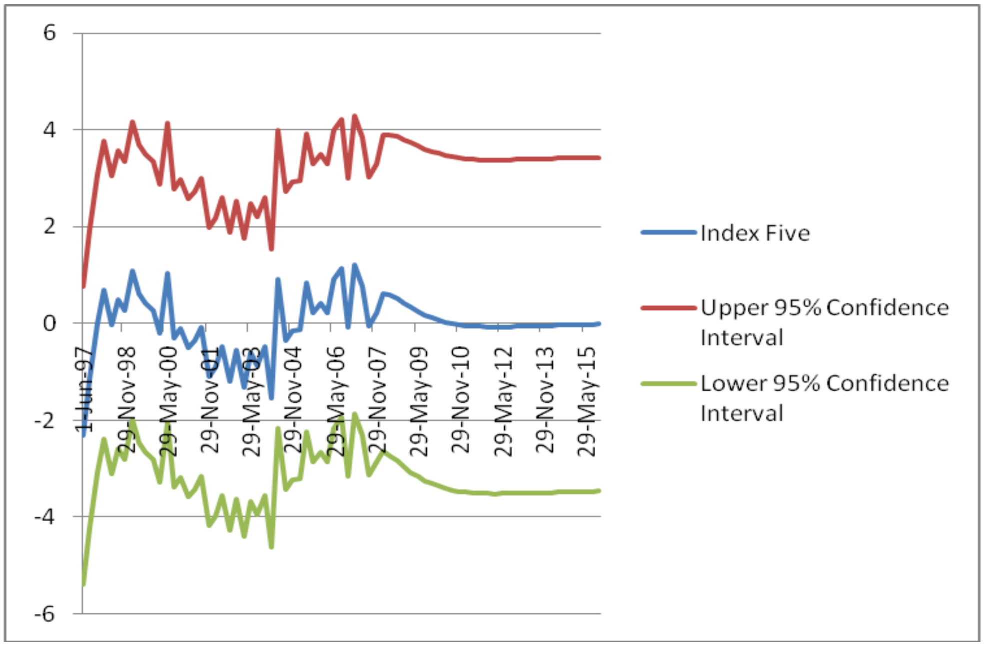

Figure 13: Index five forecasts from January 1998 December 2015

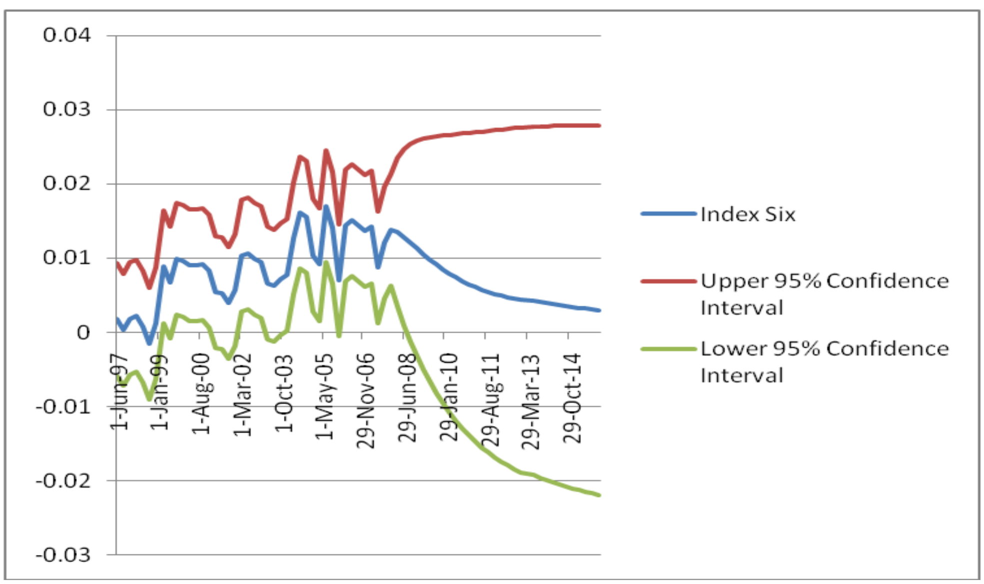

Figure 14: Index six forecast from January 1998 December 2015

5.8. Conclusions

The chapter analysed the results of fitting the statistical factor model and the VAR(1) model to the source data. The data quality of the source data was assessed in order to get an indication of the data quality of the model results, then a statistical factor model was fitted to the source data using aggregation and principal component analysis. The resulting indices from the statistical factor model were fitted to a VAR (1) model. The resulting model results were further analysed using decision theory, and sensitivity and uncertainty analysis. The model forecasts to quarter 4 of the year 2015 were analysed in conjunction with the SARB monetary policy and the SA National Treasury fiscal policy.

6. Conclusions

In this study, statistical indicators which cover the different aspects of sustainable development were collected into a harmonised modeling framework and an attempt was made to identify the key determinants of sustainable development in South Africa. Once the key components were identified, an attempt was made to identify strategies that could be used to influence them. The model performed poorly when it came to forecasting the economic crises in the decision theory analysis and the evolution of index 2 to 2015.

