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Developing a systemic macro-prudential instrument for business performance impact assessment

by

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Executive Summary

This research project forms part of ongoing research to identify methods, techniques or instruments for business performance impact assessment. A review of the literature on complexity management and macro-prudential analysis reveals a trend of top-rated financial and non-financial institutions defaulting during the current economic crisis. The complexity of such institutions together with the uncertainty of economies results in institutions being very fragile and prone to default during times of economic crisis. This indicates that conventional techniques utilised by institutions are not sufficient to determine strategies for creating and maintaining sustainable business systems: throughout the literature it is acknowledged that analysis on a macro scale must be conducted.

An industrial engineer (IE) must create an act of balance between the man, machine, money and business process aspects of a business system. An IE is constantly on a quest to determine what optimisation strategy should be implemented next in order for a business to create value for its shareholders and to be sustainable. Because financial and non-financial institutions are interconnected, it is of great importance for an IE to understand the macro-economic ecosystem in which a business must be operated.

The research objective is to find a technique or method that will enable an IE to evaluate and analyse the macro-economic ecosystem within which a business operates. This will help to determine the applicable optimisation strategies that should be implemented within a scoped business system. Such a technique or method must take the uncertainty of the macro-economic ecosystem into account while identifying the key complexity contributors that need to be addressed in order to diminish fragility.

The aim of the research project is to develop a systemic macro-prudential instrument that will aid an IE in evaluating and analysing a macro-economic ecosystem that has an impact on business performance.

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1. Introduction

During the latest economic crisis, top-rated businesses started failing. This is of great concern to an industrial engineer and poses the following question: How does an industrial engineer determine applicable optimisation strategies in order to create a sustainable business system, especially during times of economic crisis?

1.1 Operational context

This research project is set in a multidimensional context. However, the main focus is on businesses, how their performance is impacted and the challenges an industrial engineer (IE) has to face in order to create a sustainable business system. The purpose of a business is to create value for its shareholders. The main objective of an IE is to manage man, machine, money and business process aspects to create a sustainable business system that will create such value. The IE must create business plans, conduct forecasting and budget so that feasible tactics can be implemented. A common mistake that businesses make is attempting to implement optimisation strategies by analysing only various internal components of the business system. This represents a bottom-up approach. Blanchard and Fabrycky (2011:32) indicate that the use of a top-down approach, which views the whole macro-economic ecosystem, is frequently overlooked. Such an approach can help to identify and understand a business landscape and the impact it has on the performance of a business system. A combination of the bottom-up and top-down approaches will be the most suitable way for an IE to determine the relevant optimisation strategies that should be implement (Blanchard and Fabrycky 2011:59).

The recent economic crisis caused many top rated businesses to fail. This indicates that conventional risk assessment, rating and management techniques that businesses use are not sufficient for the creation and maintainability of a sustainable business system (Marczyk 2011:111). A business is unpredictable as it is interconnected with a macro-economic ecosystem that is constantly evolving: a fact that creates great uncertainty. A business can become increasingly fragile as a result of the uncertainty of the macro-economic ecosystem that it must operate in and by being a complex system in itself. A fragile business is more prone to default in times of an economic

crisis. This requires an IE to adopt new thinking, for example to opt for business stability and robustness rather than growth during times of economic crisis. The only sensible strategy is to reduce the complexity of a business system so that the business can become less fragile (Marczyk 2011:92).

2. Problem Statement

The research problem is to find a method that will enable an IE to evaluate and analyse the macro-economic ecosystem in order to determine which applicable optimisation strategies to implement. Such a technique or method must take the uncertainty of the macro-economic ecosystem into account while identifying key complexity contributors that need to be addressed in order to diminish fragility. Such key complexity contributors are mainly identified by segmenting financial stability reviews. These reviews are conducted by the South African Reserve Bank (SARB). The focus on this entity follows.

3. South African Reserve Bank

The South African Reserve Bank (SARB) contributes key control and regulatory inputs for a business system. For this reason it is crucial to understand what the Reserve Bank does and the vision the bank has on financial stability.

3.1 The South African Reserve Bank in context

The South African Reserve Bank, South Africa's central bank has as main priority ensuring price stability and maintaining it, ultimately ensuring a balance and sustainable economic growth in South Africa. Together with other financial and non-financial institutions, the Bank must ensure that all its actions lead to the country being financially stable (SARB 2011a).

3.2 View on financial stability

The South African Reserve Bank defines financial stability as the collective stability of all financial institutions and the markets in which they operate. This means that financial institutions are robust and sound and able to absorb unexpected shocks while

markets strive to be less volatile. In order to achieve such stability, effective regulatory measures and macro-prudential analysis should be in place. The SARB defines a financially stable system as one that is able to withstand shocks from all conditions, not only at domestic level but at international level as well (SARB 2011b).

3.3 What is macro-prudential analysis?

Macro-prudential analysis is a systemic analysis of a country's financial stability. It analyses key indicators in the domestic financial sector and its counterparts, namely the corporate and household sectors (SARB 2009:14). Because of the interrelated nature of financial stability and international sectors, other external sector indicators, such as the real-estate market and real economic activity, are also analysed (SARB 2011c:15). Macro-prudential analysis is done so that potential areas of concern that could lead to instability issues of the financial system are highlighted at an early stage as well as to minimise the impact of such issues as effectively as possible.

4. Project Aim

The aim of this project is to develop a systemic macro-prudential instrument (MI) for an IE, using complexity analysis as foundation. This instrument will enable an IE to evaluate and analyse the macro-economic ecosystem in which the business operates as well as the business's value chain in order to determine which applicable optimisation strategies should be implemented. Complexity analysis is viewed as a feasible method to analyse the various data sources and measurements within a typical macro-economic ecosystem.

5. Why a MI?

A MI is a risk management tool that can be used to understand a specific environment in order to plan for business sustainability. The SARB lists in its Financial Stability Review (SARB 2010:32) a number of attributes that distinguish a MI from normal monetary policy and micro-prudential policy instruments. These attributes include the following:

- A MI has a much broader financial stability objective than the above-mentioned conventional instruments.
- A MI does not use a collective approach but analyses each risk individually. Jacek Marczyk (Marczyk 2011:84, 85) explains that systemic risk is not always the total of all individual risk exposures as is assumed by conventional instruments.
- A MI is developed in such a manner that it counters the unavoidable fluctuating nature encountered by business and financial institutions.
- A MI focuses on limiting excess credit growth. At the level of an individual business excess credit growth is perceived as a low level risk. This causes the build-up of systemic risk to be disguised and may lead to devastating circumstances. In contrast, monetary policy looks only at what impact such excess credit growth might have on inflation.
- A MI is concerned with systemic interconnectedness, thus broadening the exposure to risk. Information about financial institutions, non-financial institutions and any other corporate sector that may have a systemic impact on financial stability is taken into account.

6. Project Scope

The approach used to develop a MI is depicted in the following diagram. Block B illustrates the macro-economic ecosystem within which a business must operate. For an IE to determine which optimisation strategies to implement (Block A), a Business Landscape needs to be identified. Using a top-down approach the macro-economic ecosystem can, for example, be segmented as follows: financial and economic developments in advanced economies, financial and economic developments in emerging markets and developing countries and a domestic macro-prudential analysis according to the financial stability reviews that are done by the SARB (SARB 2011c).

Diagram 1: Approach to developing a macro-prudential instrument

C. Mining of key indicator data from multiple sources, for example:

- Percentage change in real GDP
- Global oil production
- Electric current generated

B. Macro-economic Ecosystem

International system

Financial and economic developments in advanced economies

Geography

Financial and economic developments in emerging markets and developing countries

Industry

Domestic macro-prudential analysis

Business B

Business A

D. Data Cleaning

	Var 1	Var 2	Var 3	...
Jan				
Feb				
March				

A. IE Application

Business Landscape

Income Statement & Balance Sheet

Revenue → + Reserves

Cost → + Loans

Strategy → Business Plan

Plan & Control → Forecasting

Core Value Chain → Budgeting

Support

G. Interpretation

- South African Reserve Bank

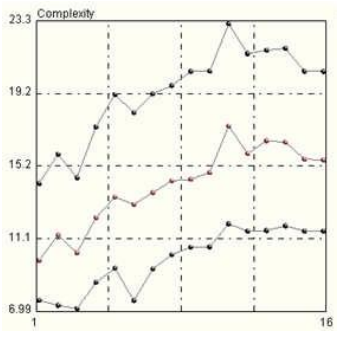
E. Business Intelligence Tool

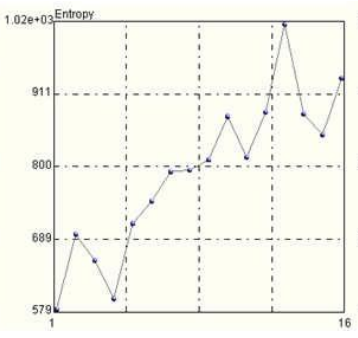
ONTONIX COMPLEXITY MANAGEMENT

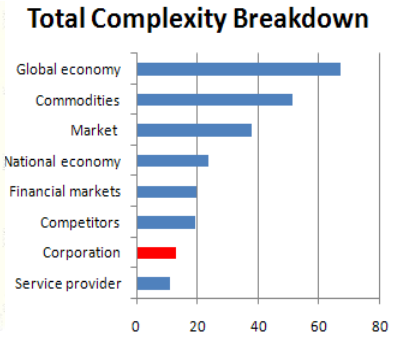
F. Results

- Evolution of complexity
- Entropy
- Complexity contribution

(Marczyk 2011:77, 91)







Block C illustrates the "mining" of key indicator data that may influence business performance within each segment from multiple sources. Data mining is also known by many other names, including knowledge extraction, information harvesting and data pattern processing to name but a few. Such data will typically include, for example, the percentage change in real gross domestic product (GDP) for advanced economies and on a domestic level, the electric current generated in a country. In block D, after the relevant data has been sourced, a method called "Data Cleaning" will be applied to the data in order to organise the data, obtain unity throughout it and to prepare it for input into a Business Intelligence Tool (Kurgan and Musilek 2006).

A Business Intelligence Tool named OntoSpace that was created by Ontonix (block E) is used for complexity analysis. OntoSpace adopts a model-free approach in order to avoid adding additional uncertainty to a problem. OntoSpace uses this approach to identify structure and patterns within multi-dimensional data (Ontonix 2011a).

Block F illustrates the results that will be obtained from OntoSpace. The Evolution of Complexity chart for example can then be compared to existing instruments to determine whether any correlations exist. The possibility exists of presenting the obtained results, the correlations and the conclusions drawn to the SARB to interpret them. After the interpretation by the SARB it will be possible to determine if such a MI will be applicable for IE usage.

7. Literature Review

The literature review was conducted to assist with the development of a systemic macro-prudential instrument. The development of the instrument is substantiated from the literature.

7.1 Introduction

Innovation, the globalisation of markets and increasingly demanding customers have forced businesses to supply a growing mix of products and services, each tailored to a specific customer need. This has led to increased complexity within business systems themselves as well as the macro-economic ecosystem within which the business must

operate. Because of this increase in complexity, businesses are becoming all the more difficult to control and manage. This can result in a strategic issue for businesses (Miragliotta and Perona 2004:103, 104). But is the continuous quest to fulfil each and every individual customer need worth the increased complexity? In *Angel Customers and Demon Customers* (Colvin and Selden 2003), Larry Selden and Geoff Colvin cite studies that indicate that the top 20 percent of customers are generating all the income while the bottom 20 percent are actually destroying value. In 1906 Vilfredo Pareto, an Italian economist, created a mathematical formula to describe the unequal distribution of wealth in his country. The result was that 80 percent of the country's wealth was owned by only 20 percent of the population. A few years later Dr Joseph Juran, a quality management pioneer, recognised a universal principle which he called the "vital few and trivial many". The observations of both men led to the Pareto Principle, also known as the 80/20 Rule. This principle means that 80 percent of anything makes only a 20 percent contribution, and vice-versa. This clearly indicates that businesses should opt for simplicity and focus on the 20 percent that creates the most value.

"Simplicity is the ultimate sophistication."
Leonardo da Vinci

For an industrial engineer (IE) to create the ultimate sophisticated business system, the IE must choose the appropriate strategies that need to be implemented to create it. This requires the IE to analyse and interpret the complexity in a business as well as the macro-economic ecosystem within which the business is operated. Then the IE must manage or even decrease the amount of complexity in order to create a simpler, more controllable business system.

7.2 Risk versus complexity

One of the best definitions of risk is that risk is the exposure to uncertainty. But everything is, to a certain extent, exposed to uncertainty, all the time. Therefore, this definition makes the concept of risk itself redundant because it then states that everything is at risk all the time. Also, from a philosophical standpoint, the concept

of risk is useless. An example is the failure of Lehman Brothers Bank during the recent economic crisis. The bank had a triple -A rating and they boasted the most advanced risk management technology but defaulted suddenly and unexpectedly. Risk does not exist in nature. It is an imaginary and intangible quantity and therefore it cannot be measured. The unnatural concept of risk needs to be replaced by something natural and scientifically sound. This is where complexity comes in (Marczyk 2011:17, 18, 27).

7.3 What is complexity?

In John Mariotti's book, *The Complexity Crisis*, it is written that the term 'complexity' has been used rather loosely to define a state of various interactions between different components (Mariotti 2008:144). This is somewhat worrying because there is no mention of a complexity measurement. A good definition (Marczyk 2011:37) always suggests a metric, and serious science only starts when you begin to measure (Marczyk 2011:35). Marczyk makes an important claim in contrast to that of complexity "science" that there should be no differentiation between complex and non-complex systems. Complexity is an attribute of every system just like mass, momentum or energy (Marczyk 2011:36). It is suggested that it is time to go beyond a loose definition and the following statement is made: Complexity is a quantitative measure assigned to a system that lies between simple order and total chaos (Mariotti 2008:144). The latter definition is supported by Jacek who writes that complexity is a fundamental characteristic/property of any dynamic system. The amount of complexity in a system can determine whether a system will fulfil its functionality and reach certain goals. The functionality of a system is proportional to the amount of complexity that it possesses (Marczyk 2011:33). Finally Marczyk defines complexity as follows: Complexity is the measure of the amount of structured information in a system (Marczyk 2011:38).

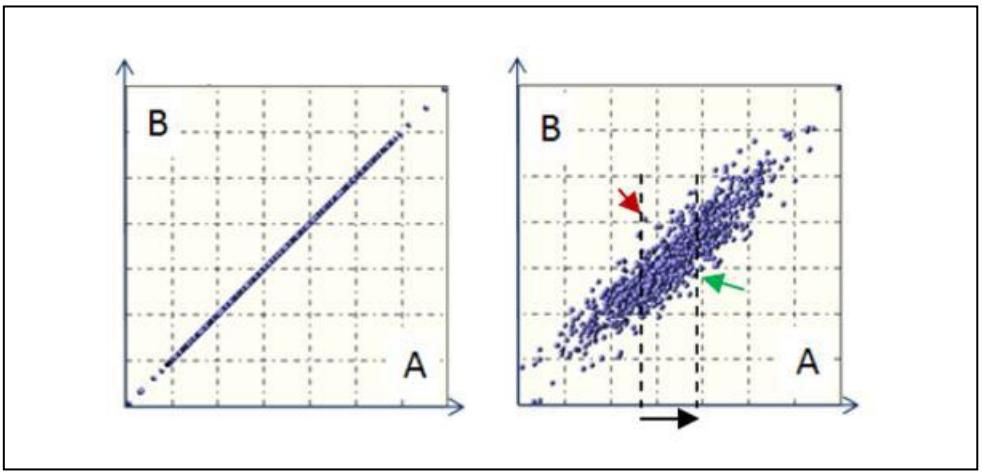
The concept 'structured information' relates to the amount of complexity that is equivalent to useful information. Useful information gives an indication of the ability of a system to create value. Structured information is a set of dynamic and inter-

related rules. A typical rule that engineers as well as other professionals use is expressed as follows:

If **A** then **B**

An example of this rule is: "if the price of crude oil goes up, then the petrol price will also rise". This is a 'fuzzy' rule (Marczyk 2011:39). It is not always a given that if the price of crude oil rises, petrol will also become more expensive.

Figure 1: An example of a crisp rule and a fuzzy rule



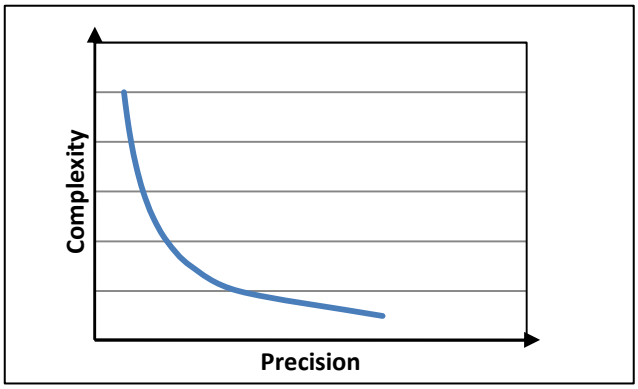
The figure above illustrates a crisp rule (left) and a fuzzy rule (right) of the rule type "if **A** then **B**". The crisp rule illustrates that if **A** increases, **B** will also increase. However, with the fuzzy rule this is not the case anymore. **A** may have a certain value, as indicated by the red arrow. If **A** increases by the amount displayed by the black arrow, **B** can take on a value such as the one indicated by the green arrow. The fuzzy rule therefore illustrates that if **A**'s value increases, it does not necessarily mean **B**'s value will also increase. The extent to which this is possible is determined by the spread of the data which has been used to build the rule and by the size of the step (as indicated by the horizontal black arrow). This means that the fuzzy rule (right) will only stand if the size of the step is large enough. The "if **A** then **B**" rule types are characterised by the degree of organisation of the corresponding (**A**:**B**) scatter plot. This degree of organisation is measured by entropy, a fundamental component of a

complexity metric. Entropy measures the amount of disorganisation in a system as well as the amount of information that is being transmitted between two points. Entropy will thus measure the degree of fuzziness of a certain rule as well as the amount of information that is being transmitted between two points (**A** and **B** for example) by that rule (Marczyk 2011:39, 40).

"Everything is vague to a degree you do not realize till you have tried to make it precise" – Bertrand Russell

The Principle of Incompatibility, as defined by Zadeh (Zadeh 1969), explains that precision and complexity are incompatible. If the one increases the other must decrease as illustrated in the figure below.

Figure 2: Complexity versus precision



As complexity increases, forecasting precision, for example, is being reduced. This principle explains why so many statements are fuzzy (Marczyk 2011:14).

Once a set of inter-related rules have been established they can easily be presented by a map or graph. Such a map defines the structure of a system while the entropy of the rules contributes to the fundamental component of uncertainty that is necessary for complexity to be measured. Two more pieces of information, namely granularity and coarse-graining, are necessary for measuring the amount of complexity in a system (Marczyk 2011:39, 41). Ultimately the following is required to compute complexity (Marczyk 2011:44):

- Structure – it reflects the topology of the relationships between the components of the system. A system's state vector is a list of variables that are used to reflect its state.
- Entropy – it is the amount of information transmitted between variables of the system's state vector. It also represents the degree of organisation within a system.
- Coarse-graining – the type and number of variables chosen to describe the system.
- Granularity – the degree of precision one employs to measure the components of the state vector.

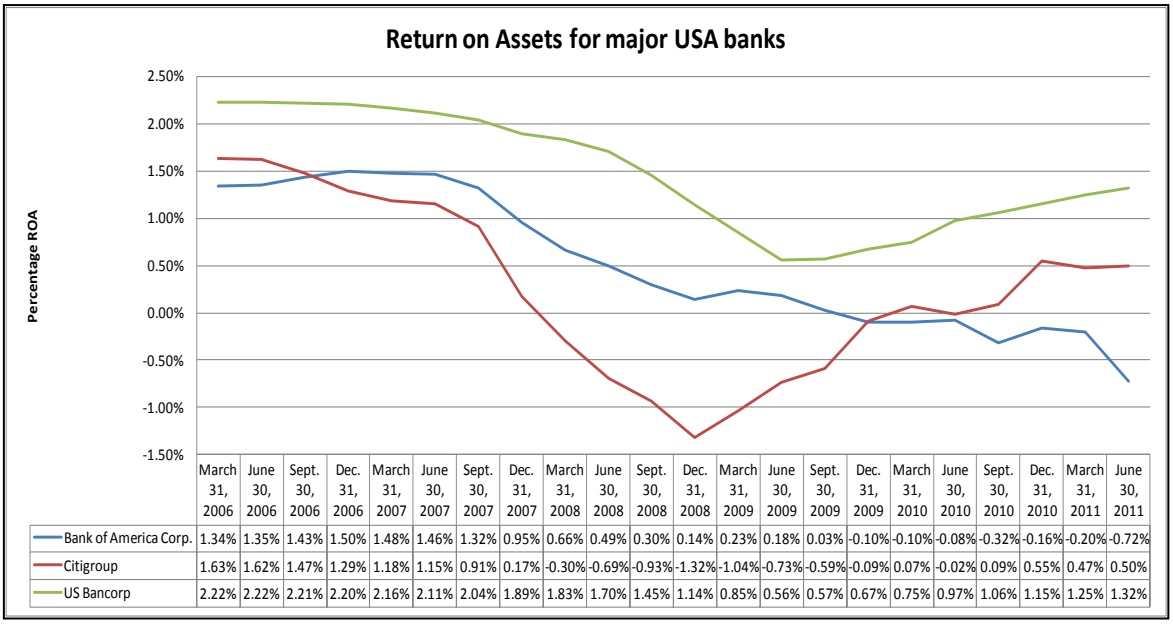
Figure 3: Internal components of a complicated mechanical wrist watch

To understand what complexity is, it is important to distinguish between a complicated system and a complex system. A complicated system does not necessarily possess a high amount of complexity. This can be explained by using a mechanical wrist watch as an example. Although a wrist watch comprises a large amount of internal components that are required to work together for the watch to tell the time, it does not imply a system with high complexity. In contrast, a wrist watch is a very deterministic system with very low entropy. An amount of uncertainty (entropy) within a system is required in order to be able to measure the amount of complexity that a system possesses (Marczyk 2011:63).

7.4 Why complexity?

It can be stated in biological terms that the capacity for an organism to co-evolve in its ecosystem is proportional to its complexity. When talking of biological systems one could equate fitness to complexity. But this is not the case with man-made systems. A 'fit' company can have a certain amount of complexity, but too much complexity can have devastating effects. High complexity needs to be managed and this is not always easy and can sometimes be impossible (Marczyk 2011:33). A good example is the latest economic crisis that started late in 2007 (The World Bank 2010), the result of which is still influencing the world today. Businesses and markets became unmanageable and ultimately failed. Steven Schwarcz, a Leverhulme visiting professor, stated in a lecture (Schwarcz 2010:1) that the greatest challenge to 21st Century financial regulation is complexity. Complexity has the potential to impair markets and investments in several interrelated ways. Information uncertainty, misalignment of interests and incentives among market participants, non-linear feedback and tight coupling that result in sudden unexpected market changes are a few reasons for these failures as mentioned by Schwarcz. These failures are similar to those that engineers face when working with systems that possess high complexity and have non-linear feedback effects (Schwarcz 2010:8). What makes these failures even worse is the fact that markets and businesses are interconnected and interactive. A domino-effect is created when say for example one market defaults on its obligations to another market participant which then causes that specific market participant to default on its obligations and so on (Schwarcz 2010:6, 7). Schwarcz confirms Miragliotta and Perona's statement by saying that the increase in complexity in financial markets is a result of the response to investors who demand securities that meet their personal investment criteria. An example of this domino-effect is portrayed in the figure below. Three major banks in the United States of America (USA) are represented. It can clearly be seen how all three of the banks' Return on Assets (ROA) dropped more or less simultaneously at the start of the recent economic crisis in late 2007.

Figure 4: Return on Assets for major USA banks



	March 31, 2006	June 30, 2006	Sept. 30, 2006	Dec. 31, 2006	March 31, 2007	June 30, 2007	Sept. 30, 2007	Dec. 31, 2007	March 31, 2008	June 30, 2008	Sept. 30, 2008	Dec. 31, 2008	March 31, 2009	June 30, 2009	Sept. 30, 2009	Dec. 31, 2009	March 31, 2010	June 30, 2010	Sept. 30, 2010	Dec. 31, 2010	March 31, 2011	June 30, 2011
Bank of America Corp.	1.34%	1.35%	1.43%	1.50%	1.48%	1.46%	1.32%	0.95%	0.66%	0.49%	0.30%	0.14%	0.23%	0.18%	0.03%	-0.10%	-0.10%	-0.08%	-0.32%	-0.16%	-0.20%	-0.72%
Citigroup	1.63%	1.62%	1.47%	1.29%	1.18%	1.15%	0.91%	0.17%	-0.30%	-0.69%	-0.93%	-1.32%	-1.04%	-0.73%	-0.59%	-0.09%	0.07%	-0.02%	0.09%	0.55%	0.47%	0.50%
US Bancorp	2.22%	2.22%	2.21%	2.20%	2.16%	2.11%	2.04%	1.89%	1.83%	1.70%	1.45%	1.14%	0.85%	0.56%	0.57%	0.67%	0.75%	0.97%	1.06%	1.15%	1.25%	1.32%

Because of this domino-effect, an IE would want to analyse the macro-economic ecosystem within which a business is operated. This will help to determine which applicable optimisation strategies should be implemented within a scoped business system in order to create a sustainable business system. A key mistake that many people make is to try to micro-manage businesses, markets and economies without a holistic view (Marczyk 2011:34) and acknowledgment of correlations among businesses and markets. The latest financial crisis is a clear indication of this flaw. Financial institutions failed to see not only the interconnectedness among banks and non-bank financial firms but also the interaction that financial firms have with other markets. As mentioned earlier, what made this financial crisis even more devastating is the fact that these failures combined to facilitate the transmission of economic shocks (Schwarcz 2010:6, 7).