Despite the limitations the model was able to identify the key components of South Africa's fiscal and monetary prudentiality stance, namely, the identification of macroprudentiality to combat the global economic crisis in the SARB monetary policy statements; and the National Treasury budgetary reviews of 2008, 2009, 2010 and 2011. The access of government services to the public is a key fiscal stance that is promised by the South African Presidency. These include access to health, education and housing services and the combating of poverty (poverty as defined in deprivation terms) which are identified by the model.

The limitations of the model and the data quality assessment provide the relevant controls in using the model to craft policy. The model was based on 43 data points where the minimum allowed by the SAS software is 40, which indicates a possible lack of stability in the estimated parameters. Thus, it can be expected that the model performance will improve as more time points are fitted thus allowing the modeling framework to incorporate more of the economy's properties, especially when pertaining to economic, social (political) and environmental cycles.

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Appendix one: Utility functions

Banking Prudential Index

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4)*0.5.
The utility when a bad event occurs and the model predicts no action is quantified as 0.02* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates no action is quantified as -2*0.025* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Household Prudential Index

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4)*0.5.
The utility when a bad event occurs and the model predicts no action is quantified as 0.02* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Terrestrial Degradation Index

The formulation on the Terrestrial degradation index is based on South African Tourism (2008).
The utility when a bad event occurs and the model indicates mitigation is quantified as -0.04695*0.01* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4)*0.5.

The utility when a bad event occurs and the model predicts no action is quantified as 0.093*0.02* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Economic Structure Index

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01*Average Quarterly Compensation of Employees (between 1997 Q1 and 2007 Q4)*0.5.

The utility when a bad event occurs and the model predicts no action is quantified as 0.02*Average Quarterly Compensation of Employees (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

BEE M&A

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01*Average Quarterly value of BEE M&A (between 1997 Q1 and 2007 Q4)*0.5.

The utility when a bad event occurs and the model predicts no action is quantified as 0.02*Average Quarterly value of BEE M&A (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Percentage Real GDP growth in Sub-Sahara

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01*Average Quarterly value of Exports to Sub-Saharan countries, excluding Namibia, Lesotho and Swaziland (between 1997 Q1 and 2007 Q4)*0.5.
The utility when a bad event occurs and the model predicts no action is quantified as 0.02*Average Quarterly value of Exports to Sub-Saharan countries, excluding Namibia, Lesotho and Swaziland (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 *Average Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 *Average Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Security Index

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01*Average Quarterly value of Foreign Direct Investment into South Africa (between 1997 Q1 and 2007 Q4)*0.5.
The utility when a bad event occurs and the model predicts no action is quantified as 0.02*Average Quarterly value of Foreign Direct Investment into South Africa (between 1997 Q1 and 2007 Q4)*0.5.
The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 *Average Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 *Average Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Health Index

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01*0.75*(malaria incidence +TB incidence-malaria cures-TB cures)*Average Quarterly Seasonally adjusted GDP (between 1997 Q1 and 2007 Q4)*0.5.

The utility when a bad event occurs and the model predicts no action is quantified as 0.02*0.75*(malaria incidence +TB incidence-malaria cures-TB cures)*Average Quarterly Seasonally adjusted GDP (between 1997 Q1 and 2007 Q4)*0.5.

The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 *Average Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Education Index

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01*0.75*(malaria incidence +TB incidence-malaria cures-tb cures)*Average Quarterly Seasonally adjusted GDP per capita (between 1997 Q1 and 2007 Q4)*0.5*adult literacy rate in 2008)+(Average FDI into South Africa (between 1997 Q1 and 2007 Q4)*matriculants who passed in 2008).

The utility when a bad event occurs and the model indicates mitigation is quantified as 0.02*0.75*(malaria incidence +TB incidence-malaria cures-tb cures)*Average Quarterly Seasonally adjusted GDP per capita (between 1997 Q1 and 2007 Q4)*0.5*adult literacy rate in 2008)+(Average FDI into South Africa (between 1997 Q1 and 2007 Q4)*matriculants who passed in 2008).

The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 *Average Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 *Average Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Air Quality Index

The utility when a bad event occurs and the model indicates mitigation is quantified as -(average number of deaths from respiratory diseases in 2008 and 2009)*Average Quarterly Seasonally adjusted GDP per capita (between 1997 Q1 and 2007 Q4)*0.5.

The utility when a bad event occurs and the model indicates mitigation is quantified as (average number of deaths from respiratory diseases in 2008 and 2009)*Average Quarterly Seasonally adjusted GDP per capita (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 *Average Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 *Average Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Household Conditions Index

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.125*((total population in 2008)/(total number of households in 2008))*((number of households in informal housing + number of households without electricity+ number of households without potable water +number of households without sanitation)/4)*Average Quarterly Seasonally adjusted GDP per capita (between 1997 Q1 and 2007 Q4)*0.125.

The utility when a bad event occurs and the model indicates mitigation is quantified as 0.25*((total population in 2008)/(total number of households in 2008))*((number of households in informal housing + number of households without electricity+ number of households without potable water +number of households without sanitation)/4)*Average Quarterly Seasonally adjusted GDP per capita (between 1997 Q1 and 2007 Q4)*0.125.