A macro-economic complexity analysis will take the amount of uncertainty of the macro-economic ecosystem into account while identifying the key complexity contributors that need to be addressed in order to diminish fragility within a business. This philosophy can be logically outlined in the following equation (Marczyk 2011:92):

$$F = U_{Eco} * C_{BS}$$

Where:

F = Fragility

U_{Eco} = Uncertainty of macro-economic ecosystem

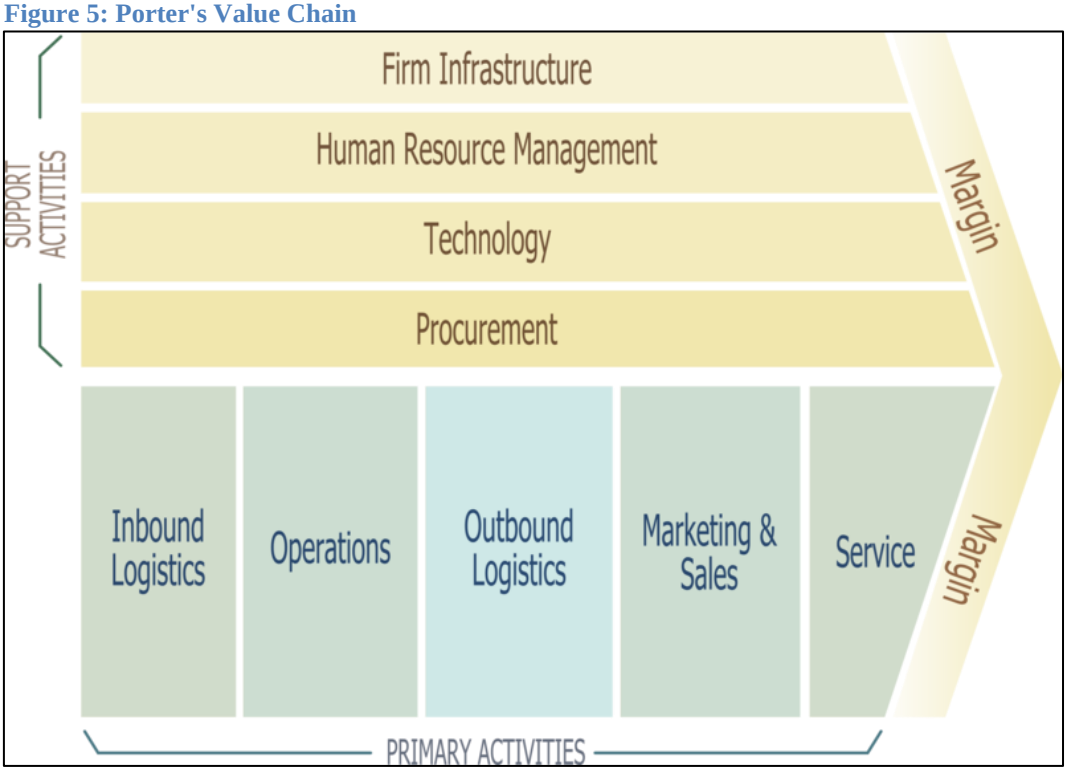
C_{BS} = Complexity of business system

Fragility (vulnerability) is the replacement of risk and the entire conceptual infrastructure that revolves around it. The difference between risk and fragility is the fact that fragility can be computed. Because fragility can be computed, it can be rationally managed (Marczyk 2011:95). A fragile business is more prone to default, especially in times of an economic crisis. The only sensible strategy for an IE is to reduce the complexity of a business system so that the business can become less fragile (Marczyk 2011:92).

7.5 Industrial engineering application

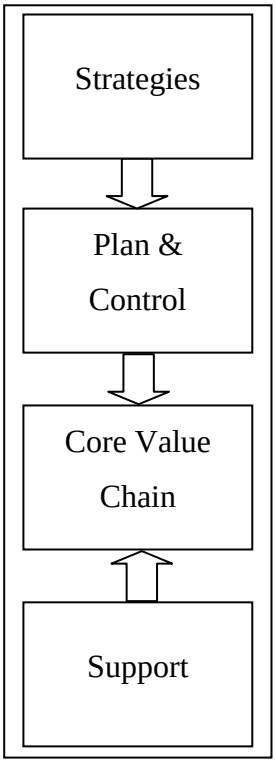
Porter's Value Chain has been widely adopted by businesses as a mechanism to understand and comprehend complexity within a business system and to structure the business in order to gain a competitive advantage (Van Rensburg 2009:1). Porter's Value Chain can be used to obtain a process view of the interactions between the various organisations that can be found in a business. The model illustrates the flow of inputs and outputs ultimately necessary to create a value added product or service. According to Michael Porter, the necessary activities that are required to transform inputs into valuable outputs can be categorised into primary and support activities as illustrated below (Miller and Porter 1985):

Figure 5: Porter's Value Chain



An IE is responsible for determining applicable strategies that will ensure that the core value chain of a business is operating optimally. The implementation of the applicable strategies needs to be planned and managed/controlled on a continuous basis to ensure a sustainable business system that creates value for its shareholders. Ultimately, the manner in which core value chain activities are carried out determines the costs that a business will incur and also has an impact on a business's profits (Institute for Manufacturing 2011). To illustrate the involvement of IE activities, Porter's Value Chain was improved by Prof. Antonie van Rensburg, a senior lecturer in the University of Pretoria's Department of Industrial and Systems Engineering (Van Rensburg 2011). The following figure depicts the improved Porter's Value Chain:

Figure 6: Improved Porter's Value Chain



An IE typically monitors and analyses various business Key Performance Indicators (KPIs) in order to determine applicable optimisation strategies. KPIs are indicators that give an overhead view of a business's performance to executives and shareholders. Such KPIs may include financial indicators that represent the money aspect that an IE needs to manage together with the man, machine and business process aspects of a business. Typical profit and loss-type data, such as the following are used for such financial indicators (Marczyk 2011:117, 118):

Main financial data:

- Orders
- Backlog end of period
- Value of production
- Revenues
- Earnings before the deduction of interest, tax and amortisation expenses (EBITA)
- Earnings before interest and tax (EBIT)
- Net attributable group profit
- Costs for purchases
- Costs for services

- Personnel costs
- Depreciation and impairment
- Other operating costs
- Financial expense
- Intangible assets
- Tangible assets
- Trade receivables
- Other receivables
- Inventories
- Work in progress
- Cash and cash equivalents
- Trade payables
- Other borrowings
- Total assets
- Shareholders' equity
- Net capital employed
- Net debt
- Cash-flow from operating activities
- Investment in non-current assets
- Total employees
- Number of plants
- Number of stores
- Number of customer transactions
- Total subsidiary companies

Ratios:

- Return on investment (ROI)
- Return on equity (ROE)
- Return on sales (ROS)
- Economic value added (EVA®)
- Debt to equity

Market capitalisation and shares

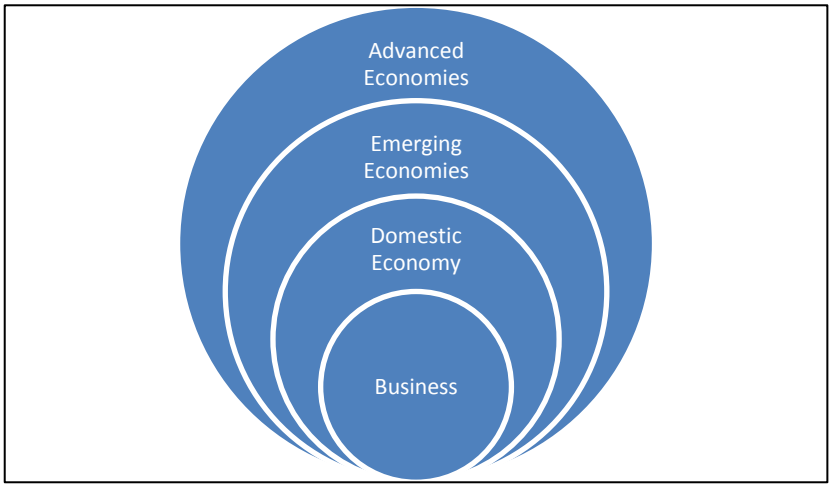
- Market capitalisation
- Price-to-earnings (P/E) ratio
- Earnings per basic share
- Earnings per diluted share
- Dividend per share

Other data:

- Total research and development costs

These types of data can be found in any business's financial statements. An IE would, for example, analyse a business's Income Statement and Balance Sheet to determine which of the above financial drivers have the greatest influence on the revenue and cost of a business. The IE would then accordingly determine which optimisation strategies to implement in order to improve the business' performance. But having a holistic approach to analysing a business's performance should not be ignored. An IE cannot use a bottom-up approach to micro-manage and optimise a business by looking at internal financial data only. When using such an approach 'hidden' relationships between business parameters and influential macro-economic parameters are not exposed and can therefore not be managed. This may result in the failure of a business. An IE must determine a Business Landscape to examine whether there are external factors that are influencing the performance of a business. Because of the extensive interconnectedness of businesses and markets, not only domestically but globally as well, today's businesses must be seen in a macro-economic ecosystem context. A typical business landscape is illustrated below:

Figure 7: An example of a typical business landscape



Such dense interconnectedness in a business landscape ensures a high amount of complexity in a macro-economic ecosystem within which a business is operated. It is impossible to predict the future (Marczyk 2011:11). Attempting to forecast in such a complex and entropy driven environment is very daring and would most probably give unreliable results. In order for an IE to establish and maintain a sustainable business, it is of the utmost importance to determine the amount of complexity that such a business landscape possesses. An IE must also determine which business parameters have the strongest relationships (correlations) with external macro-economic parameters. Only then can the IE begin to reduce and manage the complexity of a business in order for it to become less fragile.

7.6 Existing case studies

High complexity is only an asset if one is able to manage and control it. For this reason businesses are striving to be less complex in order to be more manageable. An example of a company that declared war on complexity is General Motors (GM) in the United States. They had too many options to choose from and too few people to afford it. After the government had forced GM to file for bankruptcy in mid 2009, the company decided to make drastic changes. A noticeable change was the reduction of complexity. This allowed GM to make a remarkable comeback (Mariotti 2011). This comeback is supported by the following numbers:

Table 1: Percentage change in various figures of GM after complexity had been decreased

	GM 2008	GM 2011	% Change
Number of car "brands" (badges)	8	4	50%
Number of car models	86	49	43%
Number of car plants in the US	47	32	32%
Number of US union employees	62,000	49,000	21%
Number of global employees	263,000	208,000	21%
Number of cars produced	2,200,000	2,400,000	8%
Cars per employee/year	8.64	11.53	25%
Cost of sales ($ billions)	$43.50	$33.80	22%
Sales revenue ($ billions)	$38.20	$39.40	3%
Profit/Loss ($ billions)	($15.50)	$2.50	720%
Sales per employee	$145,000	$189,000	23%
Profit per employee	($59,000)	$12,000	592%

The term "War on Complexity" was taken to heart by Theresa Metty who made this statement in an address after she had moved from IBM to Motorola. When Metty arrived at Motorola she found that they had not yet made the switch from analogue to digital mobile phones. This led to a surge in innovation in attempts to regain a market share from Nokia. Even though the intention was good, the result was a drastic increase in Motorola's complexity. One particular mobile phone had the following attributes that added to the amount of complexity:

- Over 100 different factory configurations
- Four housing colours
- Thirty software versions
- No software postponement
- No hardware postponement
- Non-standard IC, display, battery
- Lead-time of four-plus weeks for components from suppliers

Such a product will create forecasting and production headaches for any company. In order to decrease complexity Motorola implemented solutions such as opting for fewer products, more standard-parts usage and more re-use of products from other phones to name but a few (Mariotti 2008:54, 55).

The type of business an industrial engineer finds himself in does not matter. The fact is that a decrease in complexity, as proven by the GM and Motorola cases, will have a positive outcome. This includes the following (Dover 2008):

- Increased profits and performance
- Better employee morale
- More satisfying work
- Increased sustainability within a business

7.7 How to analyse, interpret and manage/reduce complexity

Ian Dover, founder of the Simpler Management Institute in Australia, summarises managing of complication and complexity as three options (Dover 2008):

- Do nothing and accept the higher costs, lower profits and low staff morale.
- Introduce more sophisticated systems to manage the rising complexity.
- Reduce or remove as much of the unnecessary complexity as possible.

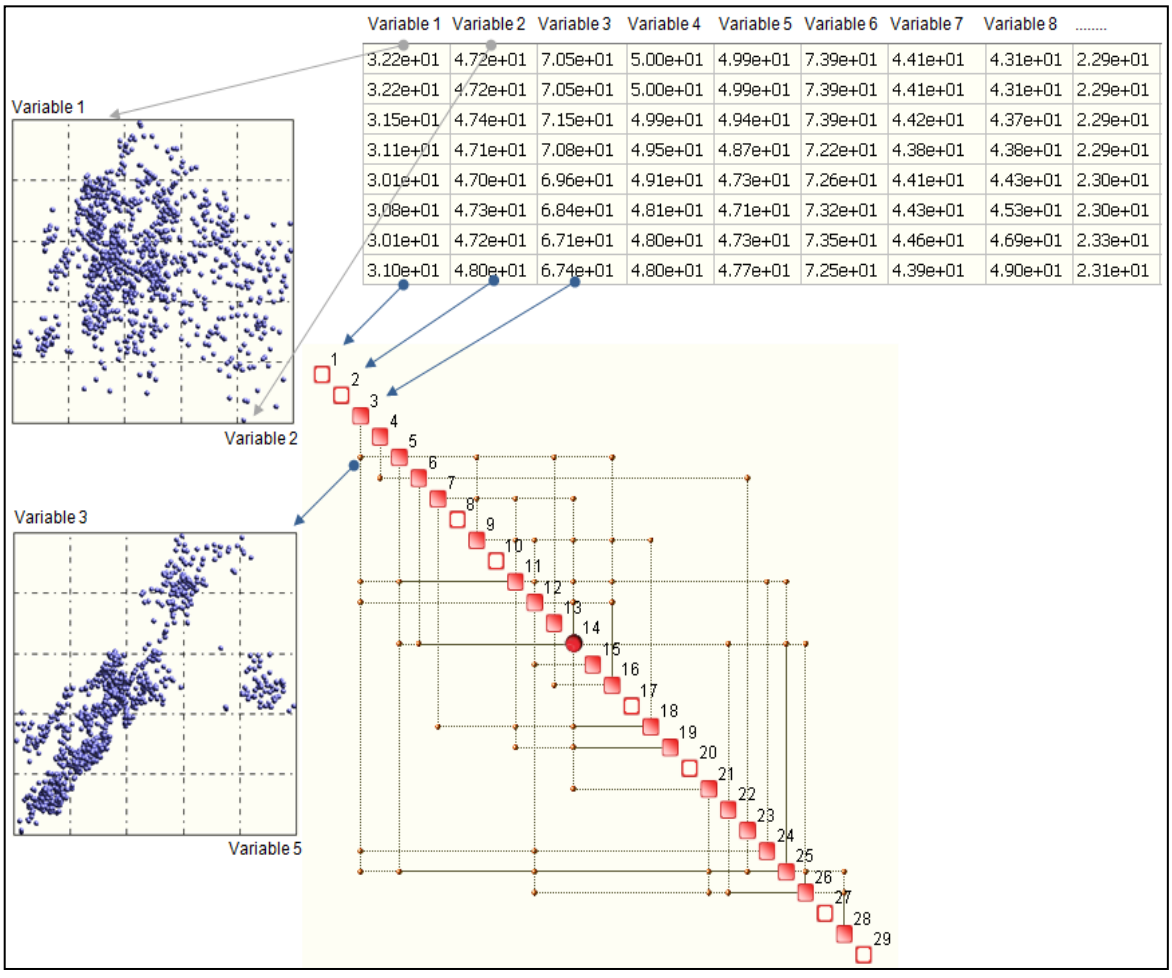
The third option allows any business to simplify before applying technology and delivers the greatest performance and profit improvements. One way of implementing this option is to apply five key principles that were developed by the Simpler Business Institute. The following five key principles will help to analyse, implement and sustain a simpler business (Dover 2010:20):

- Think the 80/20 Rule – "strive for the most from the least". This thinking should be applied to sales, marketing, development, procurement, production, distribution, people, finance and, in essence, to all aspects that you can think of in a business.
- Instigate simple, consistent problem solving. Business employees must propagate the habit of bringing solutions to the table rather than problems so that a simpler business can be created.
- Get everyone focused on Customer Value. Customer Value should be simply defined as "the things we do that make our customers more successful in their own eyes". This approach would lead to beneficial discussions about the value that the business creates or could create.

- Continuously seek to remove just the few "main constraints" of a business's processes. Much money can then be saved during process improvement.
- Simplify things before automating them. Automation can increase the amount of complexity in a business, upset employees and may even lead to a lower return on capital.

Another way in which to implement Dover's third option is to use a business intelligence tool such as OntoSpace created by Ontonix. As mentioned earlier, a map is a great way to define and illustrate the structure of a system. The first task of OntoSpace is to determine the structure (map) of the information flow of a system. An example of such a map, also known as a Process Map, is illustrated in the figure below.

Figure 8: Data structure and corresponding Process Map and examples of significant and insignificant scatter plots



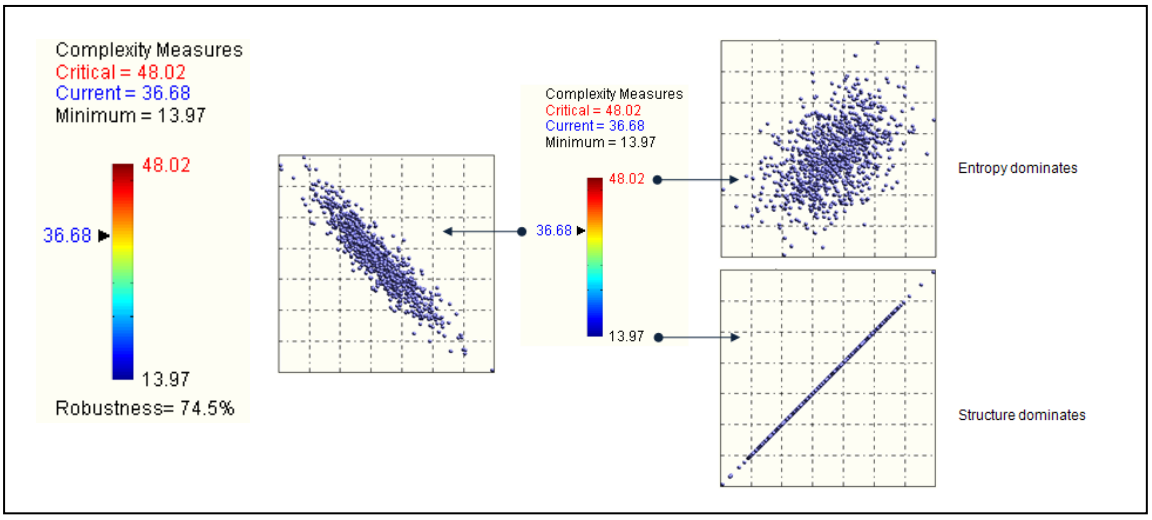
Variable 1	Variable 2	Variable 3	Variable 4	Variable 5	Variable 6	Variable 7	Variable 8	.....
3.22e+01	4.72e+01	7.05e+01	5.00e+01	4.99e+01	7.39e+01	4.41e+01	4.31e+01	2.29e+01
3.22e+01	4.72e+01	7.05e+01	5.00e+01	4.99e+01	7.39e+01	4.41e+01	4.31e+01	2.29e+01
3.15e+01	4.74e+01	7.15e+01	4.99e+01	4.94e+01	7.39e+01	4.42e+01	4.37e+01	2.29e+01
3.11e+01	4.71e+01	7.08e+01	4.95e+01	4.87e+01	7.22e+01	4.38e+01	4.38e+01	2.29e+01
3.01e+01	4.70e+01	6.96e+01	4.91e+01	4.73e+01	7.26e+01	4.41e+01	4.43e+01	2.30e+01
3.08e+01	4.73e+01	6.84e+01	4.81e+01	4.71e+01	7.32e+01	4.43e+01	4.53e+01	2.30e+01
3.01e+01	4.72e+01	6.71e+01	4.80e+01	4.73e+01	7.35e+01	4.46e+01	4.69e+01	2.33e+01
3.10e+01	4.80e+01	6.74e+01	4.80e+01	4.77e+01	7.25e+01	4.39e+01	4.90e+01	2.31e+01

The various data variables are displayed as nodes along the diagonal. Horizontal or vertical links, which represent relationships between variables, are drawn between the nodes in such a manner that null crossings are minimal. When two variables are related, the corresponding link is marked by a connector/dot (Marczyk 2011:61). Where links cross without a connecter, it represents a null-crossing. Two examples of scatter plots can be found in the figure on the left. The top scatter plot illustrates two variables that do not have a significant relationship with each other or with the rest of the data set and thus no links from these variables are drawn on the map. However, the bottom scatter plot illustrates a strong enough relationship for a link to be drawn. For some nodes a circle is used to indicate a variable. Such a variable is known as a 'hub'. Hubs are extremely important because they possess the highest number of relationships in a map. It is crucial to identify a system's hubs. In fragile systems, where the amount of relationships (density) that non-hub variables possess is much lower than that of the hub variables, it all rests on the hubs' shoulders. The loss of a hub may have a devastating effect on a system. Any trauma (or cure) that originates from a hub will quickly spread throughout the system (Marczyk 2011:62, 68). It is important to mention that managers and engineers are often concerned with the strongest points in a system (the hubs) only and tend to forget about the vulnerable points that are more prone to default than the strong ones. The number of relationships is called a degree. The strength of a link corresponds to the amount of information an image conveys (Marczyk 2011:62, 67). Density, a valuable property of the map, can be used to identify certain situations such as the following (Marczyk 2011:65):

- A complicated system
- High redundancy – most variables have numerous relationships with all other variables.
- Compromising certain nodes will not be easily done because a specific node might have relationships with various other nodes and thus it can be difficult to satisfy multiple objectives and constraints.
- Traumas or stresses get easily transferred.
- It may indicate a system that can be very difficult to manage.

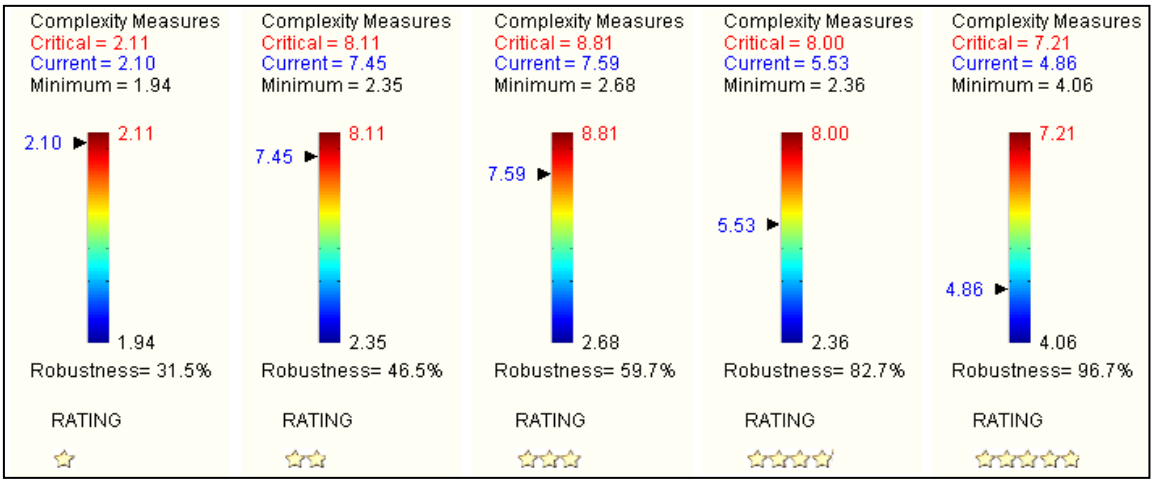
Apart from the Process Map, complexity measures as well as a robustness measure can be located. The robustness measure gives no indication of the performance of a system. It is merely a measurement of the resilience of the topology of information flow within a system – how well a system will be able to cope with a crisis (Marczyk 2011:65). Complexity measures are known as the critical, current and minimum complexity measurements. The critical measurement is the upper bound and indicates the maximum amount of complexity that a system can sustain. At this stage a system is entropy-driven and is being operated on the verge of collapse. On the opposite, when the current measurement is near the minimum complexity metric, also known as the lower bound, a system is operating in a deterministic manner (Marczyk 2011:64).

Figure 9: An example of Complexity measures and Robustness measure



There is another visual indicator that displays how a system is standing in terms of complexity. When a system is analysed it is given a Complexity Rating in the form of stars. A complexity rating quantifies the system's ability to preserve its structure and functionality (Marczyk 2011:52). A system can receive between one and five stars and can be categorised as follows (Ontonix 2011b):

Figure 10: An example of the five different Complexity Rating categories



Rating: ☆

Business complexity is very high. The business is globally close to its critical complexity. Its structure is weak. The business is unsustainable and very fragile. Exposure is very high and the business is highly inefficient and very difficult to manage. It is impossible to make forecasts and define realistic goals.

Rating: ☆☆

Business complexity is high. The business is highly complex and difficult to manage and control. Exposure and inefficiency are high. The structure of the business is fragile and hence vulnerable. It is difficult to make forecasts.

Rating: ☆☆☆

Business complexity is medium. The structure of the business is fairly robust. Performance predictability is acceptable. Exposure is moderate.

Rating: ☆☆☆☆

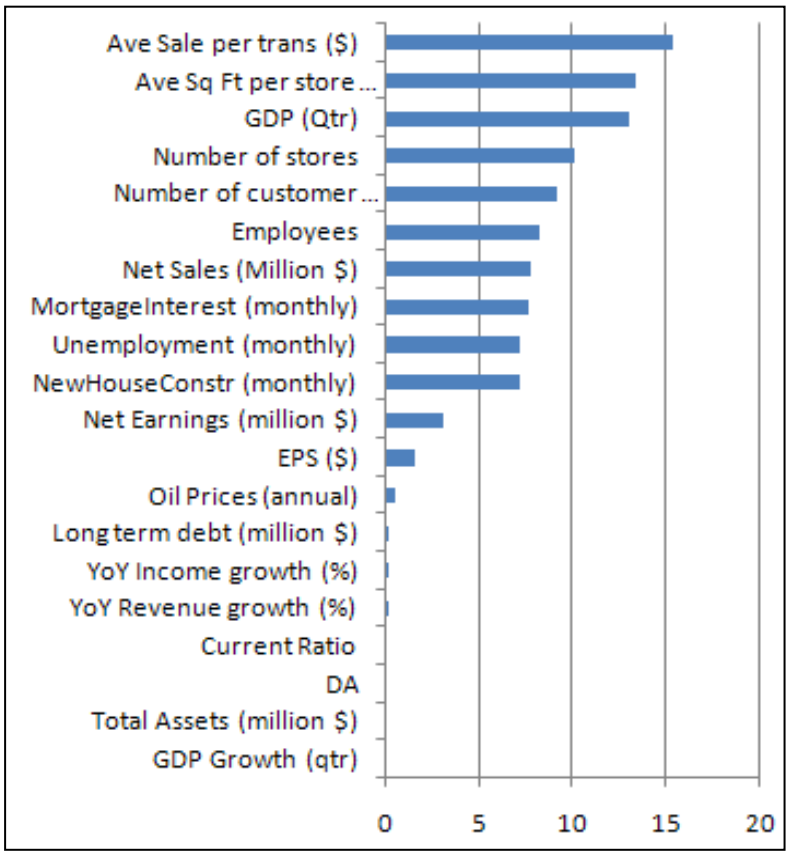
Business complexity is low. This indicates a robust business structure. Predictability is high, exposure is low. Business sustainability and efficiency are quite high.