The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Index of Exchange Market Pressure

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.02* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4)*0.5.
The utility when a bad event occurs and the model predicts no action is quantified as 0.02* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Quarterly seasonally Adjusted GDP

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.02* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4)*0.5.
The utility when a bad event occurs and the model predicts no action is quantified as 0.02* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 *Average Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Epidemic Index

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01* number of adults on ART* Quarterly Seasonally Adjusted GDP per capita (between 1997 Q1 and 2007 Q4)-(cost on the AIDS strategy for the year 2008) -(cost of foster care and child grants expressed as a percentage of total cost of grant provision for 2008).
The utility when a bad event occurs and the model predicts no action is quantified as 0.02* number of adults on ART* Quarterly Seasonally Adjusted GDP per capita (between 1997 Q1 and 2007 Q4)-(cost on the AIDS strategy for the year 2008) -(cost of foster care and child grants expressed as a percentage of total cost of grant provision for 2008).

The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Employment to population ratio

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01* Average Quarterly Seasonally Adjusted Compensation of employees (between 1997 Q1 and 2007 Q4).
The utility when a bad event occurs and the model predicts no action is quantified as 0.02* Quarterly Seasonally Adjusted Compensation of employees (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 *Average QSAGDP (between 1997 Q1 and 2007 Q4).

Gender Parity

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01* (Foreign Direct investment into South Africa (between 1997 Q1 and 2007 Q4).
The utility when a bad event occurs and the model predicts no action is quantified as 0.02* (Foreign Direct investment into South Africa (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).
The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Life expectancy

The utility when a bad event occurs and the model indicates mitigation is quantified as -0.01* (Average Seasonally adjusted annualised GDP (between 1997 Q1 and 2007 Q4)/life expectancy in 2008)*(0.765)*(life expectancy in 2008*0.98).

The utility when a bad event occurs and the model predicts no action is quantified as 0.02* (Average Seasonally adjusted annualised GDP (between 1997 Q1 and 2007 Q4)/life expectancy in 2008)*(0.765)*(life expectancy in 2008*0.98).

The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Water Quality Index

The formulation on the utility of the Water Quality index is based on South African Tourism (2008) and Statistics South Africa (2010o). The utility when a bad event occurs and the model indicates mitigation is quantified as -0.04695*0.01* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4) - 0.01*quarterly expenditure on water by the economy.

The utility when a bad event occurs and the model predicts no action is quantified as 0.093*0.02* Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4)+ 0.02*quarterly expenditure on water by the economy.

The utility when a good event occurs and the model indicates mitigation is quantified as 0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

The utility when a good event occurs and the model indicates no action is quantified as -2*0.025 * Quarterly Seasonally Adjusted GDP (between 1997 Q1 and 2007 Q4).

Appendix two: Methodology for the generation of forecast probabilities for a vector autoregressive model of order one

Let $\mathbf{V}_t$'=(V_{1t}, V_{2t},………, V_{mt}) denote an (m*1) vector of random variables, called multivariate white noise, with zero mean vector, **0**, and $\mathbf{V}_t$ at different times are uncorrelated. The covariance matrix of $\mathbf{V}_t$ is given by

$\Gamma(k) = \begin{cases} \Gamma_0 & k = 0 \\ 0_m & k \neq 0 \end{cases}$, where Γ_0 denotes an (m*m) symmetric positive-definite matrix and 0_m denotes an (m*m) matrix of zeros.

The model fitted was a Vector Autoregressive (VAR) model. The VAR(1) model fitted to the statistical factors, f_{jt}, (for j=1,….,m) is given by $\mathbf{X}_t = \mathbf{\Phi_1}\, \mathbf{X}_{t-1} + \mathbf{Z}_t$ where $\mathbf{\Phi_1}$ is a 6*6 matrix, for $\mathbf{X}_t$'=(X_{1t},X_{2t},……, X_{6t}) and $\mathbf{Z}_t$ denotes multivariate white noise, for t=1,….,T.

The algorithm implemented for the estimation of forecast probability was that of absence of parameter uncertainty.

In the method we suppose that the maximum likelihood estimators of $\mathbf{\Phi_1}$ and Γ(k) (k=1,..,m) are given by $\hat{\Phi}_1$ and $\hat{\Sigma}$, respectively. Then the point estimates of the h-step forecasts of $\mathbf{X}_{T+h}$ conditional on Ω_T, denoted by $\hat{X}_{T+h}$, can be obtained recursively by

$\hat{X}_{T+h} = \hat{\Phi}_1 \hat{X}_{T+h}$ for h=1,…., where the initial values, $\mathbf{X}_T$ and $\mathbf{X}_{T-1}$, are given. To obtain probability forecasts by simulation we simulate the values of $\mathbf{X}_{T+h}$, by
$\hat{X}^{(r)}_{T+h} = \hat{\Phi}_1 X^{(r)}_{T+h} + v^{(r)}_{T+h}$, H=1,2,…; r=1,2,…R, where the superscript 'r' refers the rth replication of the simulation algorithm, and $\hat{X}^{(r)}_{T}$ = X_T , $\hat{X}^{(r)}_{T-1}$ = X_{T-1} for all r. The $v^{(r)}_{T+h}$'s can be drawn by a parametric or non-parametric method. The forecast probability