Rating: ☆☆☆☆☆

Business complexity is very low. This business structure is very strong. Exposure is very low. The business is manageable and it is possible to make credible forecasts. The business is potentially highly sustainable and efficient.

Included in the static analysis is a very handy tool namely the Complexity Profile that gives an indication of how much each variable in the system is contributing to the total complexity. With the knowledge gained by this chart, it can easily be determined which variables need attention in terms of complexity management. Figure 11 illustrates such an example of a Complexity Profile.

Figure 11: An example of a Complexity Profile



When a dynamic (time-dependent) analysis is conducted data is divided into windows (steps). The number of samples in the data sets, the chosen window size and overlap will determine how many steps will be generated. The window overlap option allows the user to analyse a specific window while taking into account some information from a previous window. The window size and overlap depends on the specific characteristic time-constants of the underlying process or phenomenon. As in the static analysis, OntoSpace will generate a Process Map and compute the amount of complexity for each individual step (Marczyk 2011:71, 72). The figure below illustrates non-overlapping windows. A window size of 3 and overlap of 0 is chosen for this example analysis.

Figure 12: An example of non-overlapping windows

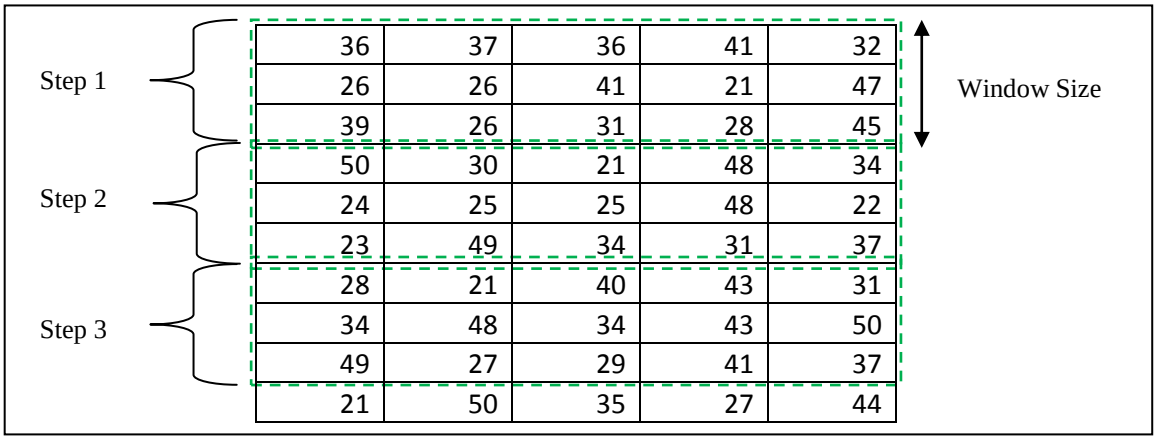
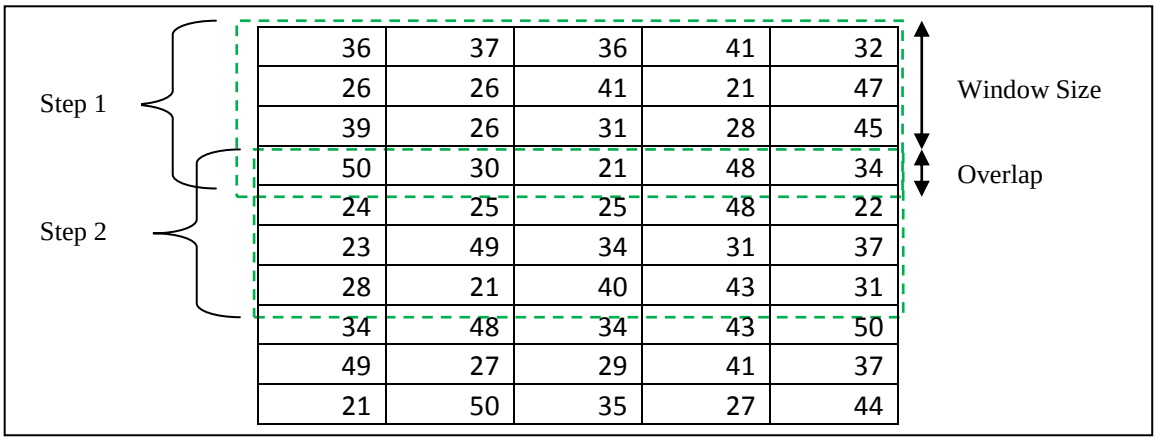


Figure 13: An example of overlapping windows

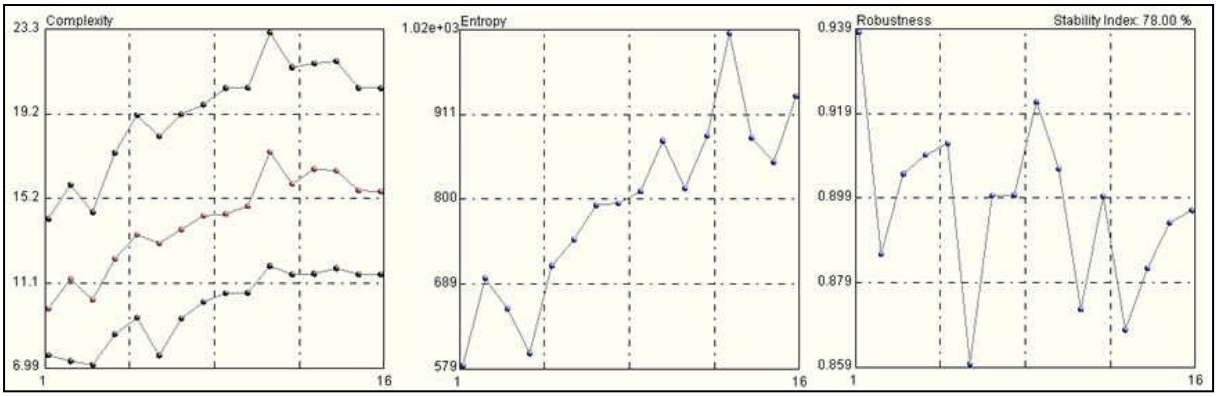


In the figure above it can be seen how an overlap is used to take information from a previous step into account. In this example a window size of 4 and overlap of 1 is chosen.

When conducting a dynamic analysis, three additional results are provided by OntoSpace. These results include:

- An Evolution of Complexity chart
- An Evolution of Entropy chart
- An Evolution of Robustness chart

Figure 14: Examples of the Evolution charts of Complexity, Entropy and Robustness respectively



The figure above illustrates examples of the change in the three ratings over time. In the Evolution of Complexity chart the upper and lower curves represent the upper complexity bound and lower complexity bound respectively. At the top right hand corner of the figure is a Stability Index. This index is a measurement of how stable a business is at the time of analysis (Marczyk 2011:101).

8. Development of a macro-prudential instrument

OntoSpace complexity analysis was conducted in order to illustrate the analysis and interpretation of a macro-economic ecosystem's complexity; and the impact global parameters have on businesses' performance because of the interconnectedness and interaction between businesses and markets that operate in such an ecosystem; and the functionality of OntoSpace as a systemic macro-prudential instrument.

8.1 Segmentation

For this research report the March 2011 *Financial Stability Review*, published by the South African Reserve Bank (SARB), was used to help with the segmentation of a macro-economic ecosystem within which South African businesses operate. The macro-economic ecosystem can be segmented in the following three main areas:

- Financial and economic developments in advanced economies.
- Financial and economic developments in emerging markets and developing countries.
- A domestic macro-prudential analysis.

Each main area is then again segmented into various other sub-areas that contribute to the main area. The "Financial and economic developments in advanced economies" area is segmented as follows:

- Economic growth
- Vulnerabilities in the euro area
- Financial-sector fragility
- Global imbalances

The "Financial and economic developments in emerging markets and developing countries" area is segmented into two sub-areas, namely:

- Emerging-market economies
- Africa, sub-Saharan Africa and the Southern African Development Community region

The "Domestic macro-prudential analysis" area is further segmented into the following sub-areas:

- Indicators of real economic activity
- Confidence in the financial services sector
- Banking sector
- Insurance sector
- Bond and equity markets
- External sector
- Corporate sector
- Household sector
- Residential real-estate sector

8.2 Data mining

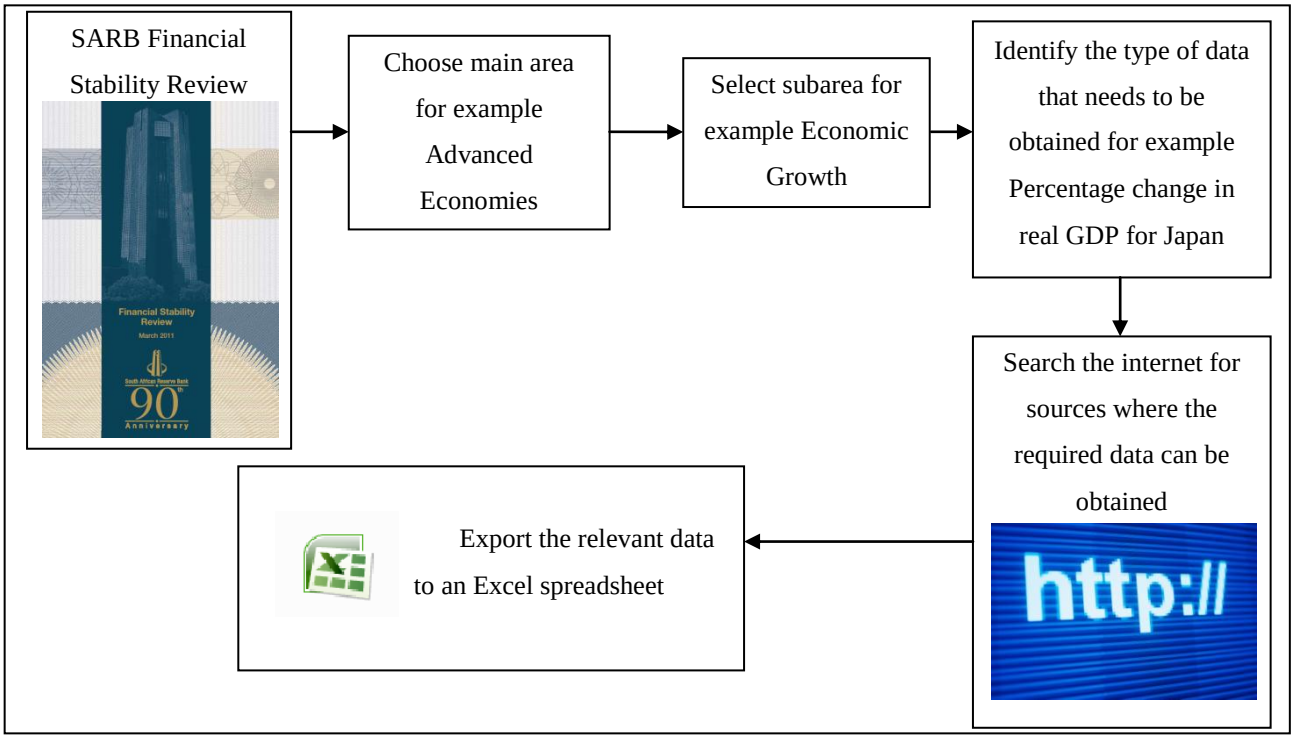
After the segmentation of the macro-economic ecosystem, data mining was commenced. Key indicator data within each segment was obtained from multiple sources. Data was obtained only from open sources that do not ask a fee for the use of their data. Therefore, some of the paid-for data that is used in certain segments was

not obtained and was thus not included in the analysis. Open sources data was obtained from include the following:

- The South African Reserve Bank
- Statistics South Africa
- The Bureau for Economic Research
- The International Monetary Fund
- Thompson Reuters/Jefferies
- S&P Case – Shiller
- The Food and Agriculture Organisation of the United States
- McGregor BFA
- Yahoo Finance
- The United States Federal Reserve System
- The United Kingdom Land Registry
- Ernst & Young

The typical path that was followed to obtain the necessary data is illustrated in the diagram below.

Diagram 2: Typical path followed to obtain data



After the data had been obtained from the various sources, it had to be prepared for input into OntoSpace. Data preparation included the deletion of unnecessary headings, date columns and the merging of various data sets into one where applicable, to name but a few. The time series that was chosen for the analysis ranges from January 2000 to December 2010. It was decided to use monthly values so that all data sets would have a high amount of samples that allowed a more in-depth analysis. The tables below are examples of an as-is data set and an OntoSpace-ready data set.

Table 2: An as-is data set

House Price Index report - All England & Wales (January 1995 - July 2011)					
Month	Index	Average Price (£)	Monthly Change (%)	Annual Change (%)	Sales Volume
Jan-95	100	62,364	-	-	50,099
Feb-95	101.6	63,337	1.6	-	50,514
Mar-95	101	62,981	-0.6	-	70,899
Apr-95	99.6	62,099	-1.4	-	59,909
May-95	99.8	62,223	0.2	-	67,289
Jun-95	99.6	62,097	-0.2	-	76,459
Jul-95	97.8	61,011	-1.7	-	67,389
Aug-95	96.9	60,447	-0.9	-	72,678
Sep-95	97.9	61,031	1	-	70,968
Oct-95	97.6	60,886	-0.2	-	64,399
Nov-95	97.6	60,838	-0.1	-	67,314
Dec-95	98.1	61,203	0.6	-	73,038

Table 3: An OntoSpace-ready data set

US House Price Index	UK House Price Index
33.59333333	127.2
33.59333333	128.3
33.59333333	130
34.47333333	131.9
34.47333333	133.1
34.47333333	134.3
35.22666667	135.4
35.22666667	136
35.22666667	136
36.02333333	136.3
36.02333333	137
36.02333333	138.2
36.7	139.7
36.7	140.4
36.7	141.1

The various OntoSpace-ready data sets of the different segments were then used in OntoSpace to conduct complexity analysis.

8.3 OntoSpace analysis

Several analyses were conducted to determine the structure of a system, identify system hubs, measure the distance from critical complexity to establish complexity ratings and analyse how business performance is impacted when operating in a specific business landscape. The analyses can be broken down accordingly:

- A "Financial and economic developments in advanced economies" segment analysis.
- A "Financial and economic developments in emerging markets and developing countries" segment individually.
- "A domestic macro-prudential analysis" segment analysis.
- A macro-economic ecosystem analysis where all the data sets of three main segments are combined.

Thereafter two businesses' data were each combined with that of each segment respectively to conduct an analysis and determine which factors in a specific segment are having an impact on the performance of a business which is operated in such a segment. A fundamental decision, namely choosing the number of fuzzy levels, has to be made when not only static but dynamic analysis as well are conducted. Only three possibilities for the number of fuzzy levels are available and the selection of one specific possibility depends on the resolution (level of trust) of the data. These three possibilities can be categorised as follows:

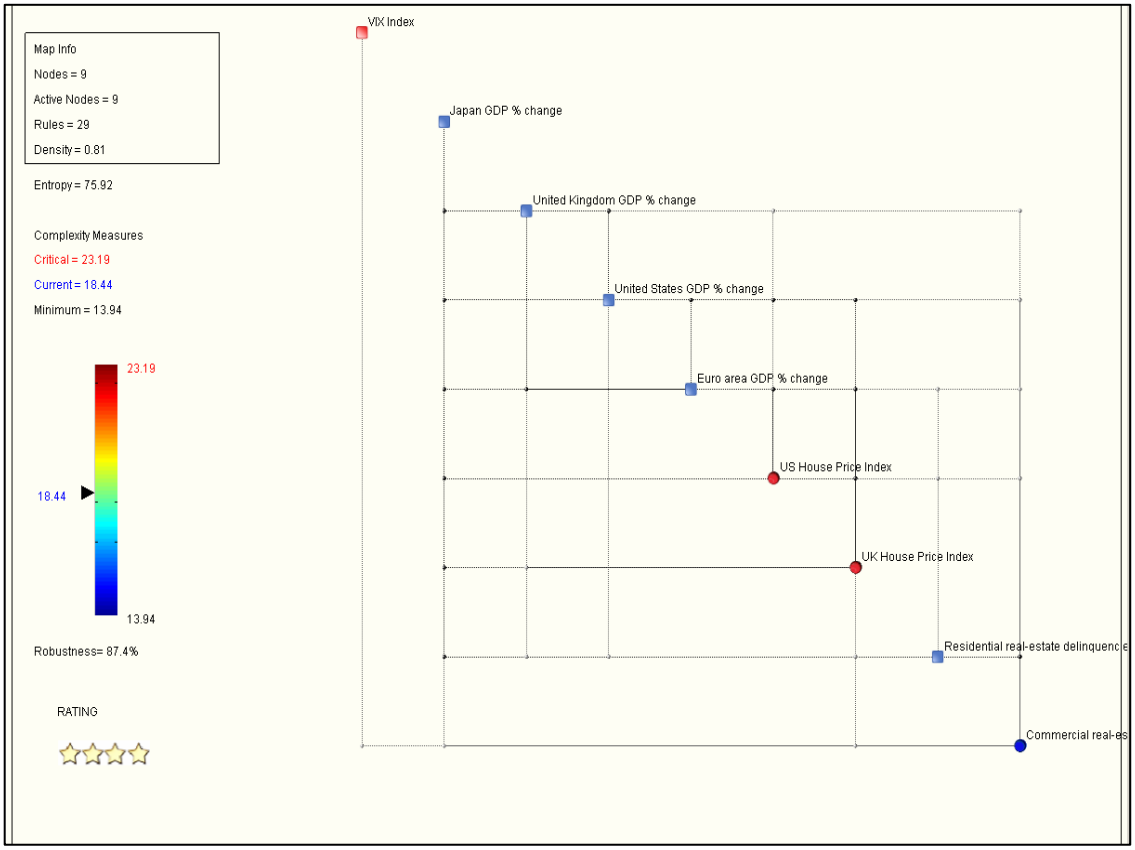
- 3 Fuzzy levels for when data sets have a small number of samples for example less than 9
- 5 Fuzzy levels for data sets that contain between 10 and 25 samples
- 7 Fuzzy levels for data sets that have a sample size greater than 49

Possibility number three (7 fuzzy levels) was selected for all the static as well as dynamic analyses.

8.3.1 Financial and economic developments in advanced economies

OntoSpace calculates the generalized correlation for each variable and then creates a process map accordingly (Van Rensburg 2011:9). The following figure illustrates the process map of the "Financial and economic developments in advanced economies" segment:

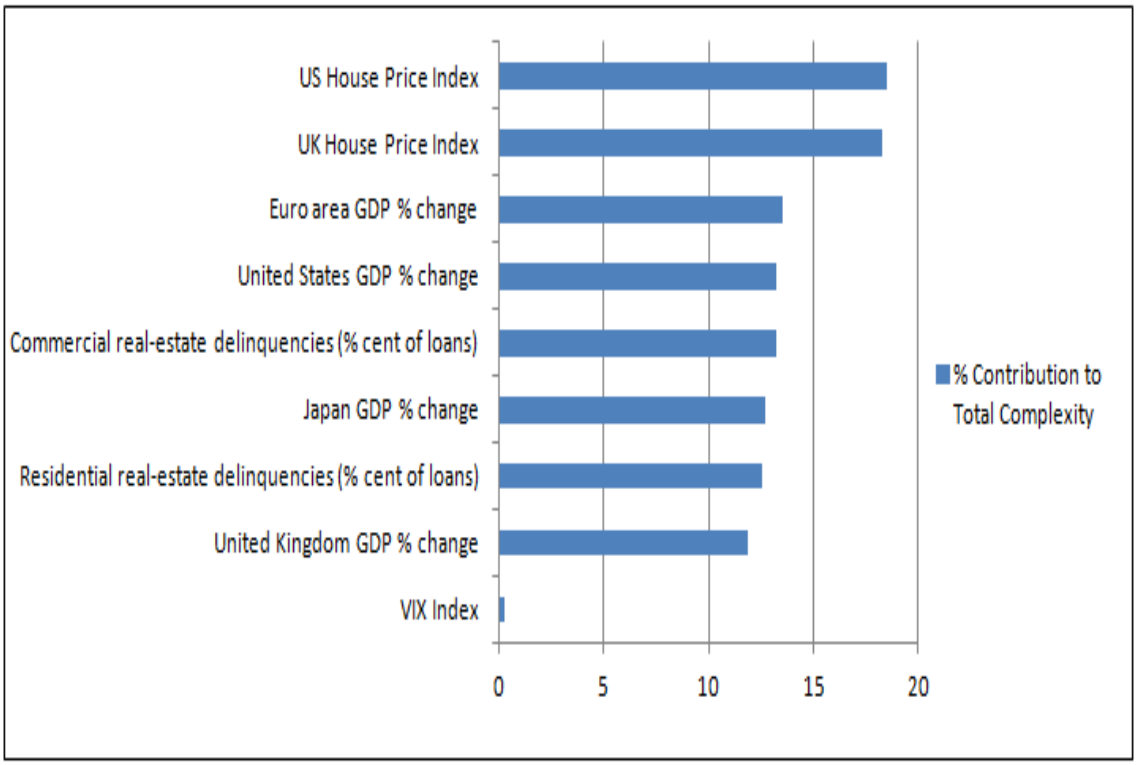
Figure 15: The "Financial and economic developments in advanced economies" segment process map



It can be seen from the process map that that the current complexity measurement (18.44) is more or less in the middle of the "advanced economies" system's critical (23.19) and minimum (13.94) complexity measurements, and therefore the four star complexity rating. This indicates that the system possesses a low amount of complexity and that the system has a robust structure. The latter is supported by the robustness measurement of 87.4 % which means that the system will most probably be able to comfortably cope with a crisis when it occurs. Forecasting within such an environment can be done with confidence because of the acceptable amount of entropy that the system possesses. This system's sustainability and efficiency is quite

high. It is important to note that there are no inactive (independent) nodes which mean that all of the variables in the data sets have at least one relationship with another variable. Because of this, the system's density is measured as 0.81. A density measurement above 0.5 indicates that it might be difficult to make changes within such a system and to manage it. In addition to the process map OntoSpace calculates the percentage contribution that each variable makes towards the total amount of complexity that the system possesses and displays it on a graph. This graph is known as the system's Complexity Profile. The figure below illustrates the complexity profile of the "advanced economies" segment:

Figure 16: The complexity profile of the "advanced economies" segment



The United States of America (US) House Price Index and the United Kingdom (UK) House Price Index, both identified as hubs by OntoSpace, are the two biggest contributors to the total amount of complexity. The Volatility Index (VIX Index) makes only a small contribution. OntoSpace also calculates all possible system variable pairs' generalized correlations. The ten variable pairs with the strongest relationships can be ranked as follows:

Table 4: The top ten generalized correlation variable pairs for the "advanced economies" segment

Variable 1	Variable 2	Generalized Correlation
Set 2: Japan GDP % change	Set 2: United States GDP % change	0.89
Set 3: US House Price Index	Set 3: UK House Price Index	0.84
Set 2: Japan GDP % change	Set 2: United Kingdom GDP % change	0.82
Set 2: United States GDP % change	Set 3: US House Price Index	0.81
Set 2: United States GDP % change	Set 3: UK House Price Index	0.8
Set 2: United States GDP % change	Set 2: Euro area GDP % change	0.8
Set 2: United Kingdom GDP % change	Set 2: United States GDP % change	0.8
Set 2: Japan GDP % change	Set 2: Euro area GDP % change	0.78
Set 2: Euro area GDP % change	Set 3: US House Price Index	0.78
Set 2: United Kingdom GDP % change	Set 2: Euro area GDP % change	0.78

From the table above it can be assumed that when something happens to Japan's Gross Domestic Product (GDP), it will also influence the US GDP and vice-versa because they have the strongest generalized correlation of all the variable pairs. A scatter plot of any variable pair can be obtained from OntoSpace. Scatter plots are used to illustrate how structured the information between two variables is. It is also possible to export the data of a specific scatter plot to Excel so that further data plotting, manipulation and analysis can be conducted. In Excel a trend line can be added to a scatter plot to illustrate if a variable pair is deprived of structure or has a strong generalized correlation. If most of the data points of a variable pair are grouped closely to the linear line, it is understood that the variable pair has a strong generalized correlation. The first image below illustrates the OntoSpace obtained scatter plot for the 'United States/Japan GDP % change' variable pair and the second image illustrates the Excel constructed scatter plot for the variable pair where a linear trend line has been added to illustrate the strong generalized correlation:

Figure 17: The OntoSpace obtained scatter plot for the 'US/Japan GDP % change' variable pair