φ($X^{(r)}_{T+1},...,X^{(r)}_{T+h}$)< **a**$_l$ can be computed as φ($X^{(r)}_{T+1},...,X^{(r)}_{T+h}$)=$\frac{1}{R}\sum_{r=1}^{R} I(a_l - \varphi(X^{(r)}_{T+1},...,^{(r)}_{T+h}))$,

where I (A) is an indicator function which takes the value unity if A>0, and zero otherwise. A is defined in such a manner as such that **a**$_l$ can be used to define forecast probabilities of the events under investigation.

In the study the errors $v^{(r)}_{T+h}$ where for h= -∞,…,0,1,…, were simulated by assuming that they emanate from a multivariate probability distribution (i.e. parametrically), with mean **0** (m*1) and (m*m) covariance matrix, $\hat{\Sigma}$. The simulated errors for m variables over h periods, were simulated by generating m*h draws from an assumed i.i.d. distribution which us denoted $\varepsilon^{(r,s)}_{T+i}$, i=1, 2,…,h. These are used to obtain $\{v^{(r,s)}_{T+i}, i=1,...,h\}$ computed as $v^{(r,s)}_{T+h} = \hat{P}^{(s)}\varepsilon^{(r,s)}_{T+h}$ for r=1,2,…,R and s=1,…,S, where $\hat{P}^{(s)}$ is a lower triangular Choleski factor of $\hat{\Sigma}^{(s)} = \hat{P}^{(s)}\hat{P}^{(s)\prime}$ and $\hat{\Sigma}^{(s)}$ is the best estimate of $\hat{\Sigma}$ in the s-th replication of the boot-strap procedure described above. In the presence of parameter uncertainty assumed $v^{(r)}_{T+h} = \hat{P}\varepsilon^{(r)}_{T+h}$ with $\hat{P}$ being the lower triangular Choleski factor of $\hat{\Sigma}$. In the procedure for each r and s, the $\varepsilon^{(r,s)}_{T+i}$ were generated as IIN(**0**,**I**$_m$).

Appendix three: Sensitivity measures of the vector autoregressive model parameter estimates

Main effects of the VAR(1) coefficient estimates to the model output using an IFFD

Parameter 1	1.74055356	1.49E-17	-2E-17	-1.1E-17	2E-17	-3.06623
Parameter 2	-2.78875262	-5E-18	-1.8E-18	1.34E-17	-1.2E-18	-0.23403
Parameter 3	-3.066234701	3.15E-17	2.85E-17	-8E-19	-1E-17	-0.25124
Parameter 4	-0.234029209	-8.5E-18	-7.2E-18	-2.6E-17	5.87E-18	0.013913
Parameter 5	-0.251242746	5.18E-17	-1.6E-18	-1.5E-17	5.34E-19	-3.1E-17
Parameter 6	0.013912933	8.01E-18	-3.5E-18	-9.7E-18	-2E-17	-1.3E-17
Parameter 7	-2.075E-17	1.740554	-7.4E-18	-4.5E-18	-5.3E-18	4.67E-18
Parameter 8	-2.99573E-17	-2.78875	1.15E-17	-2.9E-18	2.14E-17	2.26E-17
Parameter 9	1.4545E-17	-3.06623	-3.1E-17	-5.4E-17	-5.3E-19	-1.9E-17
Parameter 10	-3.15967E-18	-0.23403	1.96E-17	1.98E-18	1.31E-17	4.21E-18
Parameter 11	-2.2885E-17	-0.25124	-1.9E-17	1.07E-18	8.01E-18	-9.3E-17
Parameter 12	4.73046E-17	0.013913	-1.4E-17	1.33E-18	4.46E-17	-3.1E-18
Parameter 13	-5.93809E-18	-1E-17	1.740554	8.01E-19	-2.7E-19	2.63E-17
Parameter 14	2.24895E-17	-9.9E-18	-2.78875	-3E-18	-2.7E-18	-5.6E-18
Parameter 15	-3.48475E-17	1.88E-17	-3.06623	1.53E-17	2.1E-17	-1.6E-17
Parameter 16	2.71051E-19	-1E-16	-0.23403	2.74E-17	-5.4E-17	-3.4E-18
Parameter 17	0.149500904	-0.43741	-0.44414	-0.14158	0.030502	0.001978
Parameter 18	-5.26612E-18	-3.5E-17	0.013913	-2.1E-18	3.72E-17	1.24E-18
Parameter 19	-1.74807E-	4.27E-18	5.55E-18	1.740554	-7.2E-18	-5.2E-18