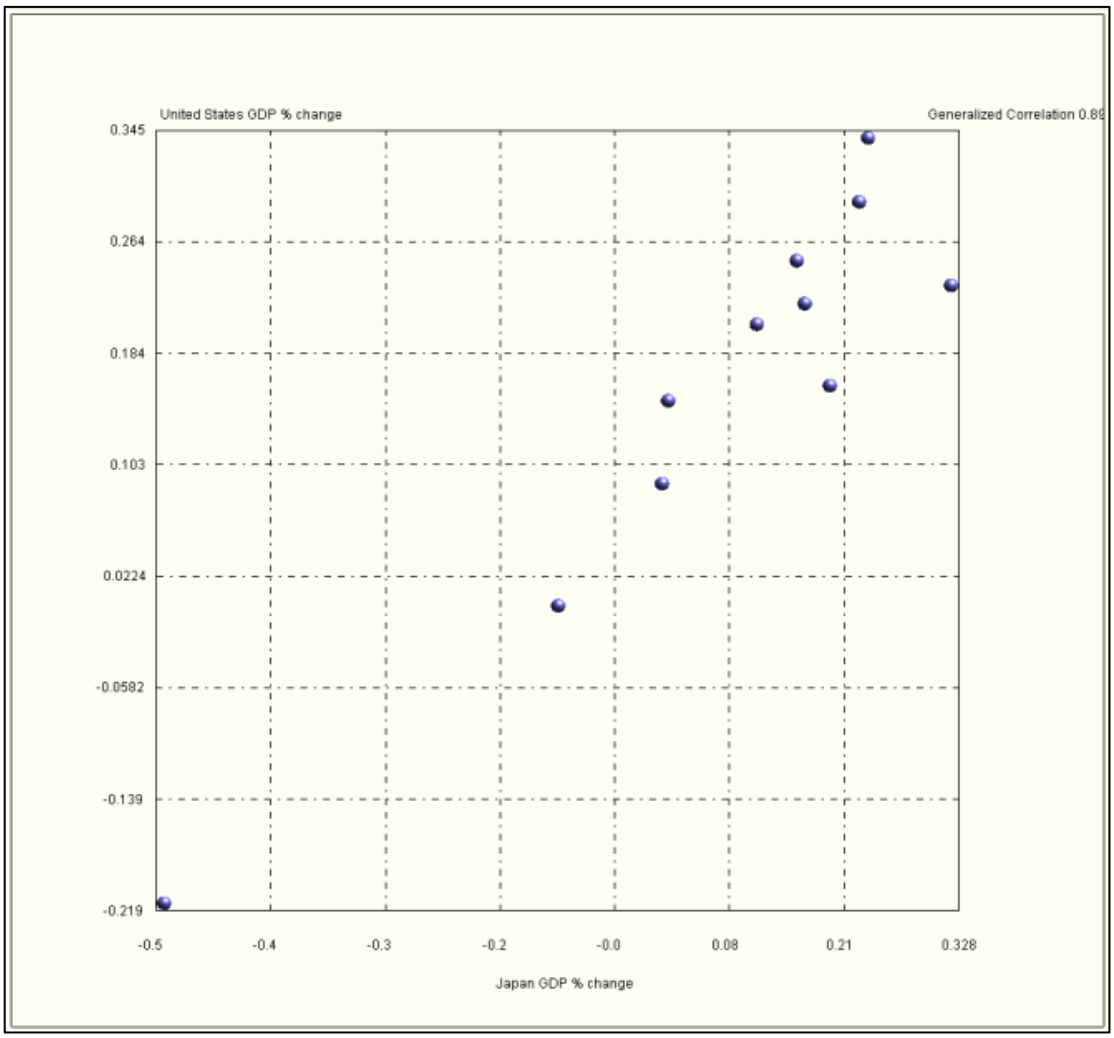
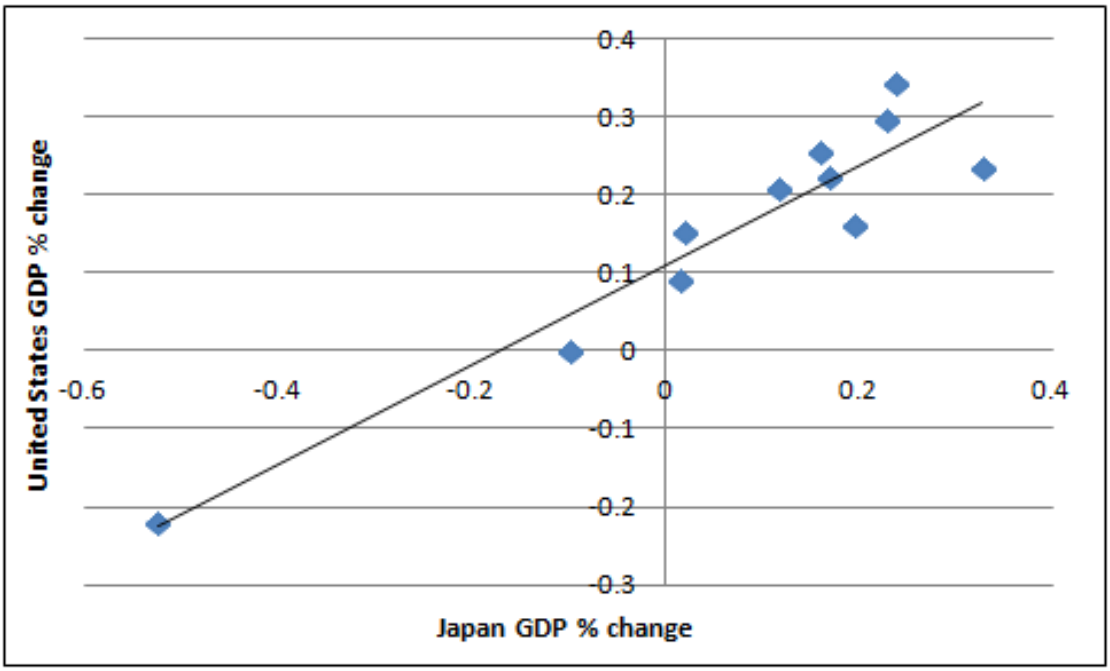
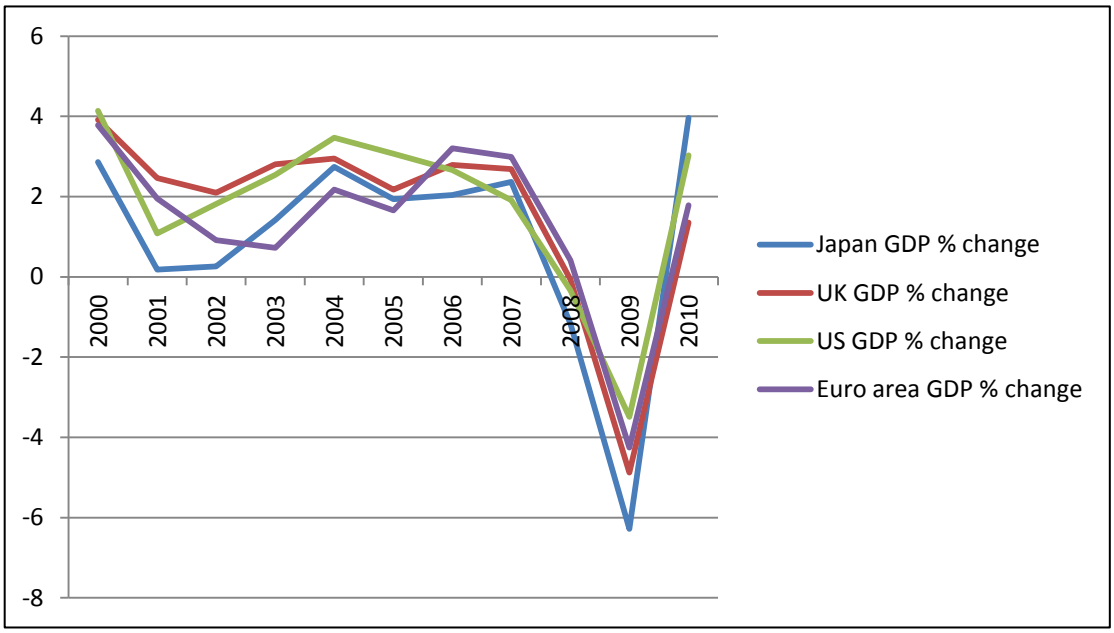


Figure 18: The Excel created scatter plot for the 'US/Japan GDP % change' variable pair



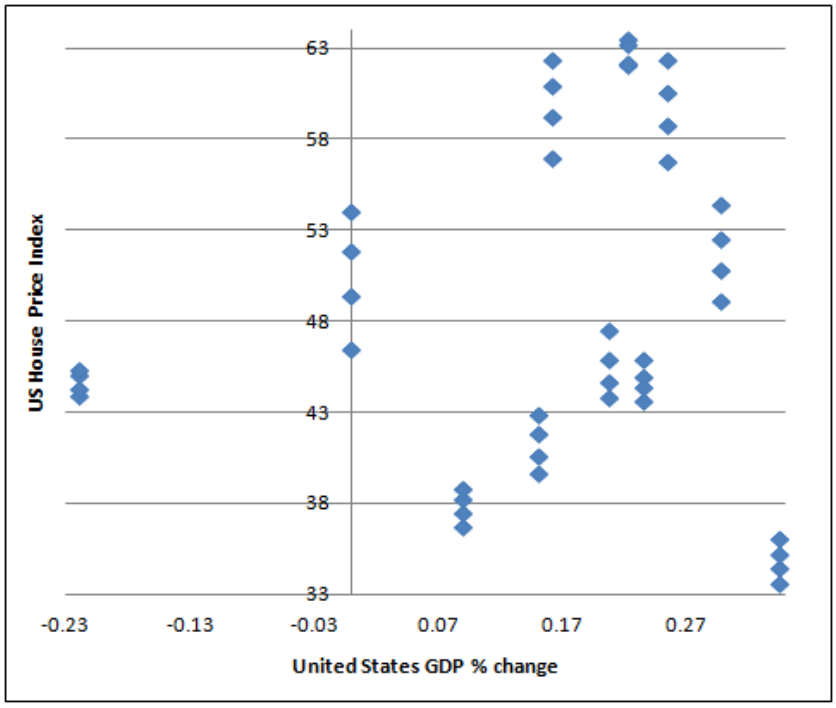
In figure 18 it can be seen how most of the data points of the 'United States/Japan GDP % change' variable pair are closely clustered together near the linear trend line and therefore they have the strongest generalized correlation value of 0.89. A graph was constructed from data that was obtained from the International Monetary Fund's website. The graph illustrates how closely the respective advanced economy GDP's percentage change follow the same trend. This graph can be seen in the following figure:

Figure 19: The respective advanced economy GDP's percentage change



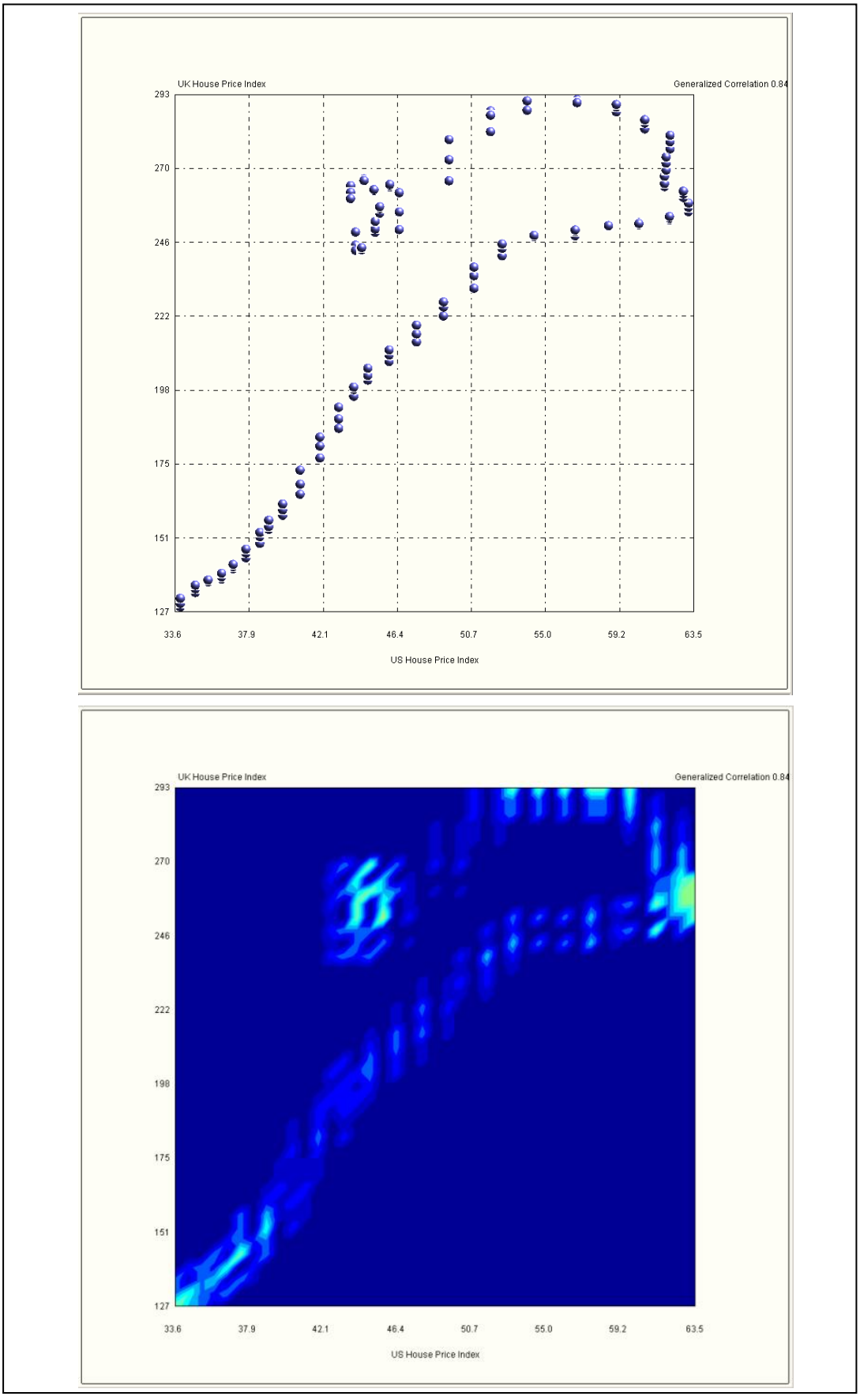
The economic production and growth that a country's GDP represents has a large impact on nearly everyone within that economy. However, the generalized correlations in table four indicates that the impact of a country's economic production and growth is not limited to the country's economy alone, but to the whole macro-economic ecosystem within which it operates. This is evident from visual interpretation of the graph above, where all of the advanced economy GDP's made a devastating drop in 2009. The US and UK House Price Index variables are also greatly influenced by the advanced economies' GDP variables and vice-versa as suggested by the generalized correlation table. It illustrates why it is necessary to not conduct micro-analysis within each data set alone but take all data set variables into consideration as a whole. The following scatter plot illustrates the strong generalized correlation of the 'US House Price Index/United States GDP % change' variable pair:

Figure 20: Scatter plot of the 'US House Price Index/United States GDP % change' variable pair



Although there are some open spaces that represent the presence of entropy in the system between the data points in the scatter plot, the majority of data points are clustered closely together in groups. Therefore, the calculated generalized correlation value of 0.81. The US and UK House Price Index variables also have a very strong generalized correlation which means that there are very little entropy between these two variables. A normal scatter plot (left) can be "pixelated" to transform a cloud of discrete data points into an image for better understanding of the relationships between variables. Below is the normal scatter plot (top) and "pixelated" scatter plot (bottom) for the 'US/UK House Price Index' variable pair:

Figure 21: The normal scatter plot (top) of the 'US /UK House Price Index' variable pair and the "pixelated" scatter plot (bottom)



For the dynamic analysis a window size of 60 and overlap size of 59 were used to ensure that smooth curves are obtained when the respective evolution charts are drawn. From the robustness evolution chart in OntoSpace a stability index value of 56.04% was obtained. This value tells us that the "advanced economies" segment was not very stable at the time of the analysis. This may be the result of rapid changes in the segment's structure, entropy or both. The following "advanced economies" evolution charts were obtained from the analysis:

Figure 22: Evolution of complexity chart of the "advanced economies" segment

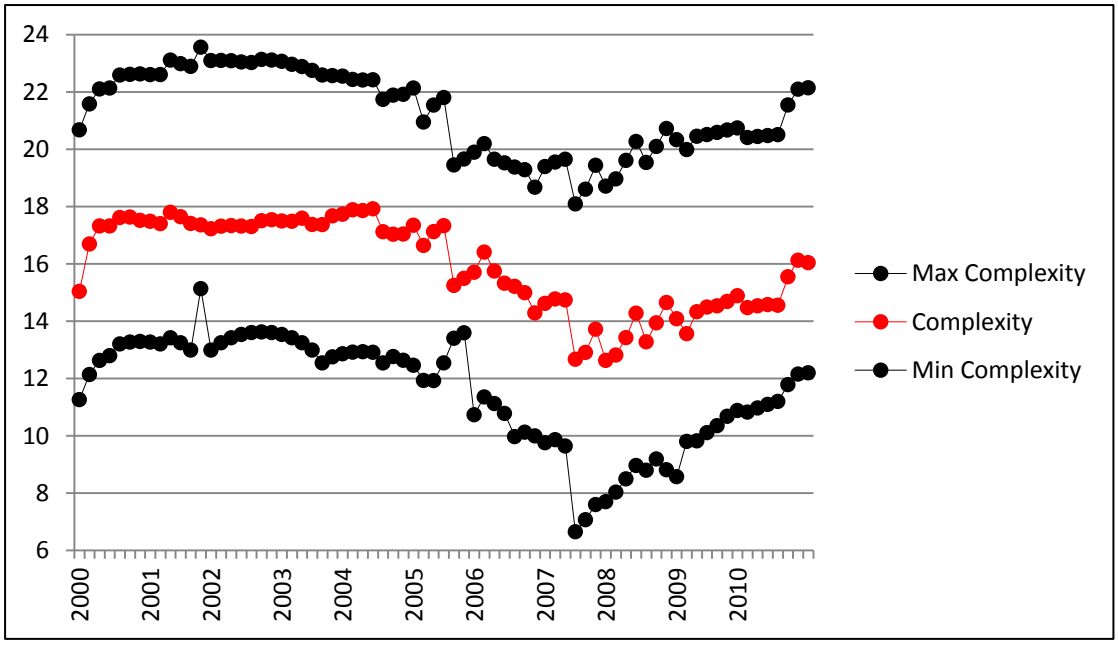


Figure 23: Evolution of entropy chart for the "advanced economies" segment

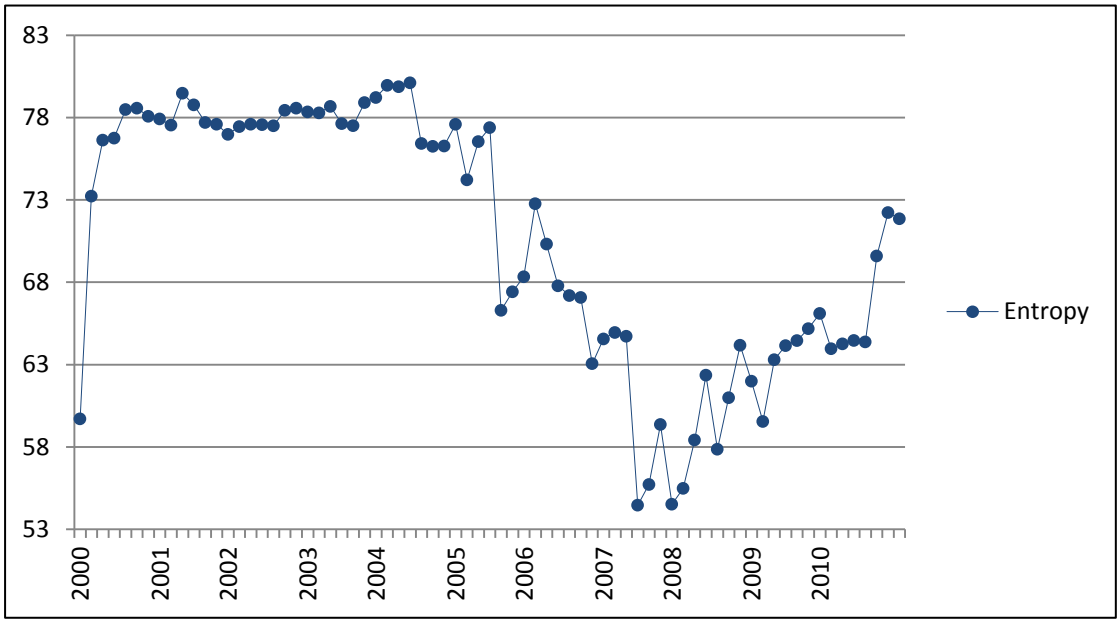
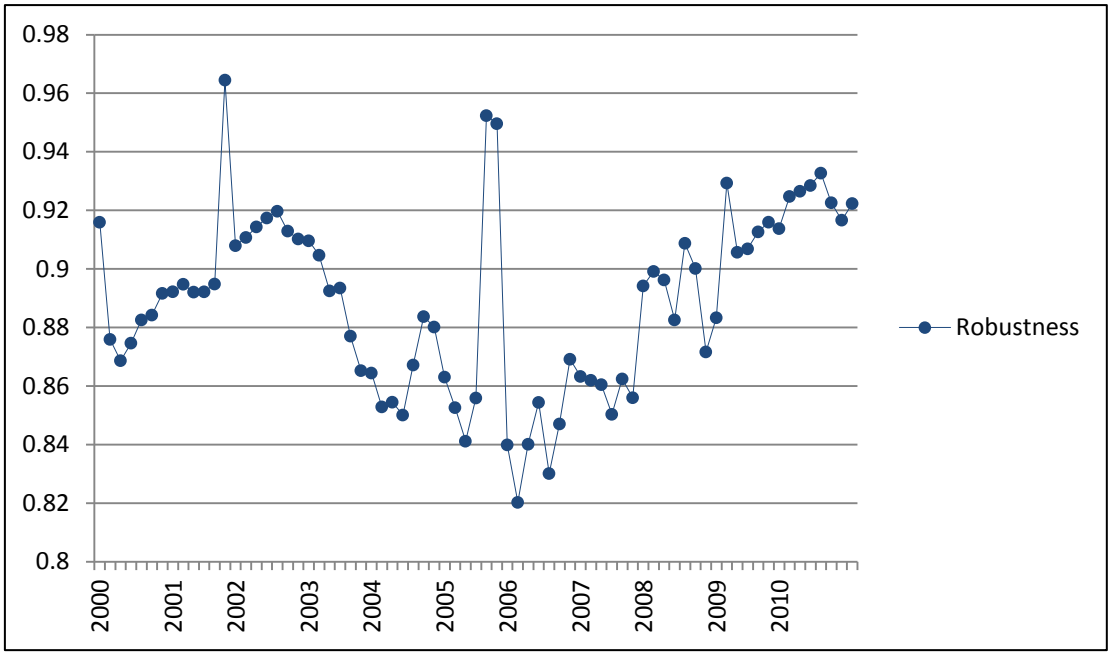


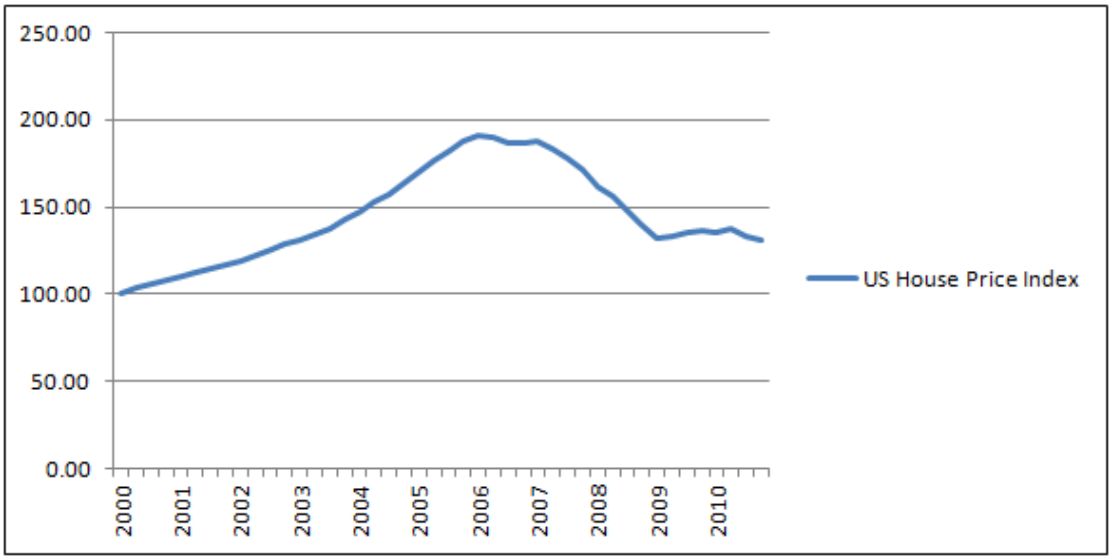
Figure 24: Evolution of robustness chart for the "advanced economies" segment



Several financial and non-financial crises in the period 2000 to 2010 most probably could have been responsible for the fluctuating values of the amount of complexity, entropy and robustness that the system possessed. For the interpretation of the evolution charts for the "advanced economies" segment, mainly crises and interventions that occurred in the US will be used. For the period of 2000 till mid 2004, the complexity and entropy of the system remained relatively even. The significant drop in robustness during the 2000 till 2001 period may be the result of a decision made by Alan Greenspan, who was leading the US Federal Reserve at the time. He lowered the reserve's benchmark interest rate eleven times which resulted in an easy-credit environment (Council on Foreign Relations 2011). The small spike in uncertainty could be attributed to terrorism attacks on the US on 11 September 2001. Al-Qaeda members hijacked four commercial airliners of which two were flown directly into the World Trade Center towers in New York. This caused great devastation and uncertainty in the country (Council on Foreign Relations 2011). January 2001 also saw the beginning of a real estate market bubble. A financial bubble depicts a situation where the price of a financial asset rapidly increases in an abnormal fashion. Such a rapid price increase is not justified by economic fundamentals and therefore the possibility of a market crash is almost inevitable (Phillips and Yu 2009:7). In the 2005-2006 period US housing prices began to fall

drastically which in turn caused the US subprime mortgage industry to collapse in early 2007. The consequences of this collapse was felt by individuals with poor credit or no cash who took out loans at subprime lending firms for a down payment (Council on Foreign Relations 2011). The following figure illustrates the rapid growth of the US House Price Index from 2001 and then the sudden drop in 2007 which is typical of a financial bubble:

Figure 25: The US House Price Index



The sudden decline in the amount of complexity and entropy in the 2005-2006 period were most probably caused by the rapid decline in US house prices when easy initial adjustment rate mortgage terms began to expire and refinancing became more difficult. The latter might be responsible for the significant increase in robustness in 2006 (Phillips and Yu 2009:13).