	17					
Parameter 20	9.6077E-18	-3.2E-18	-1.6E-17	-2.78875	8.27E-18	-3.3E-18
Parameter 21	1.04703E-17	0	-1E-18	-3.06623	-1.6E-17	-8.1E-18
Parameter 22	1.42781E-17	2.67E-18	1.94E-17	-0.23403	-4.2E-17	9.87E-18
Parameter 23	-1.17713E-18	-2.5E-17	2.23E-18	-0.25124	-3.1E-17	3.1E-18
Parameter 24	-1.56125E-17	1.12E-17	1.68E-17	0.013913	9.61E-18	-2.4E-17
Parameter 25	-5.67788E-17	-1.1E-17	-6.2E-18	-2.9E-17	1.740554	4.54E-17
Parameter 26	3.94316E-17	-4.2E-17	9.87E-18	4.23E-17	-2.78875	-9.9E-18
Parameter 27	3.26929E-18	-3.4E-17	1.12E-18	-6E-18	-3.06623	-1.1E-17
Parameter 28	4.73713E-17	-1E-17	-2.1E-18	5.6E-18	-0.23403	-8.7E-18
Parameter 29	2.02162E-17	-5.3E-18	-1.3E-17	1.71E-17	-0.25124	1.91E-17
Parameter 30	2.26848E-17	-2E-17	-1.4E-18	-3.2E-18	0.013913	-2.1E-17
Parameter 31	-9.40754E-18	2.99E-17	-5E-18	-3.5E-18	1.33E-18	1.740554
Parameter 32	2.1684E-17	-4.1E-17	-1.5E-17	1.07E-17	2.4E-18	-2.78875
Parameter 33	1.74055356	1.49E-17	-2E-17	-1.1E-17	2E-17	-3.06623
Parameter 34	-2.78875262	-5E-18	-1.8E-18	1.34E-17	-1.2E-18	-0.23403
Parameter 35	-3.066234701	3.15E-17	2.85E-17	-8E-19	-1E-17	-0.25124
Parameter 36	-0.234029209	-8.5E-18	-7.2E-18	-2.6E-17	5.87E-18	0.013913

Quadratic effects of the VAR(1) coefficient estimates model output using an IFFD

Parameter 1	-0.248650509	-3.9E-17	-3.5E-17	5.29E-18	-2.2E-17	0.438034
Parameter 2	-0.398393231	-1.9E-17	1.89E-17	4.57E-17	1.71E-17	-0.03343
Parameter 3	0.219016764	-6.6E-19	-3.8E-17	2.64E-17	1.31E-17	2.11E-17
Parameter 4	0.100298232	3.52E-17	1.02E-17	-3.9E-18	4.72E-17	-0.00596
Parameter 5	-0.089729552	6.61E-18	6.28E-18	2.61E-17	5.59E-17	-7E-19
Parameter 6	0.006956466	8.59E-18	4.31E-18	-1.4E-17	-1.1E-18	-1E-17

Parameter 7	-4.16953E-17	3.44E-16	5.93E-17	-1.2E-17	-3.5E-17	5.58E-18
Parameter 8	1.09308E-16	1.62E-16	1.31E-17	-6.8E-18	-2.6E-18	-2.5E-17
Parameter 9	-1.38571E-17	-0.87607	-1.4E-17	-8.1E-17	-2.9E-17	5.82E-18
Parameter 10	1.43528E-17	-0.03343	-3.1E-17	3.06E-18	9.17E-18	4.75E-17
Parameter 11	1.23289E-17	-0.10768	-4.1E-17	-9.7E-18	2.59E-17	-1.1E-17
Parameter 12	1.4202E-16	-0.00199	4.5E-17	-1.1E-17	1.28E-17	-1.6E-16
Parameter 13	-4.22323E-17	2.89E-17	0.497301	7.52E-18	-9.2E-17	-1.4E-17
Parameter 14	6.76336E-17	-3.5E-18	-0.39839	-4.2E-18	1.41E-17	-1E-17
Parameter 15	8.30116E-17	3.14E-17	1.984034	2.03E-17	-4.2E-17	6.2E-17
Parameter 16	1.31805E-17	-1.6E-16	-0.09636	-4.7E-18	4.15E-18	1.02E-17
Parameter 17	-0.209301266	0	0.01675	0	0	4.86E-17
Parameter 18	7.7443E-18	-1.2E-17	-0.00199	2.14E-17	-6E-17	1.53E-18
Parameter 19	1.2205E-17	-6.3E-17	-5E-18	-0.24865	1.13E-17	-4.2E-17
Parameter 20	1.27833E-17	2.33E-17	2.74E-17	0.796786	-9E-18	8.55E-18
Parameter 21	-4.61973E-17	-1.4E-16	1.94E-17	1.314101	-1.2E-16	3.73E-17
Parameter 22	-1.66657E-17	7.62E-17	8.93E-18	0.033433	-5.8E-17	3.99E-17
Parameter 23	4.9357E-18	3.97E-17	-6.2E-18	4.73E-17	1.13E-17	-2.6E-17
Parameter 24	3.17413E-17	2.23E-17	-8.4E-17	-0.00199	-8.5E-18	1.28E-17
Parameter 25	-1.41876E-17	9.91E-19	7.11E-18	-5.6E-17	-3.1E-17	1.94E-17
Parameter 26	1.26036E-16	-6.7E-17	-5.6E-18	5.72E-17	0.398393	2.17E-17
Parameter 27	3.08739E-17	-2.8E-17	1.7E-19	-9.2E-17	-0.43803	-3.7E-17
Parameter 28	8.94002E-17	-5E-19	2.16E-17	-7.4E-19	7.52E-18	2.72E-17
Parameter 29	2.53807E-17	1.8E-17	2.33E-17	7.56E-17	-0.07178	-3.7E-18
Parameter 30	-8.03342E-18	4.99E-17	-1E-17	4.96E-18	1.06E-17	5.99E-18
Parameter 31	-1.23702E-17	7.29E-17	-1.1E-16	-6.8E-17	1.43E-17	0.248651
Parameter 32	-1.14265E-16	-4.5E-18	8.44E-18	-1.2E-17	5.37E-18	0.796786
Parameter 33	-0.248650509	-3.9E-17	-3.5E-17	5.29E-18	-2.2E-17	0.438034
Parameter 34	-0.398393231	-1.9E-17	1.89E-17	4.57E-17	1.71E-17	-0.03343
Parameter 35	0.219016764	-6.6E-19	-3.8E-17	2.64E-17	1.31E-17	2.11E-17
Parameter 36	0.100298232	3.52E-17	1.02E-17	-3.9E-18	4.72E-17	-0.00596