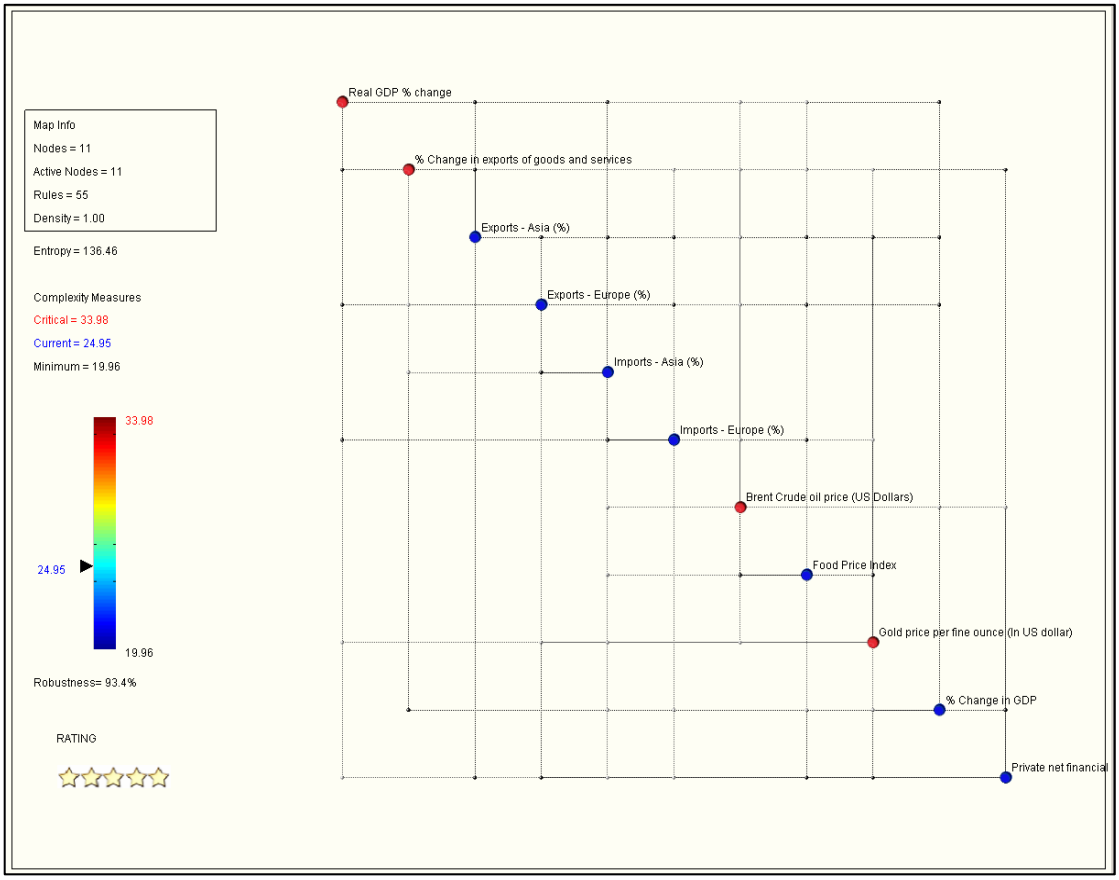
The subprime crisis is generally regarded as a critical contributor of the ongoing financial crisis that the world is experiencing. In 2007 Bear Sterns, one of the largest investment banks in the US filed for bankruptcy. The global consequences of the subprime crisis became apparent in August of that year when European banks also began to experience problems. Because of the large scale of mortgage backed securities (MBS) in the financial system, the financial traumas quickly spread to the asset positions of globally interconnected investment and commercial banks (Phillips and Yu 2009:13). An example is France's BNP Paribas who announced that it cannot

value the assets held by three of its hedge funds. These events portray the build up of 'energy' in the system which eventually should be released. Complexity and entropy increases in a system will result in a very fragile structure that may collapse. The European Central Bank immediately stepped in to offer low-interest credit lines to banks after other EU banks, such as the small German bank IKB, also made announcements similar to that of BNP Paribas and required a bail out (Council on Foreign Relations 2011). Such a bail out action will typically ensure for a robustness increase and an entropy decrease in the evolution charts. The complexity may increase or decrease depending on whether it can be regarded as good or bad complexity respectively. The beginning of 2008 saw several bail outs and increases in regulation by the US Federal Reserve. These actions would typically increase robustness, decrease entropy and maintain complexity at a manageable level or even decrease it. But the decrease in entropy did not occur as it was announced that 240,000 jobs was lost in the month of October and this continued into 2009 causing great uncertainty among the people of the US. Finally, in July 2010, drastic measures were taken when the newly appointed US president, Barack Obama, signed for a US financial overhaul. A financial reform bill was signed into law by him that allows the federal government to regulate Wall Street and prevent future financial crises in order to ultimately increase the robustness of the financial system (Council on Foreign Relations 2011).

8.3.2 Financial and economic developments in emerging markets and developing countries

The following figure illustrates the process map of the "Financial and economic developments in emerging markets and developing countries" segment:

Figure 26: The "Financial and economic developments in emerging markets and developing countries" segment process map



The "emerging economies" segment receives a five star complexity rating. This indicates that the structure of the analysed system is very strong and the amount of complexity that it possesses is very little. The system is not exposed to a lot of uncertainty and therefore it is possible to make credible forecasts. This particular system is manageable and sustainable and is operating efficiently. However, the process map indicates that all the nodes (variables) are active and are also classified as hubs. This is supported by the high density value of 1.00. It is therefore important to take all nodes into consideration when change needs to be implemented because change in one variable may significantly impact another. Because of the dense relationships between all the nodes, traumas and stresses can easily spread throughout

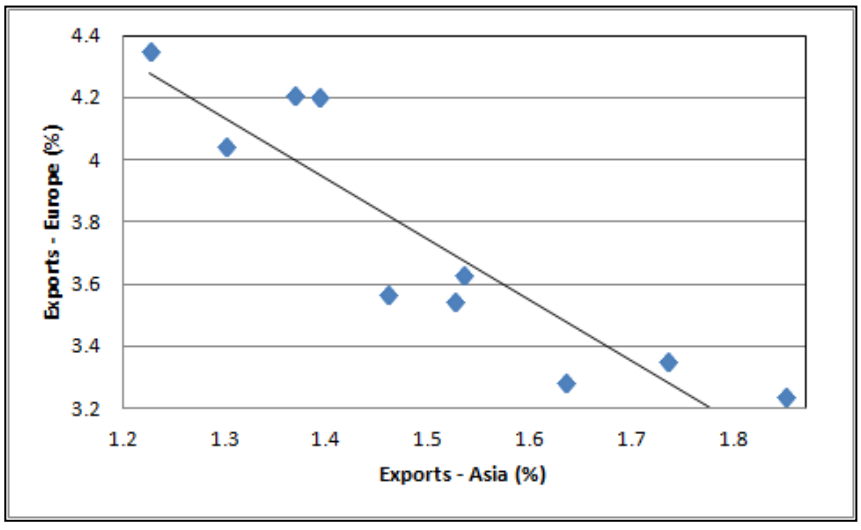
the system. However, the robustness measurement of 93.4% suggests that the system most probably will be able to cope during such circumstances.

Table 5: The top ten generalized correlation variable pairs for the "emerging economies" segment

Variable 1	Variable 2	Generalized Correlation
Set 2: Exports - Asia (%)	Set 2: Exports - Europe (%)	0.93
Set 1: Real GDP % change	Set 2: Exports - Asia (%)	0.9
Set 2: Exports - Asia (%)	Set 2: Imports - Europe (%)	0.89
Set 4: Food Price Index	Set 5: Gold price per fine ounce (In US dollar)	0.89
Set 6: % Change in GDP	Set 6: Private net financial flows in US dollar (Billions)	0.88
Set 2: Imports - Asia (%)	Set 2: Imports - Europe (%)	0.88
Set 1: Real GDP % change	Set 2: Exports - Europe (%)	0.88
Set 2: Exports - Asia (%)	Set 2: Imports - Asia (%)	0.87
Set 2: Exports - Europe (%)	Set 2: Imports - Europe (%)	0.86
Set 1: Real GDP % change	Set 2: Imports - Asia (%)	0.86

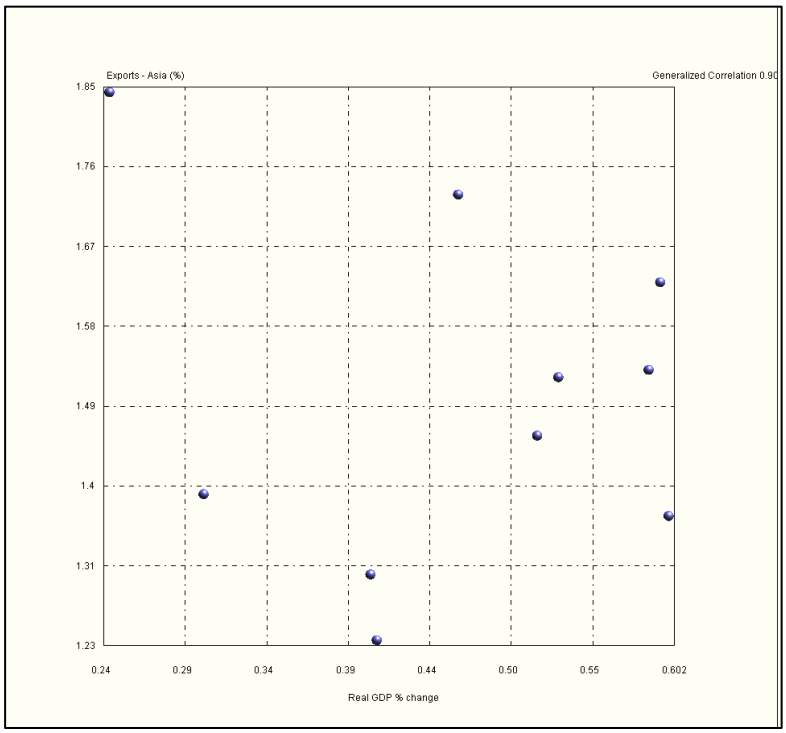
The table above demonstrates how important export and import activities are to the development of emerging markets and economies. The following scatter plot illustrates the generalized correlation of 0.93 of the 'Exports – Asia/Europe (%)' variable pairs:

Figure 27: Scatter plot of the 'Exports – Asia/Europe (%)' variable pairs



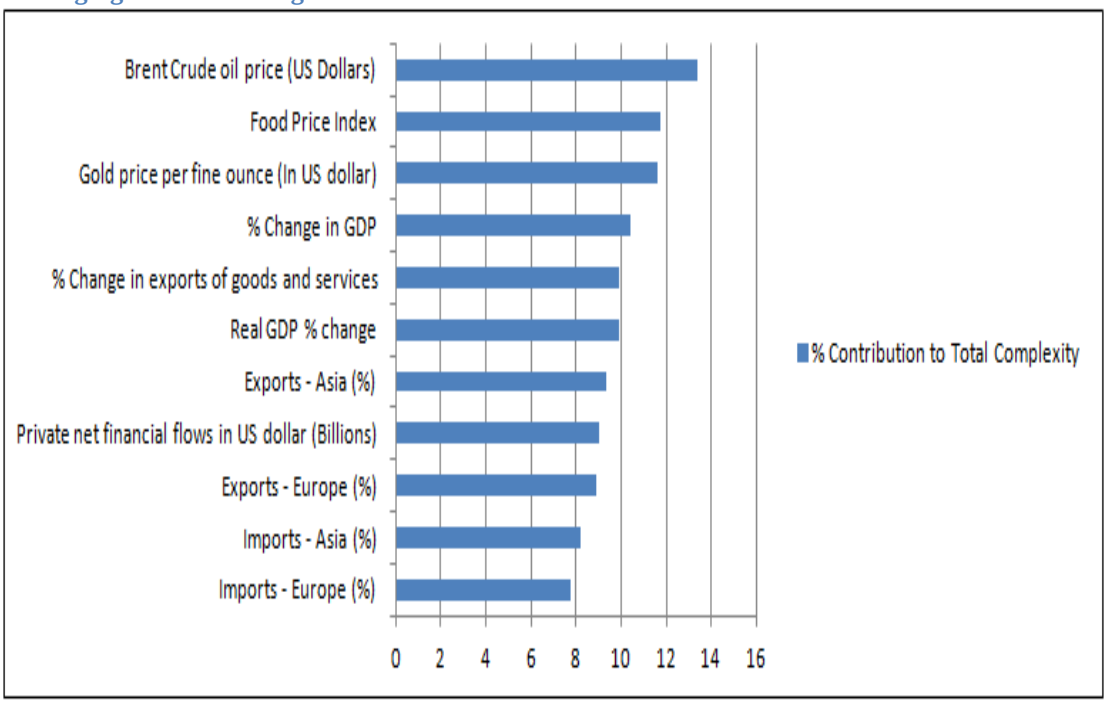
The strong generalized correlation (0.9) between the percentage exports to Asia and the percentage change in real GDP in sub-Saharan Africa emphasises the importance of a macro-economic analysis. Developments in Asia, positive or negative, will most certainly have an effect on sub-Saharan Africa and vice-versa. The following scatter plot illustrates this generalized correlation:

Figure 28: Scatter plot of the 'Exports – Asia (%)/Real GDP % change' variable pair



The complexity profile explains why all variables in this segment are classified as hubs. All of the variables make a reasonable contribution to the total complexity of this system. If a trauma would originate in one of the hubs, it most probably will quickly spread to all the other hubs within the system.

Figure 29: Each variable's percentage contribution to the total system complexity in the "emerging economies" segment



For the dynamic analysis a window size of 36 and an overlap of 35 were chosen. The "emerging economies" segment receives a very low stability index percentage (30.37%) which means that the system was very unstable at the time of analysis.

Figure 30: Evolution of complexity chart of the "emerging economies" segment

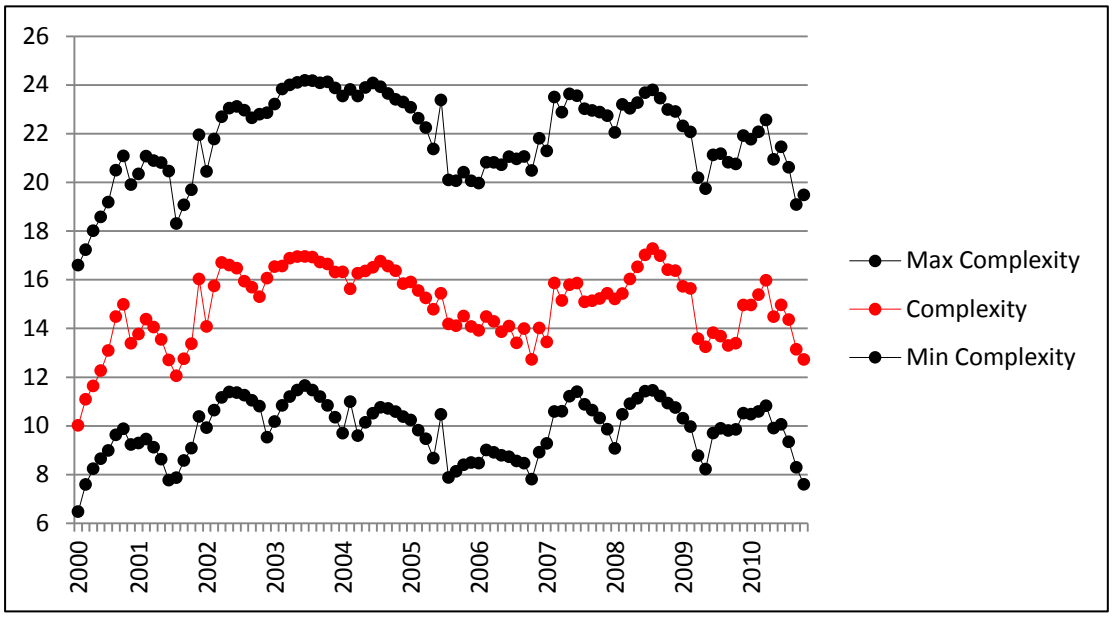


Figure 31: Evolution of entropy chart of the "emerging economies" segment

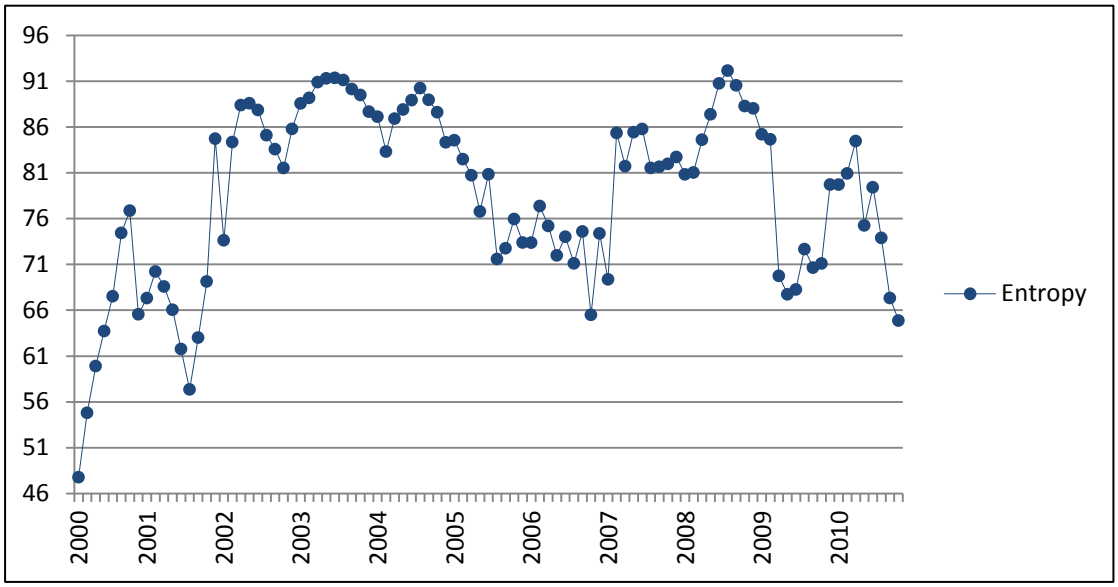
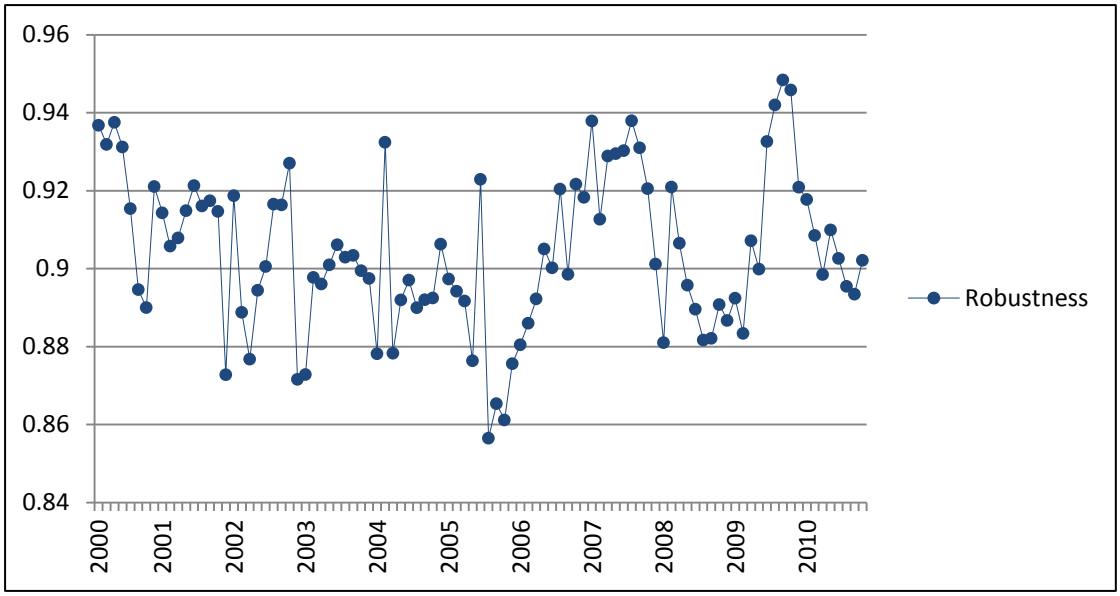


Figure 32: Evolution of robustness chart of the "emerging economies" segment



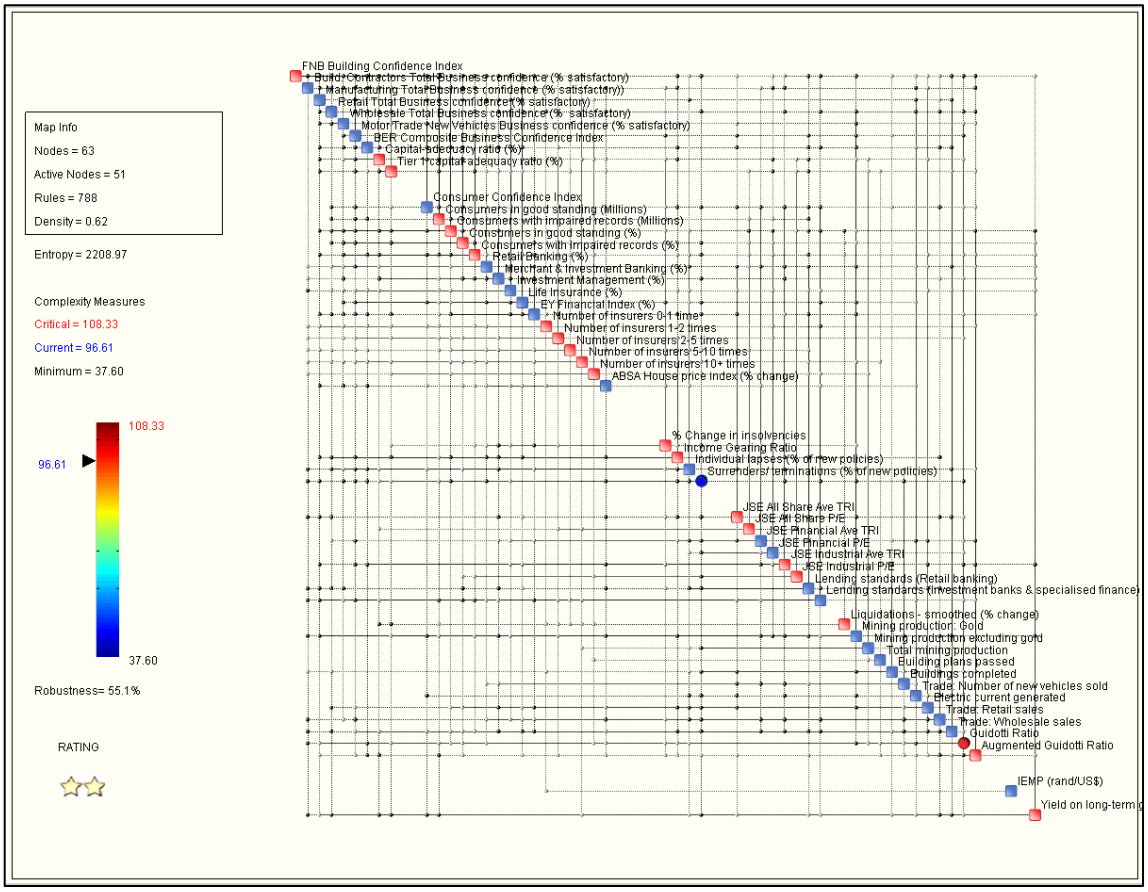
For the interpretation of the evolution charts, sub-Saharan Africa was chosen to represent the "emerging economies" segment. For most of the 2000 to 2010 period the robustness chart oscillated around the 0.9 value. The past decade saw robust growth in sub-Saharan Africa as a result of private-capital inflows from foreign investors who were looking for greater yields (Macias and Massa 2009:7). Unlike developed countries, sub-Saharan Africa did not experience a systemic banking crisis before 2009 because of the limited interaction with the rest of the world's financial markets and their low exposure to complex financial products. However, a dramatic

increase in complexity and entropy can be seen between 2007 and 2008 when fuel and food price shocks surfaced (International Monetary Fund 2009:5, 7).

8.3.3 A domestic macro-prudential analysis

This analysis is of great importance because it consists of most of the financial stability indicators that are being used by the SARB to make decisions. The following process map for the "domestic economy" segment was obtained from OntoSpace:

Figure 33: Process map of the "A domestic macro-prudential analysis" segment



The "domestic economy" segment is very volatile and fragile as indicated by the two star complexity rating that it receives. Only 51 out of 63 nodes are active. This means that 12 variables are independent and no relationship could be established between each of these variables and all other variables that were used in the analysis. Regardless of this the system still receives a density measurement of 0.62. This

indicates a complex system which will be difficult to manage and control. This system is very exposed and therefore the high entropy value which makes forecasting for this system difficult. The system is operating very closely to its critical complexity value and the robustness measurement of 55.1% gives an alarming sense that the system will not be able to cope with a large crisis such as the late economic crisis of 2007.

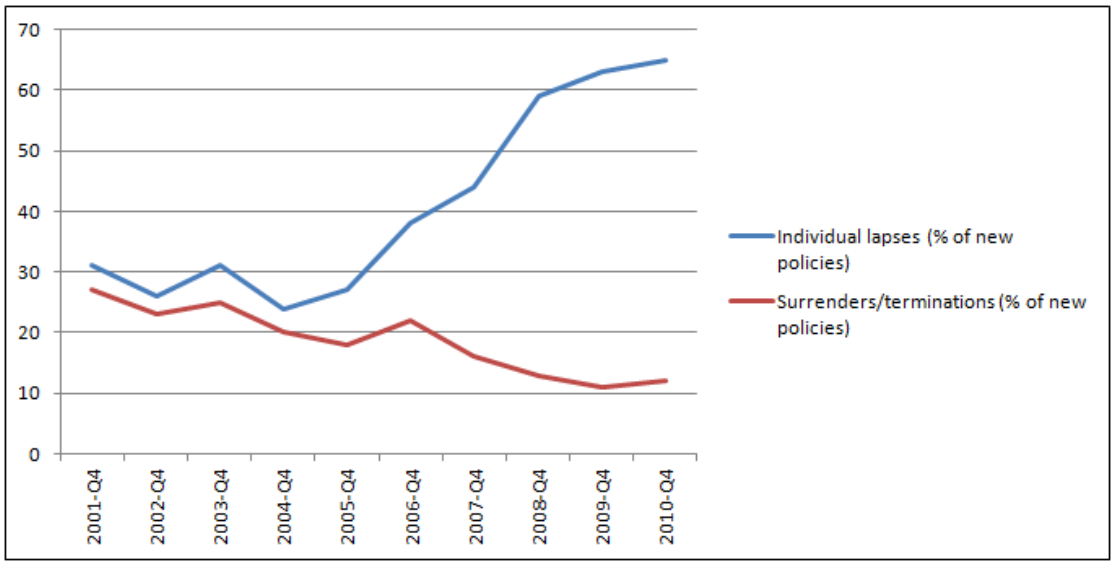
The following table contains the ten variable pairs in the "domestic economy" segment with the highest generalized correlation values:

Table 6: The top ten generalized correlation variable pairs for the "domestic economy" segment

Variable 1	Variable 2	Generalized Correlation
Set 10: Individual lapses (% of new policies)	Set 10: Surrenders/ terminations (% of new policies)	0.92
Set 10: Surrenders/ terminations (% of new policies)	Set 16: Mining production: Gold	0.91
Set 5: Consumers with impaired records (Millions)	Set 5: Consumers in good standing (%)	0.9
Set 11: JSE All Share Ave TRI	Set 13: JSE Industrial Ave TRI	0.89
Set 2: Retail Total Business confidence (% satisfactory)	Set 2: BER Composite Business Confidence Index	0.89
Set 1: FNB Building Confidence Index	Set 2: Build. Contractors Total Business confidence (% satisfactory)	0.88
Set 2: Build. Contractors Total Business confidence (% satisfactory)	Set 2: BER Composite Business Confidence Index	0.88
Set 10: Surrenders/ terminations (% of new policies)	Set 16: Trade: Retail sales	0.88
Set 2: BER Composite Business Confidence Index	Set 10: Surrenders/ terminations (% of new policies)	0.87
Set 13: JSE Industrial Ave TRI	Set 16: Trade: Retail sales	0.87

Data from the SARB were used to construct the following graph which explains the generalized correlation value of the top ranked variable pair. It can be seen that the two variables followed the same trend up until mid 2005 when the "Individual lapses" variable began to increase and the "Surrenders/terminations" variable decreased.