Appendix four: Statistical Quality Assessment metadata for the source data

1. GDP growth (SDDS, DQAF, SASQAF, IMF (2009))
2. Basel II indicators (SDDS, DQAF, SASQAF, IMF (2010b))
3. Open Leontief multipliers (SDDS, DQAF, SASQAF)
4. Gini AMPS (South African Advertising Research Foundation (2010) quality measures, **confidence intervals**)
5. Poverty Headcount index AMPS (South African Advertising Research Foundation (2010) quality measures, **confidence intervals**)
6. Severity of poverty (South African Advertising Research Foundation (2010) quality measures, **confidence intervals**)
7. Income of poorest 20% AMPS (South African Advertising Research Foundation (2010) quality measures, **confidence intervals**)
8. Mid-year population estimates (SDDS, DQAF, IMF(2009))
9. BEE M&A (Ernst and Young (2009) quality measures)
10. Employment (QLFS SASQAF score, SDDS, DQAF, IMF(2009))
11. under 5 mortality (Johnson, L., Dorrington, R. and Matthews, A. (2006) and SASQAF on HSRC data)
12. under one mortality (Johnson, L., Dorrington, R. and Matthews, A. (2006) and SASQAF on HSRC data with **confidence intervals, response rates and participation rates** for accuracy measures)
13. Immunization (SASQAF**,** Garrib, Stoops, McKenzie, *et al*., 2008, and **completeness of registers**)
14. TB, incidence, TB cure rate, Malaria incidence and Malaria deaths (SASQAF**,** Garrib, Stoops, McKenzie, *et al*., 2008, and **completeness of registers**)
15. HIV prevalence Johnson, L., Dorrington, R. and Matthews, A. (2006) and SASQAF on HSRC data with **confidence intervals, response rates and participation rates** for accuracy measures)

16. Life expectancy Johnson, L., Dorrington, R. and Matthews, A. (2006) and SASQAF on HSRC data with **confidence intervals, response rates and participation rates** for accuracy measures)
17. GPI (United Nations Educational, Scientific and cultural Organisation (2010))
18. GER (boys) (United Nations Educational, Scientific and cultural Organisation (2010))
19. GER (girls)(United Nations Educational, Scientific and cultural Organisation (2010))
20. Number of women in parliament (SASQAF and **completeness of electoral information according to South African Presidency (1996)**)
21. Household Index (GHS SASQAF score)
22. Democratically elected governments in Africa
23. Real GDP growth in Sub-Saharan Africa (SDDS, DQAF, GDDS of the respective countries)
24. IEMP (SDDS, DQAF of the exchange rate, international reserves, domestic interest rates)
25. Mineral Indicators (SASQAF, accuracy as indicated in Stats SA (2010g))
26. Fisheries Accounts (SASQAF, accuracy as indicated in Stats SA (2010b))
27. Rainfall Index (DWA quality indicators, SASQAF DWA completeness measures)
28. Water Quality Index (DWA quality indicators, SASQAF DWA completeness measures)
29. Manufacturing Index (SDDS, DQAF, IMF(2009))
30. Mining Index (SASQAF relevant indicators that can be scored from the publication)
31. Electricity Available for distribution (SASQAF relevant indicators that can be scored from the publication)
32. Civil Cases for debt (SASQAF, completeness of registers as indicated in the publication)
33. Company aggregate liquidations (SASQAF, completeness of registers as indicated in the publication)
34. HSRC South African National HIV Prevalence, HIV incidence, Behaviour and Communication Survey (SASQAF, **quality declarations in HSRC(2005)**)