Figure 34: The top ranked variable pair for the "domestic economy" segment

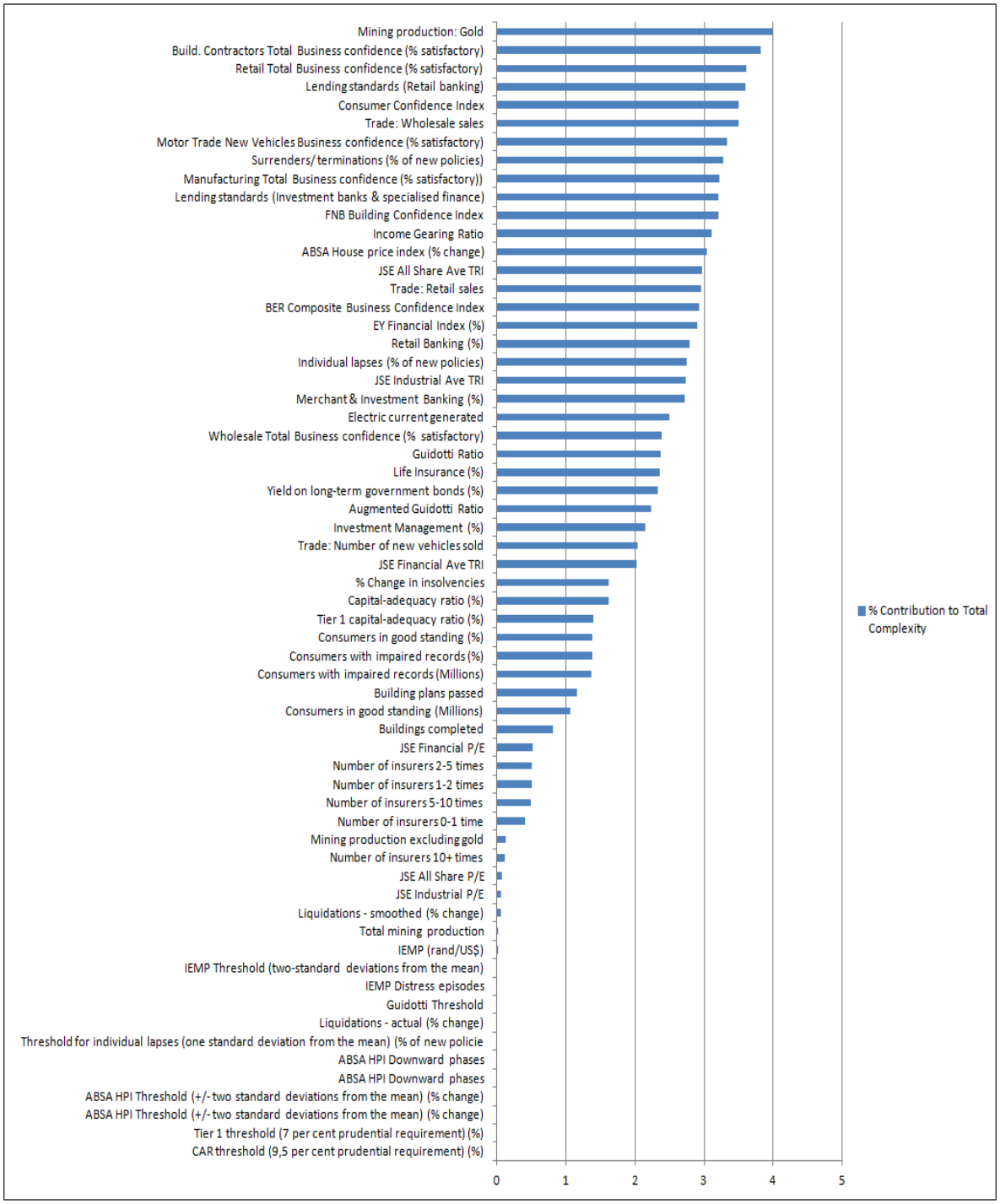


The interconnectedness between variables from different data sets becomes apparent. It can be stated that a relationship 'chain' is formed between the various variables. An example of such a chain can be outlined as follows:

- The strong generalized correlation between the "FNB Building Confidence Index" variable and the "Build. Contractors Total Business confidence" variable.
- The "Build. Contractors Total Business confidence" variable also has a strong generalized correlation with the "BER Composite Business Confidence Index" variable.
- The "BER Composite Business Confidence Index" variable has a strong connection with the "Retail Total Business confidence" variable – linking the latter to the chain.

This relationship 'chain' illustrates the extent to which changes, positive or negative, may have on the rest of the variables of the system. The following complexity profile depicts which variables in the "domestic economy" segment contribute the most to the total amount of complexity that the system possesses:

Figure 35: The percentage contribution of each variable to the total system complexity in the "domestic economy" segment



For the dynamic analysis a window size of 36 and an overlap of 35 were chosen. It can be assumed that the "domestic economy" segment was not very stable at the time of the analysis according to the stability index value of 49.51%.

Figure 36: Evolution of complexity chart of the "domestic economy" segment

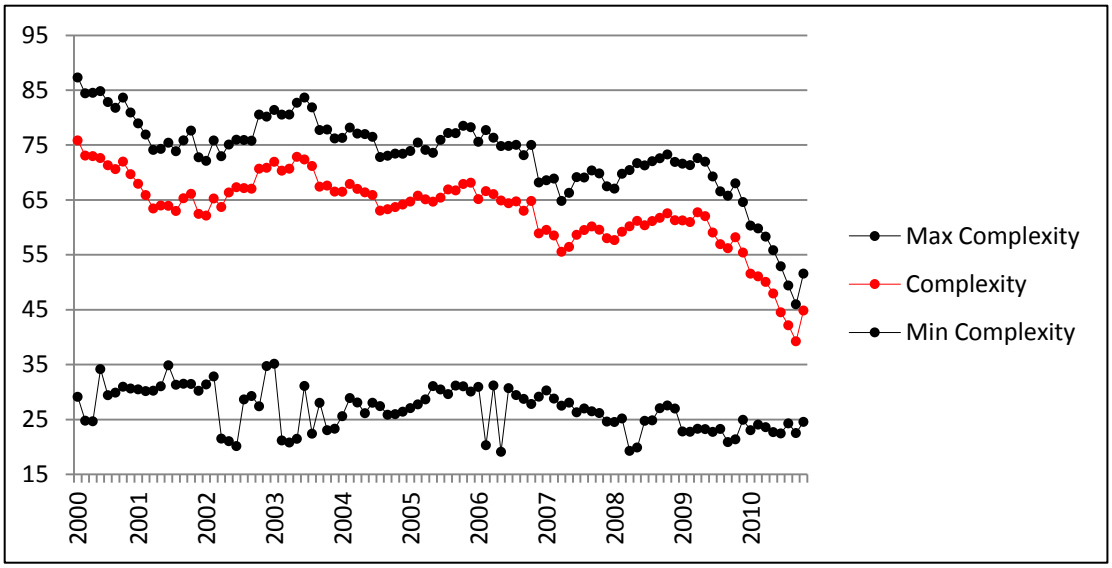


Figure 37: Evolution of entropy chart of the "domestic economy" segment

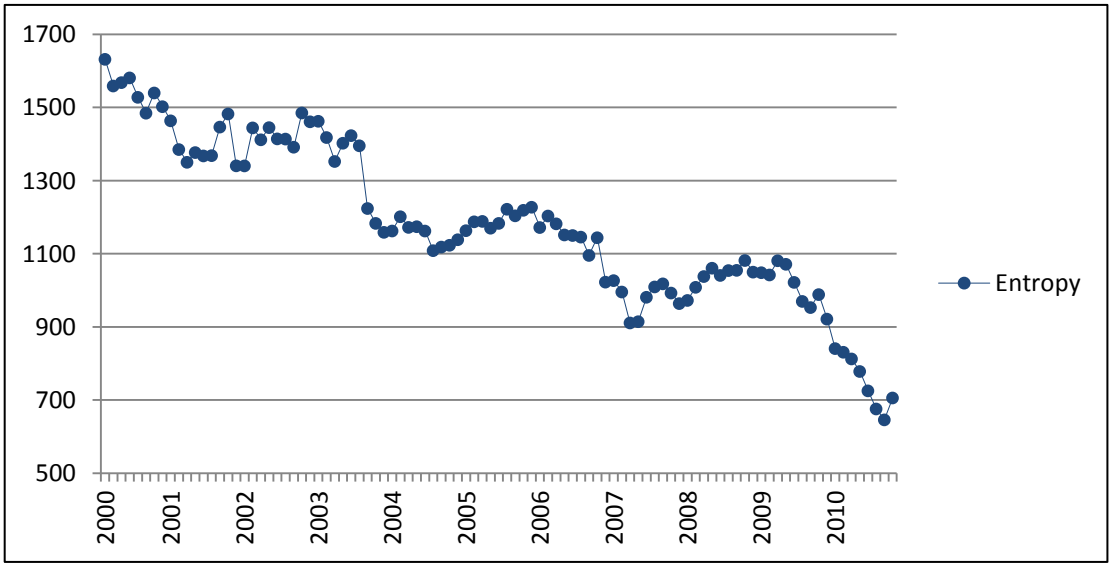
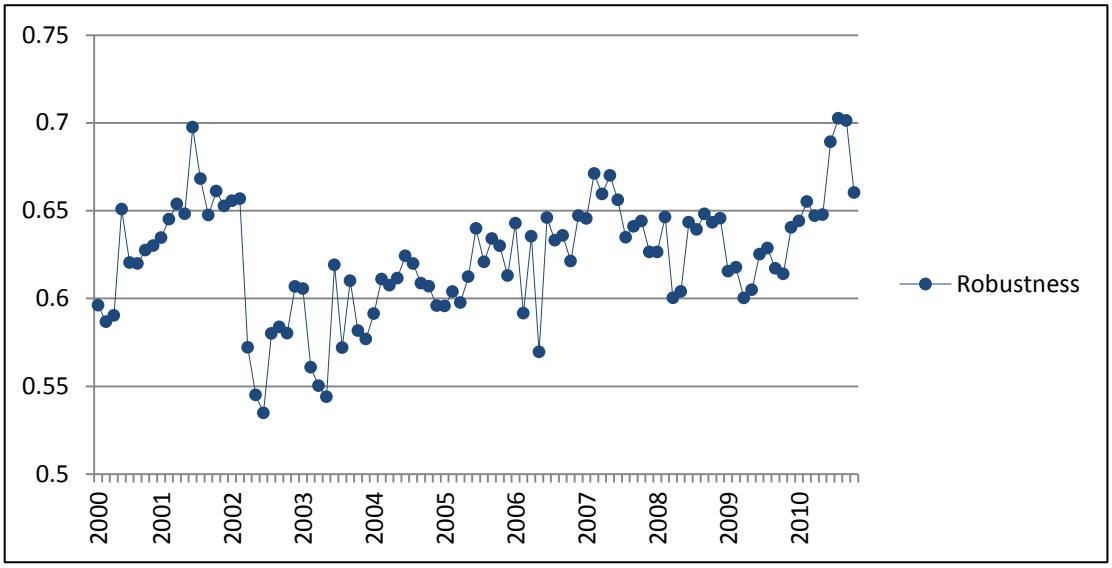


Figure 38: Evolution of robustness chart of the "domestic economy" segment

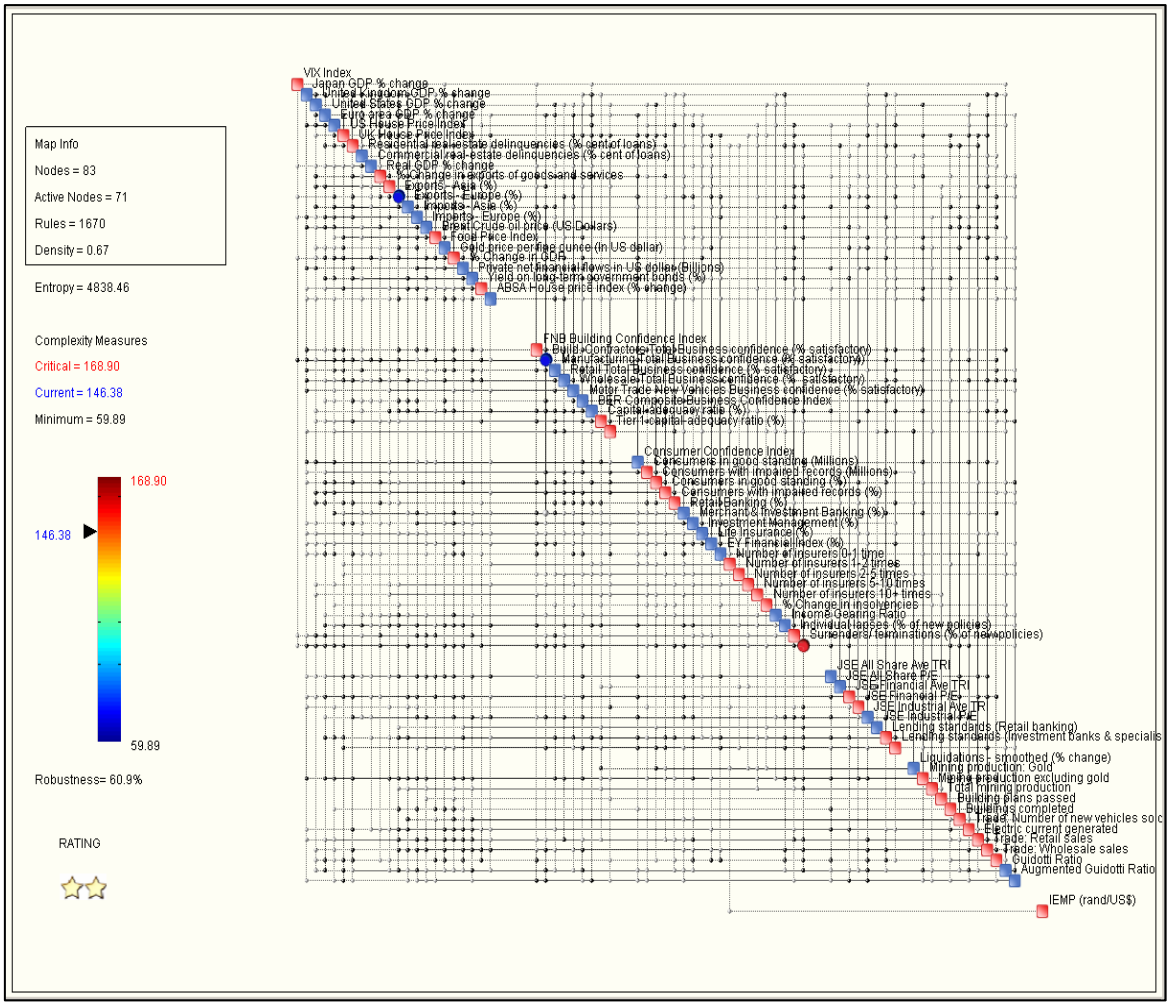


South Africa (SA) had to face many challenges in the past decade. For the interpretation of the evolution charts the effects of the latest ongoing global economic crisis was used. After the US subprime mortgage crash in 2007, which is generally regarded as the instigator of the global economic crisis, shocks began to filter through to SA. There were significant depreciations in assets, an increase in the amount of business closures, an increased unemployment rate and an overall slow-down of economic growth. By visual inspection of the respective evolution charts it can be concluded that the consequences of the shocks resulted in a dramatic fall in the amount of complexity, entropy and robustness in the year of 2007 (South Africa Government 2009:2). However, in the year of 2008 the amount of complexity and entropy that SA possessed began to increase again. The election of a new president caused wide spread political concern and crime rates remained high. The maintenance and growth of the country's infrastructure was heavily scrutinised as a result of load-shedding by Eskom. These increases in complexity and entropy were quickly counter-acted in late 2008 when increased credit rates and the implementation of the National Credit Act, that ensured for a tougher lending criteria, improved monetary regulation in the country (Massmart 2008:23, 24). The strong increase in robustness can be attributed to the better monetary regulation in SA.

8.3.4 A Macro-economic ecosystem

For this analysis the data sets of the three segments were combined to make up the typical macro-economic ecosystem within which businesses are operated. From the process map below it can be seen that this system is only given a two star rating. The system possesses a high amount of complexity (146.38) and is also being operated near its critical complexity value (168.90). This leads to a fragile and thus vulnerable structure. The latter is supported by the low robustness measurement of 60.9% that the system receives. The exposure and inefficiency of this system is high and it will be difficult to forecast for this system. Only 12 out of 83 variables are inactive and therefore the system receives a density measurement of 0.67. It would thus be difficult to manage and control this system. The process map for the "macro-economic ecosystem" is given below.

Figure 39: The "macro-economic ecosystem" process map



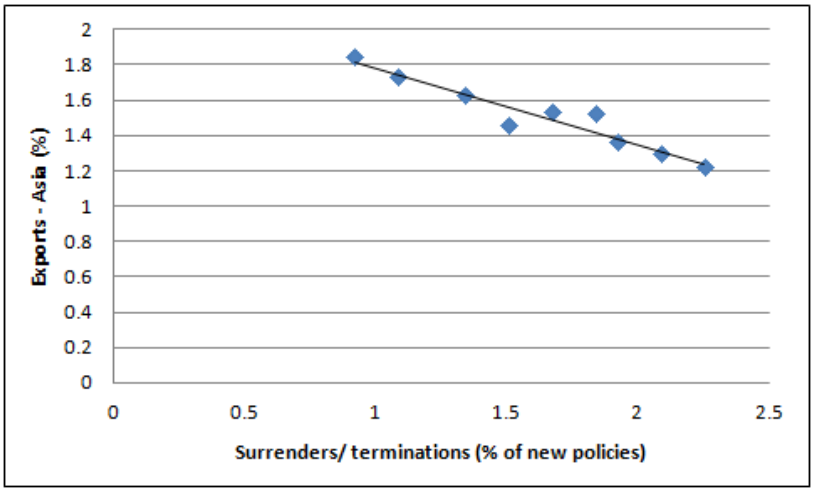
The ranking of generalized correlations between all the variables of the data sets provides fundamental insight of how the three main segments interact with each other. The following table contains the top ten generalized correlation variable pairs in the "macro-economic ecosystem":

Table 7: The top ten generalized correlation variable pairs for the "macro-economic ecosystem"

Variable 1	Variable 2	Generalized Correlation
Set 6: Exports - Asia (%)	Set 21: Surrenders/ terminations (% of new policies)	0.94
Set 2: United States GDP % change	Set 21: Surrenders/ terminations (% of new policies)	0.93
Set 5: Real GDP % change	Set 21: Surrenders/ terminations (% of new policies)	0.92
Set 6: Imports - Asia (%)	Set 21: Surrenders/ terminations (% of new policies)	0.91
Set 21: Surrenders/ terminations (% of new policies)	Set 27: Mining production: Gold	0.91
Set 2: United States GDP % change	Set 6: Exports - Asia (%)	0.91
Set 2: Euro area GDP % change	Set 21: Surrenders/ terminations (% of new policies)	0.9
Set 5: Real GDP % change	Set 6: Exports - Asia (%)	0.9
Set 3: US House Price Index	Set 21: Surrenders/ terminations (% of new policies)	0.9
Set 17: Consumers with impaired records (Millions)	Set 17: Consumers in good standing (%)	0.9

The top ranked variable pair ensures for an interesting relationship between the "emerging economies" segment and the "domestic economy" segment. The scatter plot for this variable pair is illustrated below:

Figure 40: The scatter plot for the top ranked generalized correlation variable pair in the "macro-economic ecosystem"



Two line charts of the data of the respective variables were constructed. By comparing the two charts, it can be seen that there is a general increase in the percentage of exports to Asia in the "emerging economies" segment while the percentage of terminations of new policies is decreasing. The following line charts support the generalized correlation of the variable pair:

Figure 41: The respective line charts of the top ranked generalized correlation variable pair in the "macro-economic ecosystem"

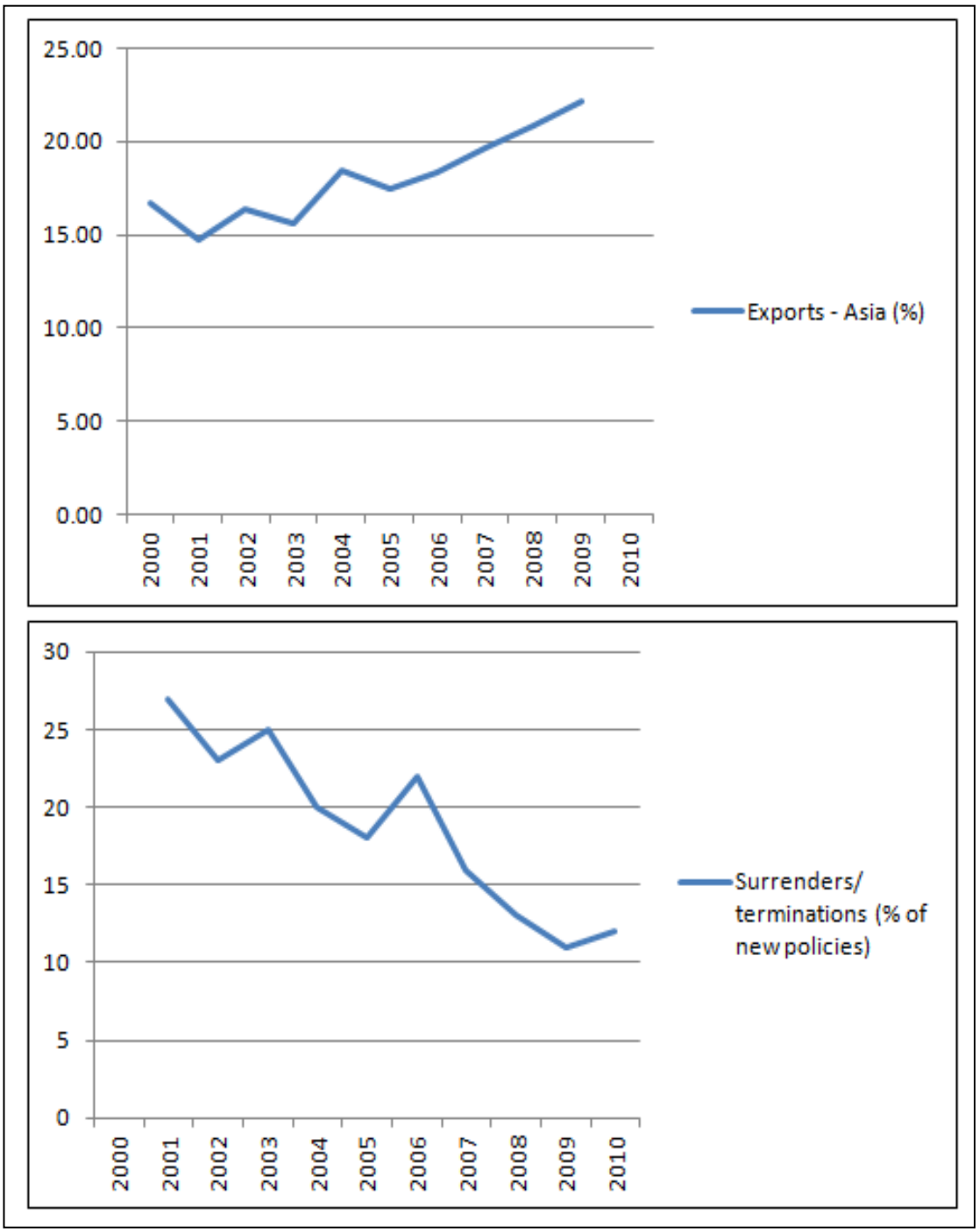
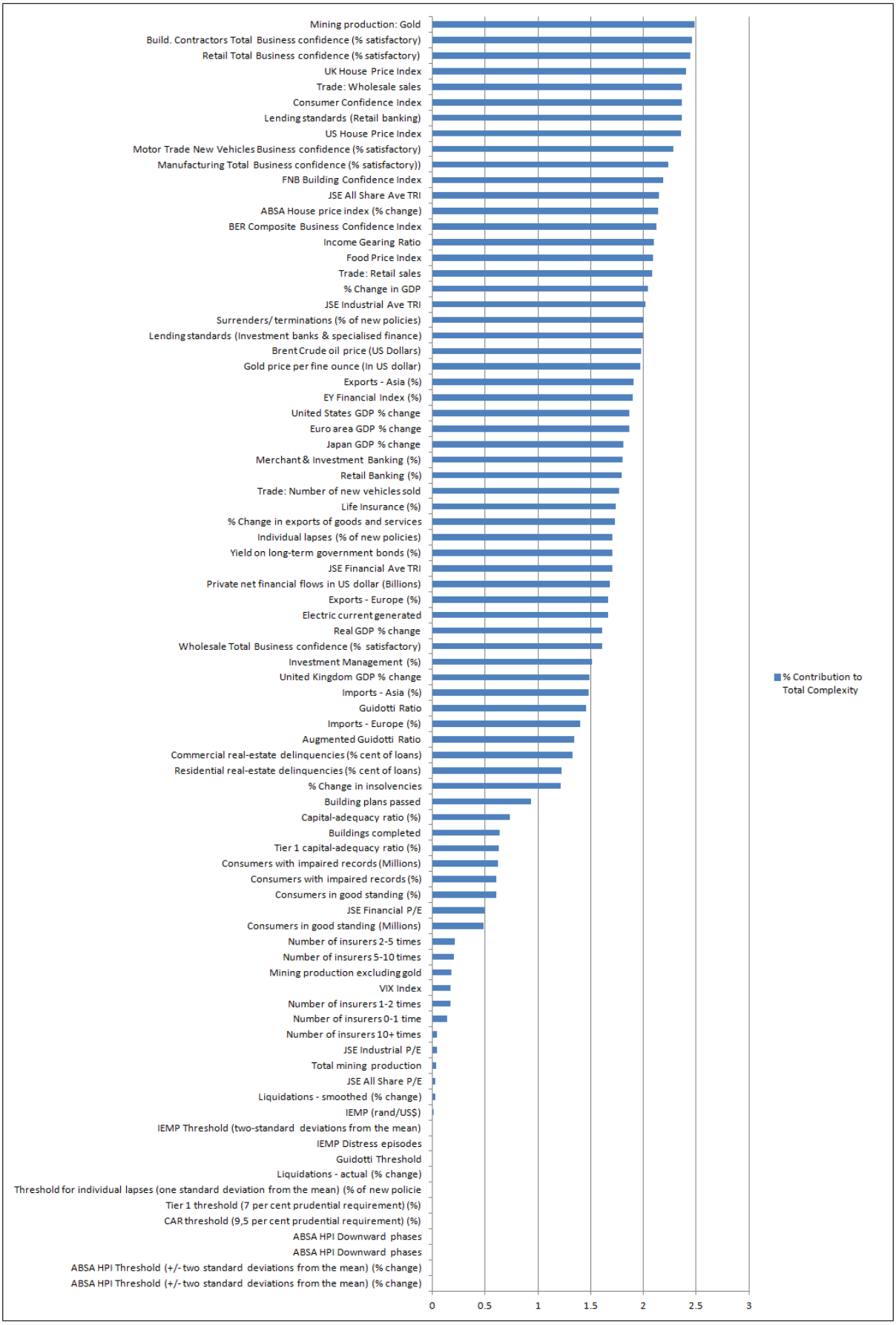