Appendix Five: Principal Component Factor Loadings

Variable	Principal Component 1	Principal Component 2	Principal Component 3	Principal Component 4	Principal Component 5
Banking Prudential Index	0.1419	0.0954	-0.1198	0.2003	0.0462
Rainfall Index	0.0752	0.0324	-0.0078	0.0271	-0.1606
Household Prudential Index	0.0400	-0.0518	-0.4283	0.4805	-0.1323
Economic Structure Prudential Index	0.0269	-0.0468	-0.4184	0.4900	-0.1397
Aquatic Ecosystems Index	-0.0795	-0.0575	0.1228	0.0575	0.3921
Structure of Poverty Index	-0.3729	-0.0279	0.1272	0.1761	-0.2354
Employment to Population Ratio	-0.2675	0.3140	-0.3068	-0.1536	0.2117
Education Index	0.2016	-0.1422	0.3577	0.3279	0.1739
Gender Parity Index	0.3414	0.2943	-0.0270	0.1322	0.1919
Health Services Index	0.0978	0.4092	0.0372	-0.1594	-0.3796
Household Index	0.1492	-0.0228	0.2281	-0.0262	-0.4426
BEE merger and acquisition transactions as a % of all merger and acquisition transactions	0.3516	0.2800	0.1456	0.1403	0.0300
Life Expectancy	0.2653	-0.2888	-0.2704	-0.3349	0.0692
GDP change in Sub-Saharan Africa	-0.3279	-0.3526	0.1735	0.1458	0.0252
% of democratically	0.1650	0.2529	0.1362	0.1393	0.2756

elected governments in Africa					
Security Index	-0.0746	0.1912	0.2091	0.0420	-0.2338
Air Quality Index	0.0571	-0.1361	0.0095	0.1572	-0.1425
Terrestrial Degradation Index	0.1055	-0.1849	0.1363	0.0828	0.1204
Economic Conditions Prudential Index	-0.0459	0.0369	0.0118	0.0529	0.1302
Epidemic index	-0.3962	0.3524	-0.1275	0.0261	0.1064
Fisheries Index	-0.1666	0.1030	0.1642	0.1486	0.2499
Index of Exchange Market Pressure	-0.1744	0.1788	0.2661	0.2185	-0.1079

Variable	Principal Component 6	Principal Component 7	Principal Component 8	Principal Component 9	Principal Component 10
Banking Prudential Index	0.3927	0.0481	-0.1848	-0.1165	0.0190
Rainfall Index	0.3527	0.0863	0.1368	-0.5272	0.4965
Household Prudential Index	-0.0943	0.0496	0.1343	0.0898	-0.0097
Economic Structure Prudential Index	-0.1037	0.0603	0.1335	0.0884	-0.0200
Aquatic Ecosystems Index	0.2649	0.4556	0.1917	-0.0410	-0.1015
Structure of Poverty Index	0.0594	0.0246	-0.3825	-0.1250	0.0778
Employment to Population Ratio	0.1995	-0.0275	0.0663	0.0362	-0.0696

Education Index	-0.1942	-0.0529	0.2098	-0.1876	-0.0332
Gender Parity Index	-0.0395	-0.1303	-0.3181	-0.0776	0.0520
Health Services Index	-0.0289	0.2494	0.0829	0.0597	-0.0381
Household Index	0.2371	-0.1071	0.1296	0.4340	-0.0178
BEE merger and acquisition transactions as a % of all merger and acquisition transactions	-0.1544	0.0410	-0.1787	-0.1096	0.1766
Life Expectancy	0.0813	0.0738	0.0824	0.0509	0.0128
GDP change in Sub-Saharan Africa	-0.0313	-0.0750	0.1425	-0.1432	0.0418
% of democratically elected governments in Africa	0.2040	-0.1492	0.3902	0.0822	-0.2984
Security Index	-0.2716	0.5243	0.1682	-0.1697	-0.2465
Air Quality Index	0.3848	0.1867	-0.2958	0.0457	-0.4318
Terrestrial Degradation Index	0.2434	0.3079	-0.2497	0.1642	0.0592
Economic Conditions Prudential Index	-0.0111	0.3455	0.1469	0.4556	0.5777
Epidemic index	0.0436	0.0314	0.0062	-0.0908	-0.0314
Fisheries Index	-0.1974	0.0157	-0.3345	0.3214	0.0466
Index of Exchange Market Pressure	0.3109	-0.3486	0.1790	0.1487	0.1271

Variable	**Principal Component**	**Principal Component**	**Principal Component**	**Principal Component**	**Principal Component**

	11	12	13	14	15
Banking Prudential Index	-0.5510	0.0052	0.5761	-0.1794	-0.0138
Rainfall Index	-0.1411	-0.0232	-0.3844	0.2722	-0.1881
Household Prudential Index	0.0312	-0.1056	-0.0686	0.0272	0.0669
Economic Structure Prudential Index	0.0305	-0.1102	-0.0674	0.0263	0.0477
Aquatic Ecosystems Index	-0.0716	-0.1456	-0.2859	-0.3630	0.4802
Structure of Poverty Index	0.2346	0.0600	0.0847	0.0794	0.3090
Employment to Population Ratio	0.0730	-0.0484	0.0577	0.1585	-0.0801
Education Index	-0.0212	0.1124	0.1765	-0.0790	-0.2208
Gender Parity Index	0.2052	0.1114	-0.1026	-0.2840	-0.0950
Health Services Index	-0.0542	-0.0605	0.2496	0.1670	0.1914
Household Index	-0.1898	-0.1948	-0.1981	-0.1413	-0.0218
BEE merger and acquisition transactions as a % of all merger and acquisition transactions	0.1498	-0.0437	0.0214	0.2229	0.4653
Life Expectancy	0.0867	0.0898	0.1880	0.1894	0.2522
GDP change in Sub-Saharan Africa	-0.0487	0.0265	0.2784	0.2553	0.1609

% of democratically elected governments in Africa	0.0840	0.0484	0.0173	0.4643	-0.0005
Security Index	-0.0112	0.0314	0.0614	-0.0381	-0.2021
Air Quality Index	0.0935	0.5452	-0.1904	0.1602	-0.0908
Terrestrial Degradation Index	0.3858	-0.5778	0.1875	0.1675	-0.3333
Economic Conditions Prudential Index	0.0973	0.4769	0.1275	-0.0168	-0.1136
Epidemic index	0.0937	-0.0374	0.0312	-0.1082	-0.1813
Fisheries Index	-0.5099	-0.0898	-0.2477	0.3631	0.0014
Index of Exchange Market Pressure	0.2284	0.0180	0.0906	-0.1703	0.1354

Variable	**Principal Component 16**	**Principal Component 17**	**Principal Component 18**	**Principal Component 19**	**Principal Component 20**
Banking Prudential Index	-0.1493	-0.1046	-0.0567	0.0705	0.0080
Rainfall Index	-0.0134	0.0736	0.0909	-0.0008	0.0062
Household Prudential Index	-0.0008	0.0467	-0.0067	0.0186	-0.0200
Economic Structure Prudential Index	0.0124	0.0377	0.0757	-0.0305	0.0235
Aquatic Ecosystems Index	0.0615	0.0370	0.0424	-0.1191	-0.0098

Structure of Poverty Index	-0.3077	-0.2317	0.3350	-0.2051	-0.3388
Employment to Population Ratio	0.3087	-0.1961	0.2017	0.1353	-0.1476
Education Index	0.3466	0.0782	0.2525	-0.0285	-0.5103
Gender Parity Index	0.0326	0.0047	0.4688	-0.1950	0.4428
Health Services Index	0.2864	0.3732	0.0441	-0.4675	-0.0180
Household Index	0.1993	-0.4215	0.2925	0.1079	0.0033
BEE merger and acquisition transactions as a % of all merger and acquisition transactions	0.2289	-0.2617	-0.2797	0.4046	-0.0187
Life Expectancy	-0.0699	0.2212	0.5115	0.3439	-0.0759
GDP change in Sub-Saharan Africa	0.3375	-0.1259	0.1189	-0.0640	0.5886
% of democratically elected governments in Africa	-0.3696	-0.2108	0.0260	-0.2140	0.0288
Security Index	-0.2988	-0.0397	0.1847	0.3851	0.2058
Air Quality Index	0.2469	0.1062	-0.1372	0.0801	0.0188
Terrestrial Degradation Index	0.0257	0.0739	-0.0604	-0.0117	0.0301
Economic Conditions Prudential Index	-0.0382	-0.1368	-0.0482	-0.0724	0.0112

Epidemic index	0.2551	-0.0515	0.0654	0.2009	-0.0561
Fisheries Index	-0.0274	0.2834	0.1962	0.1114	-0.0102
Index of Exchange Market Pressure	-0.1216	0.5155	-0.0253	0.3246	0.0714

Variable	**Principal Component 21**	**Principal Component 22**
Banking Prudential Index	0.0059	-0.0083
Rainfall Index	0.0057	0.0024
Household Prudential Index	0.0214	0.7077
Economic Structure Prudential Index	-0.0323	-0.7011
Aquatic Ecosystems Index	-0.0111	0.0032
Structure of Poverty Index	-0.0023	0.0167
Employment to Population Ratio	-0.5986	0.0288
Education Index	-0.0452	0.0100
Gender Parity Index	-0.0377	0.0473
Health Services Index	0.0356	0.0190
Household Index	0.0839	0.0153
BEE merger and acquisition transactions as a % of all merger and acquisition	0.0140	-0.0344

transactions		
Life Expectancy	0.2112	-0.0065
GDP change in Sub-Saharan Africa	0.0015	0.0323
% of democratically elected governments in Africa	0.1714	0.0000
Security Index	-0.1672	0.0223
Air Quality Index	0.0103	-0.0069
Terrestrial Degradation Index	0.0094	0.0030
Economic Conditions Prudential Index	0.0094	-0.0015
Epidemic index	0.7118	-0.0228
Fisheries Index	0.0094	0.0087
Index of Exchange Market Pressure	-0.1381	-0.0114