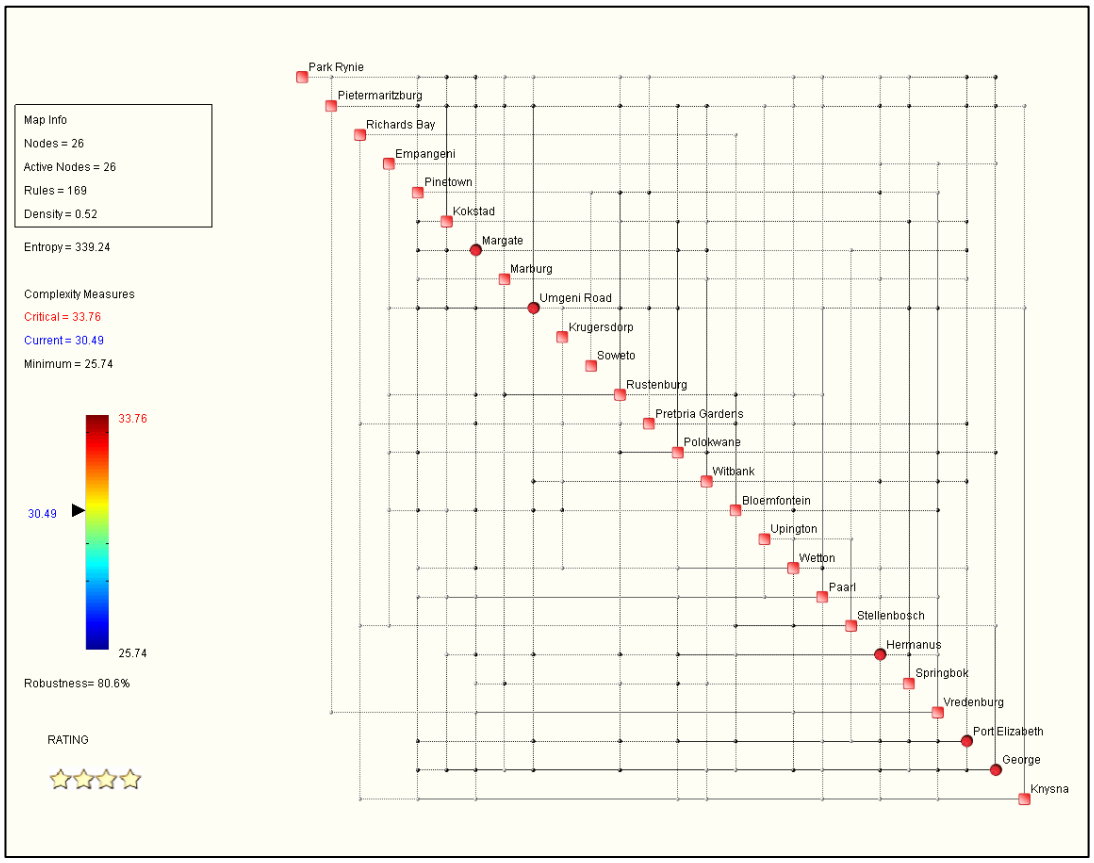
Figure 42: The complexity profile of the "macro-economic ecosystem"



8.3.5 A retail business within the three main segments

One of South Africa's largest retail businesses (name will not be disclosed for privacy reasons) was used for this case study. Firstly, a complexity analysis of the business's total monthly sales per region was conducted to obtain all the fundamental measurements from Ontospace. The total monthly sales data of the various regions of the business were then combined with the respective main segments to determine whether the business's monthly sales performance was impacted by external parameters. The following figure illustrates the process map the of business's regions only:

Figure 43: The process map of retail business



The process map reveals a robust system structure with a robustness measurement of 80.6%. The low amount of complexity that the system possesses ensures a four star complexity rating. The system is being operated more or less in the middle of the critical and minimum complexity measurements. As the system is not entropy- driven it is possible to make credible forecasts. The sustainability and efficiency of this

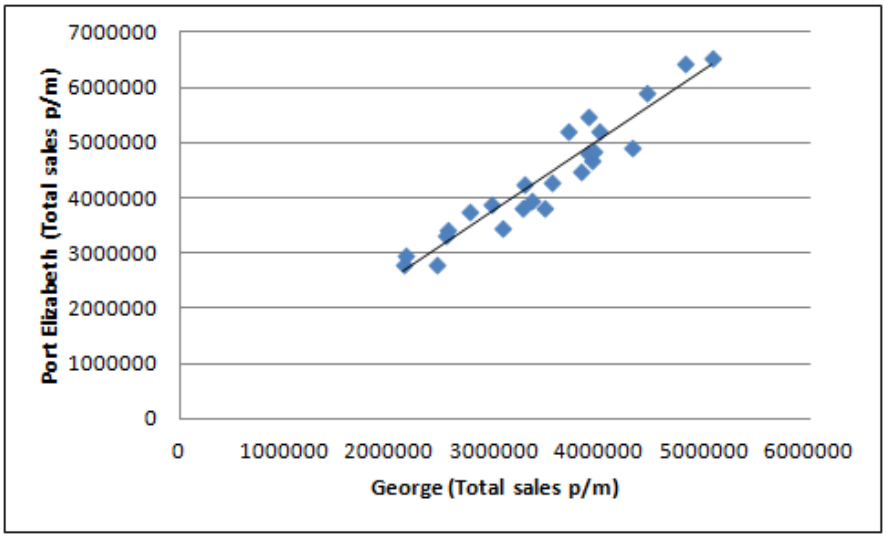
system is quite high. The density measurement is just above the 0.5 mark which indicates that this system is manageable and controllable.

Table 8: The top ten generalized correlation variable pairs of the retail business

Variable 1	Variable 2	Generalized Correlation
Set 1: Port Elizabeth	Set 1: George	0.74
Set 1: Margate	Set 1: Port Elizabeth	0.7
Set 1: Umgeni Road	Set 1: Port Elizabeth	0.69
Set 1: Pinetown	Set 1: Umgeni Road	0.66
Set 1: Umgeni Road	Set 1: George	0.65
Set 1: Umgeni Road	Set 1: Hermanus	0.64
Set 1: Vredenburg	Set 1: George	0.63
Set 1: Pinetown	Set 1: Port Elizabeth	0.63
Set 1: Umgeni Road	Set 1: Vredenburg	0.61
Set 1: Umgeni Road	Set 1: Bloemfontein	0.61

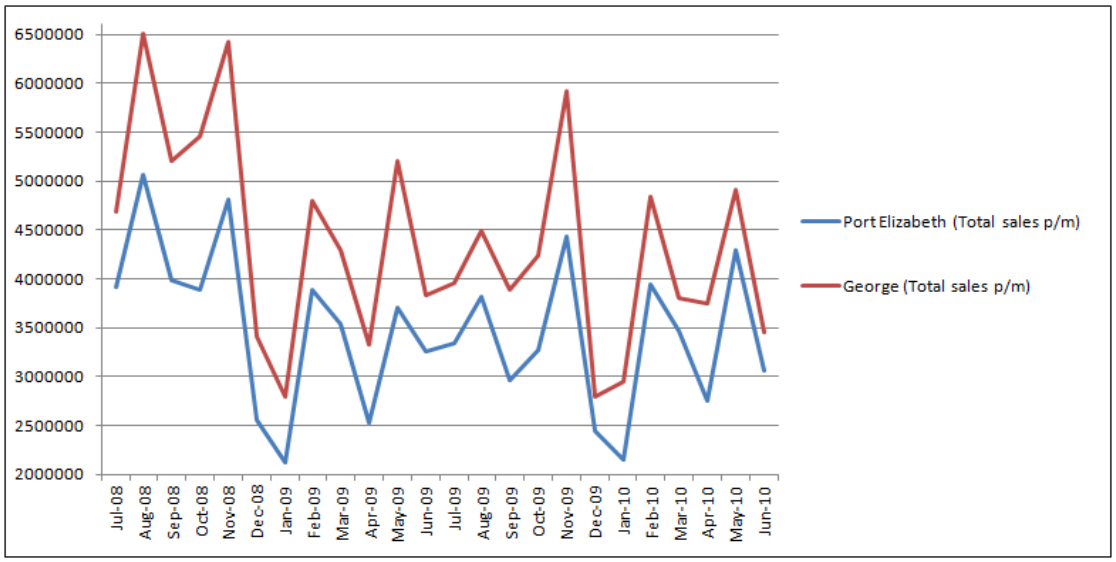
The table above ranks the generalized correlations of the top ten variable pairs. It can be seen that all five of the system's hubs appear at least once in a variable pair. This emphasises why it is necessary to identify a system's hubs. They are the backbone of the system and have strong relationships with the rest of the system's nodes. A very prominent hub is 'Port Elizabeth' which appears in the top three variable pairs. The scatter plot of the 'Port Elizabeth/George' variable pair is depicted below:

Figure 44: The scatter plot of the 'Port Elizabeth/George' variable pair



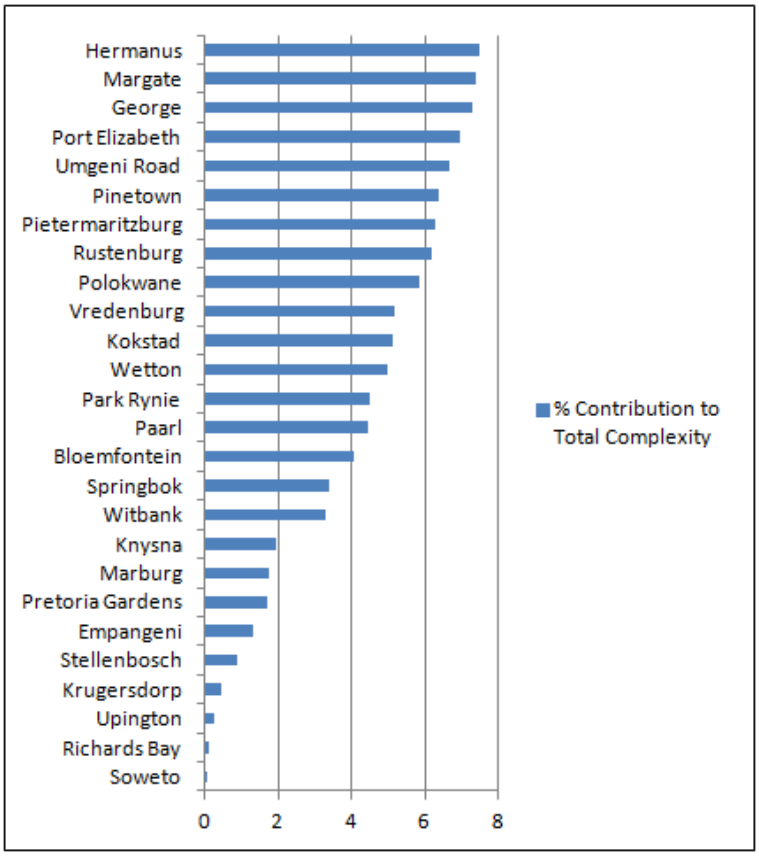
The linear trend that the data points of the variable pair illustrate explains the strong generalized correlation between these two regions. This correlation is supported by a graph of both regions' total monthly sales data. The following graph illustrates this:

Figure 45: The total monthly sales of the Port Elizabeth and George regions



It can clearly be seen how the total monthly sales of these two regions follow the same trend. The system's complexity profile confirms the importance of hub identification within a system. The top five contributors to the total complexity of the system are represented by the five hubs of the system. While hub identification is important, an IE must also investigate weak relationships such as the relationships between the Soweto region and other regions for example where the opportunity for failure is the highest.

Figure 46: The complexity profile of the retail business



A window size of 12 and overlap of 11 was selected for the dynamic analysis. The minimal fluctuation in complexity over the analysed period ensured for a very high stability index value of 95.77%. The following evolution charts were obtained from OntoSpace and will be used for comparison purposes in relation to the other three main segments:

Figure 47: Evolution of complexity chart for the retail business

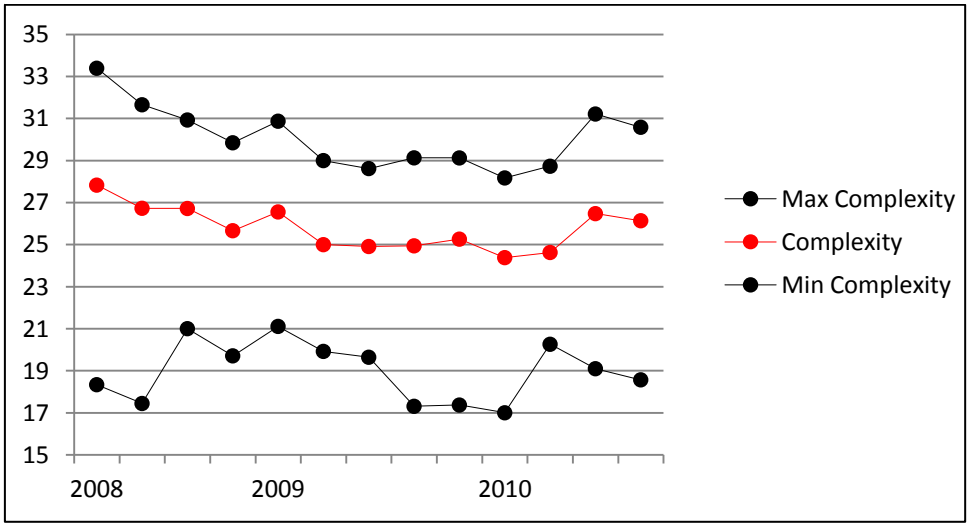


Figure 48: Evolution of entropy chart of the retail business

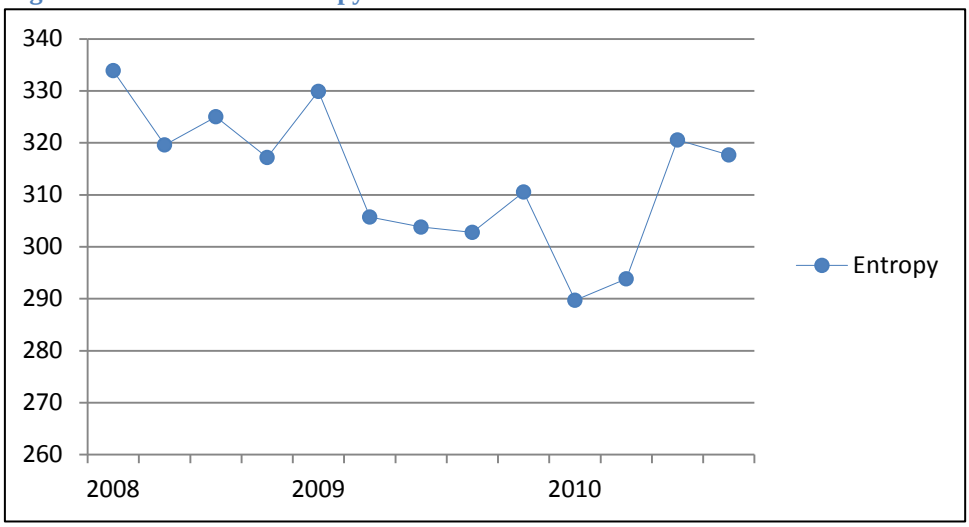
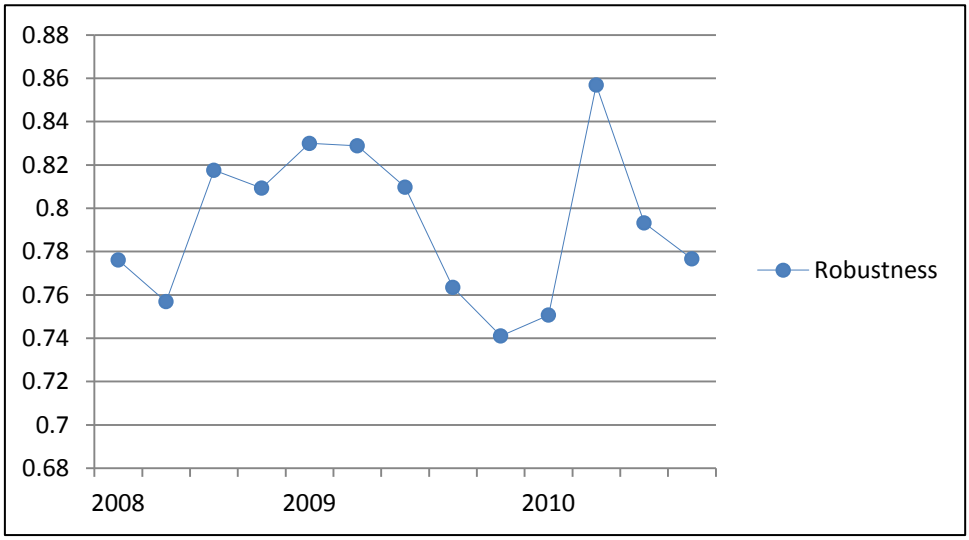
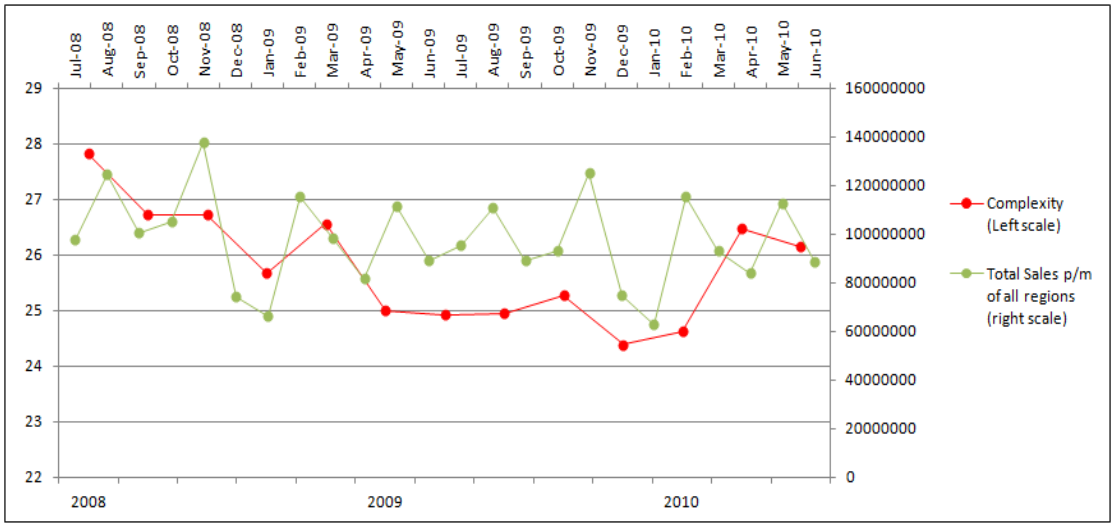


Figure 49: Evolution of robustness chart of the retail business



The following graph illustrates the comparison between the retail business's total sales per month for all the regions and the business's evolution of complexity:

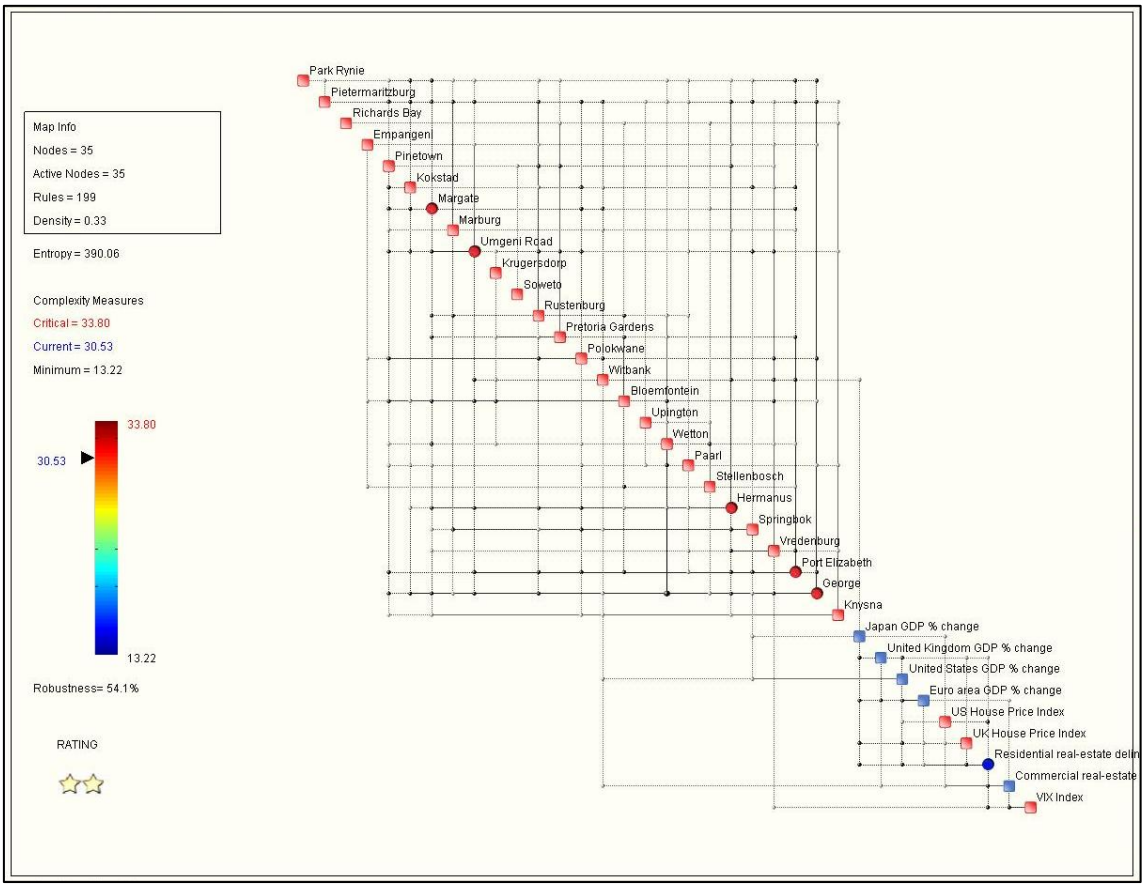
Figure 50: Business complexity versus the total sales per month of all regions



By plotting the complexity of the business and the total sales per month of all the regions on one graph, it is clear that an acceptable amount of complexity that is being managed continuously ensures that total sales per month are sustained.

The second analysis entails the combining of the data set of the retail business with the data sets of the "advanced economies" segment. The following process map was obtained from OntoSpace:

Figure 51: The combined retail business and "advanced economies" segment process map



This process map depicts a system where the retail business is operated within an "advanced economies" segment. Of note is the fact that this system is only able to obtain a two star complexity rating in contrast with the four star rating of the retail business system on its own. This suggests that the "advanced economies" segment significantly increases the amount of complexity and entropy that a system possesses. Because this system is entropy-driven it is almost certain that predictions of what

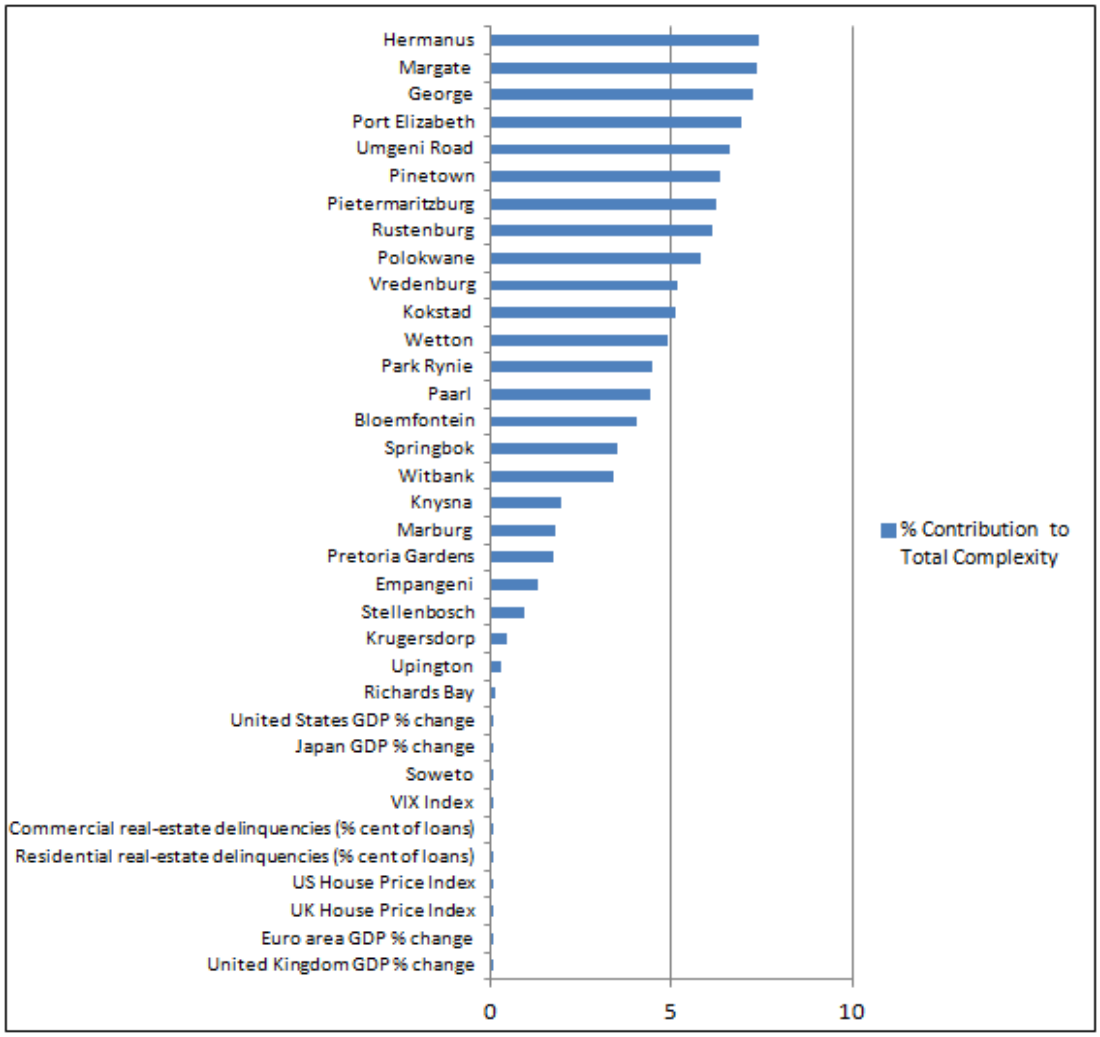
might happen will be incorrect. The process map illustrates a system that is on the verge of collapsing as it is being operated very closely to its critical complexity measurement of 33.80. The robustness measurement of 54.1% may imply that when such a collapse occurs, the system will not be able to effectively cope and might become unsustainable. There are no inactive nodes but the low density measurement of 0.33 suggests that it is possible to make changes within the system.

Table 9: The top ten generalized correlation variable pairs for the retail business and "advanced economies" segment combination

Variable 1	Variable 2	Generalized Correlation
Set 1: Port Elizabeth	Set 1: George	0.74
Set 1: Margate	Set 1: Port Elizabeth	0.7
Set 4: Residential real-estate delinquencies (% cent of loans)	Set 4: Commercial real-estate delinquencies (% cent of loans)	0.7
Set 1: Umgeni Road	Set 1: Port Elizabeth	0.69
Set 1: Pinetown	Set 1: Umgeni Road	0.66
Set 1: Umgeni Road	Set 1: George	0.65
Set 1: Umgeni Road	Set 1: Hermanus	0.64
Set 1: Vredenburg	Set 1: George	0.63
Set 1: Pinetown	Set 1: Port Elizabeth	0.63
Set 1: Umgeni Road	Set 1: Vredenburg	0.61

The table above contains the ten variable pairs with the strongest generalized correlations. There are no variable pairs within this table that contain one variable from the "advanced economies" segment and one from the retail business. The relationships are mainly strong only within the segment and business itself respectively. The complexity profile below illustrates that the retail business variables are the main complexity contributors of this system. This suggests that an IE should only look to manage the complexity of the retail business alone.

Figure 52: The combined retail business and "advanced economies" segment complexity profile



However, taking a closer look at the process map of the system reveals that the hubs within the business, although it might not be strong, do have relationships with all of the variables within the "advanced economies" section. Therefore, if an external variable effects one or more of the hubs of the business, the effect will most probably spill over to the other variables in the business. The following figures illustrate the relationships between two business hubs, the other relevant business nodes and the nodes of the "advanced economy" segment:

Figure 53: Retail business hub 1

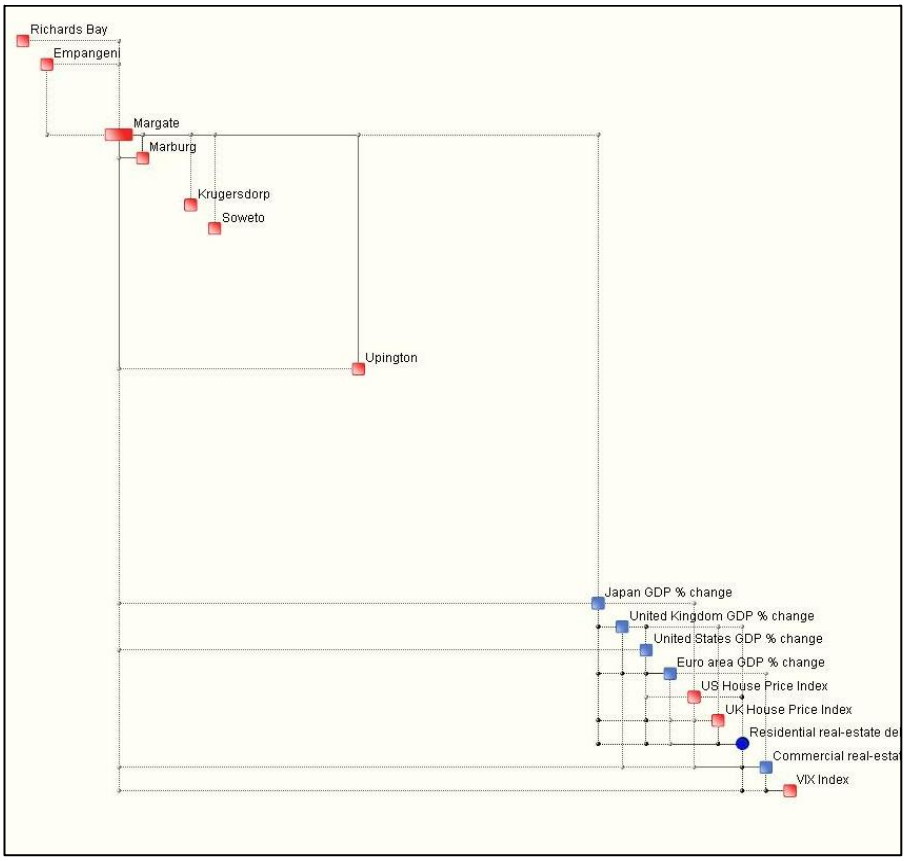
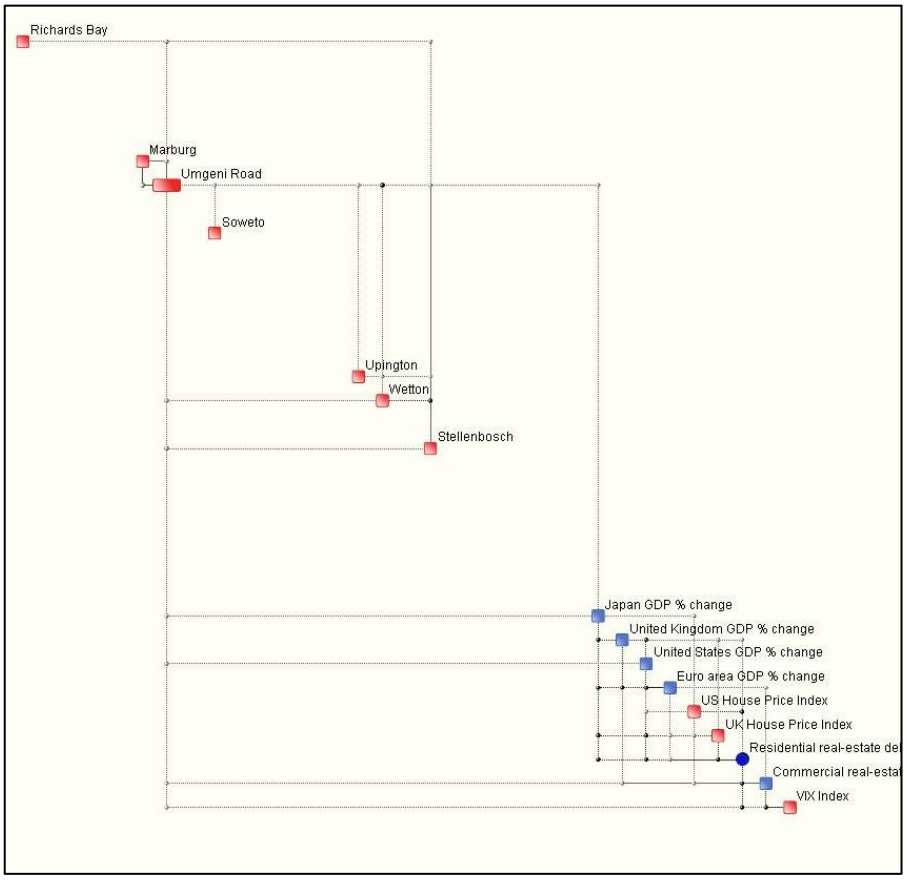


Figure 54: Retail business hub 2



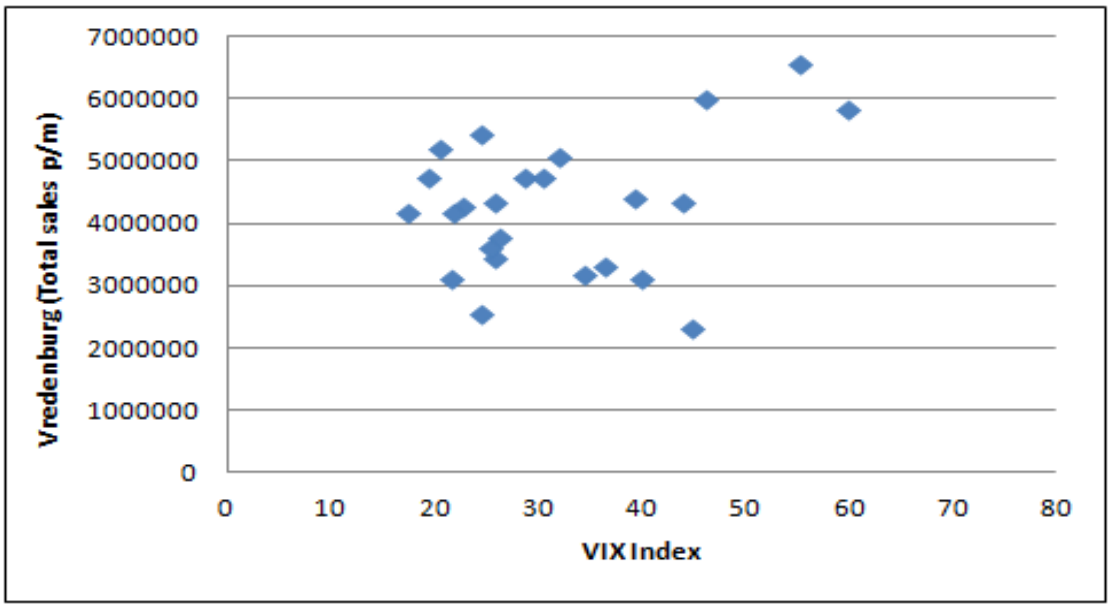
Although the relationships between the retail business hubs and "advanced economies" segment are not that strong, it can be seen that all nine of the "advanced economies" nodes are active and linked with the chosen hub. This is the case for all the other retail business hubs as well.

Table 10: The top five generalized correlation variable pairs containing one variable from the retail business and one variable from the "advanced economies" segment per pair

Variable 1	Variable 2	Generalized Correlation
Set 1: Vredenburg	Set 5: VIX Index	0.35
Set 1: Springbok	Set 4: Residential real-estate delinquencies (% cent of loans)	0.24
Set 1: Witbank	Set 4: Residential real-estate delinquencies (% cent of loans)	0.23
Set 1: Stellenbosch	Set 3: UK House Price Index	0.22
Set 1: Polokwane	Set 4: Residential real-estate delinquencies (% cent of loans)	0.21

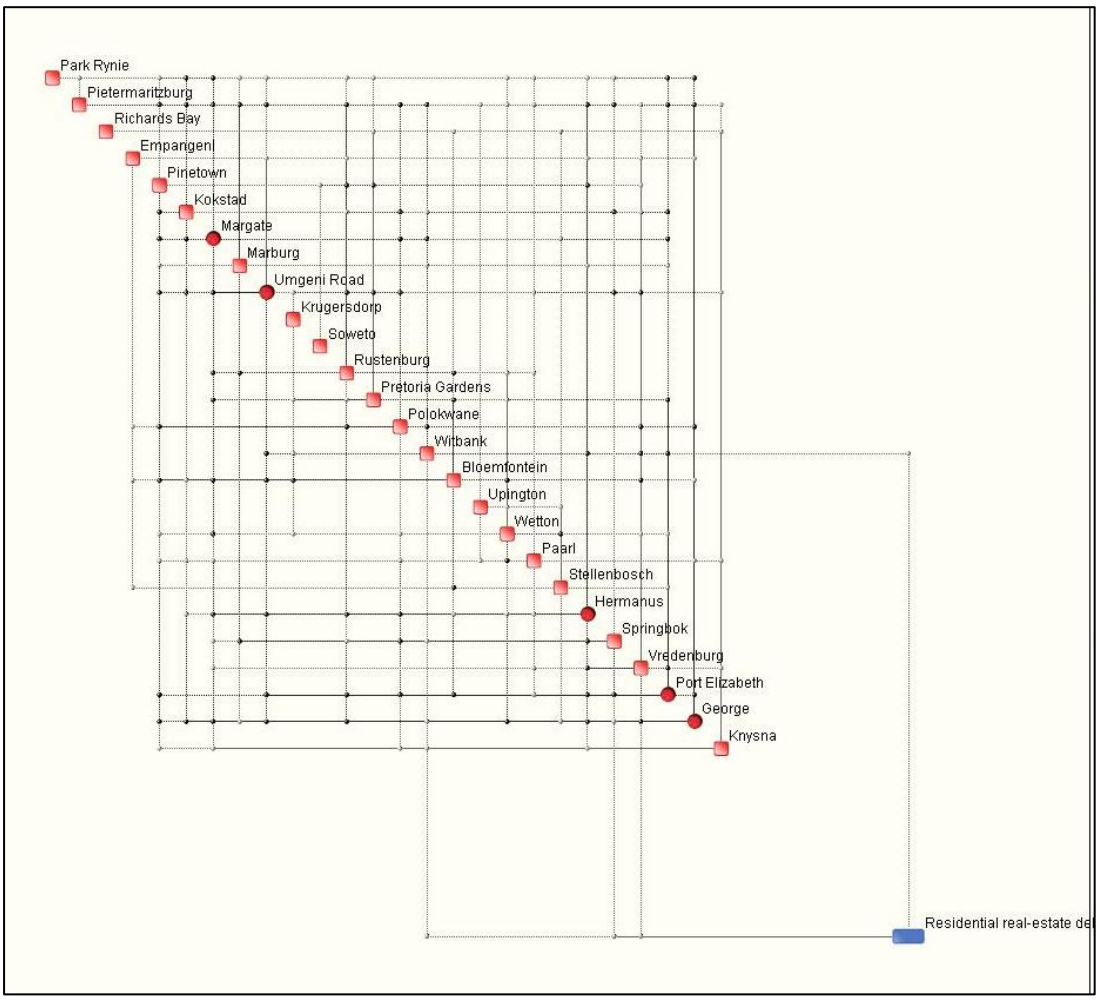
The table above contains the top five generalized correlations between a retail business variable and an "advanced economies" variable. The values are significantly lower than that of the previous table and therefore the weak relationships between the nodes of the business and the nodes of the "advanced economies" segment. The following scatter plot shows how deprived of structure the 'Vredenburg/VIX Index' variable pair is, compared to the 'Port Elizabeth/George' variable pair scatter plot:

Figure 55: The scatter plot of the 'Vredenburg/VIX Index' variable pair



However, the only hub of the "advanced economies" segment, namely 'Residential real-estate delinquencies', appear three times in the table above. In the following figure it is illustrated how this hub is connected with all the nodes of the retail business, either directly or via another node.

Figure 56: "Advanced economies" segment hub 1



A dynamic analysis of both the retail business and the "advanced economies" segment was conducted to obtain the respective evolution charts of each for comparison purposes. The time period of the analyses is from July 2008 until June 2010. A window size of 12 and an overlap of 11 were selected. The stability index value of 57.57% suggests that the "advanced economies" segment was not very stable in the period analysed. The evolution charts are as follows:

Figure 57: Evolution of complexity chart for the "advanced economies" segment

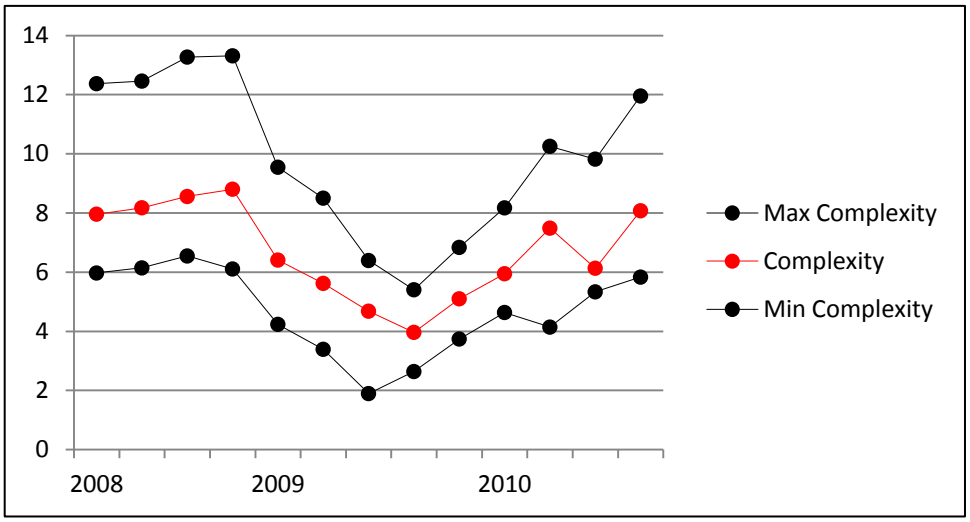


Figure 58: Evolution of entropy chart for the "advanced economies" segment

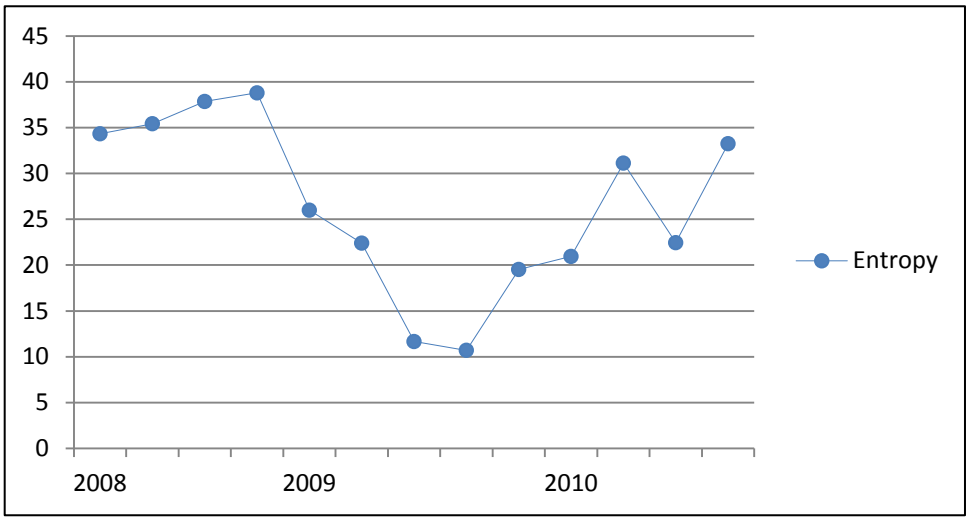
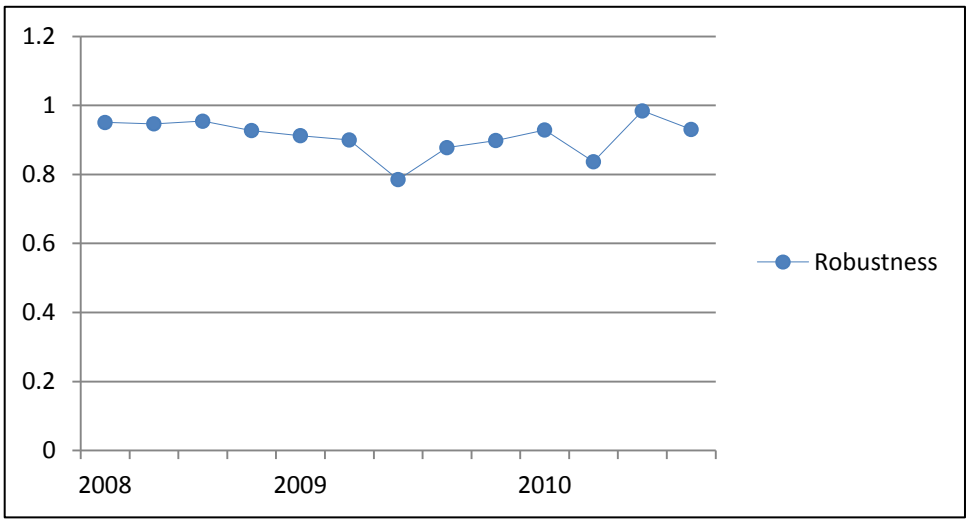


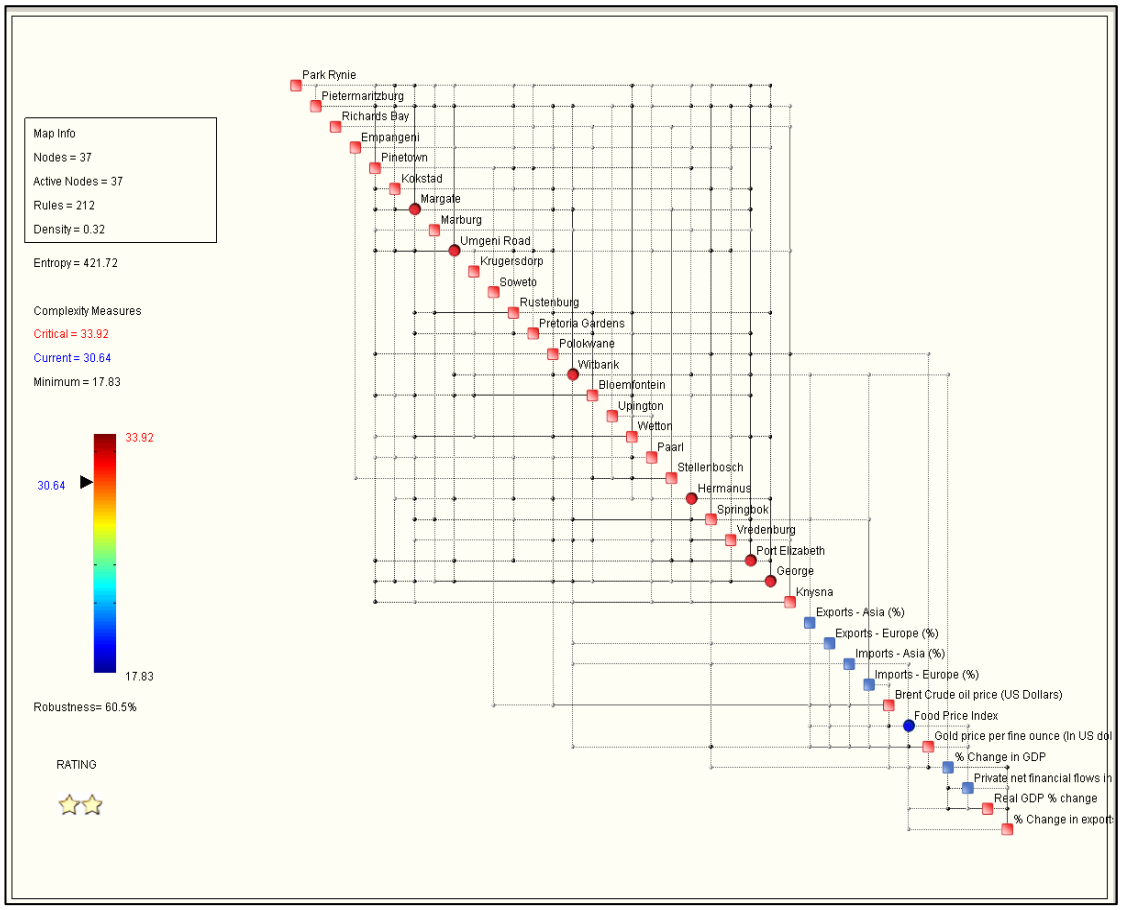
Figure 59: Evolution of robustness chart for the "advanced economies" segment



From the static analysis it can be concluded that although there are relationships between the retail business's variables and the variables of the "advanced economies" segment, they are not very strong and therefore do not have a significant influence on each other. The comparison of the three respective evolution charts of the retail business (figures 48-49) with those of the "advanced economies" segment supports this conclusion. During 2009 the amount of complexity in the retail business remained stable in contrast to the sudden decrease and the increase again of the "advanced economies" segment's complexity. There was an overall linear decrease in the retail business's entropy. The entropy of the "advanced economies" segment followed the same pattern as its complexity. The fluctuation in the business's robustness can be a result of increased unemployment in SA as well as the effects that the National Credit Act, as mentioned earlier, had on the country.

For the third analysis the retail business data set was combined with the data set of the "emerging economies" segment to determine whether variables of this segment had an impact on the business's performance. The following process map for this system was obtained from OntoSpace:

Figure 60: The combined retail business and "emerging economies" segment process map



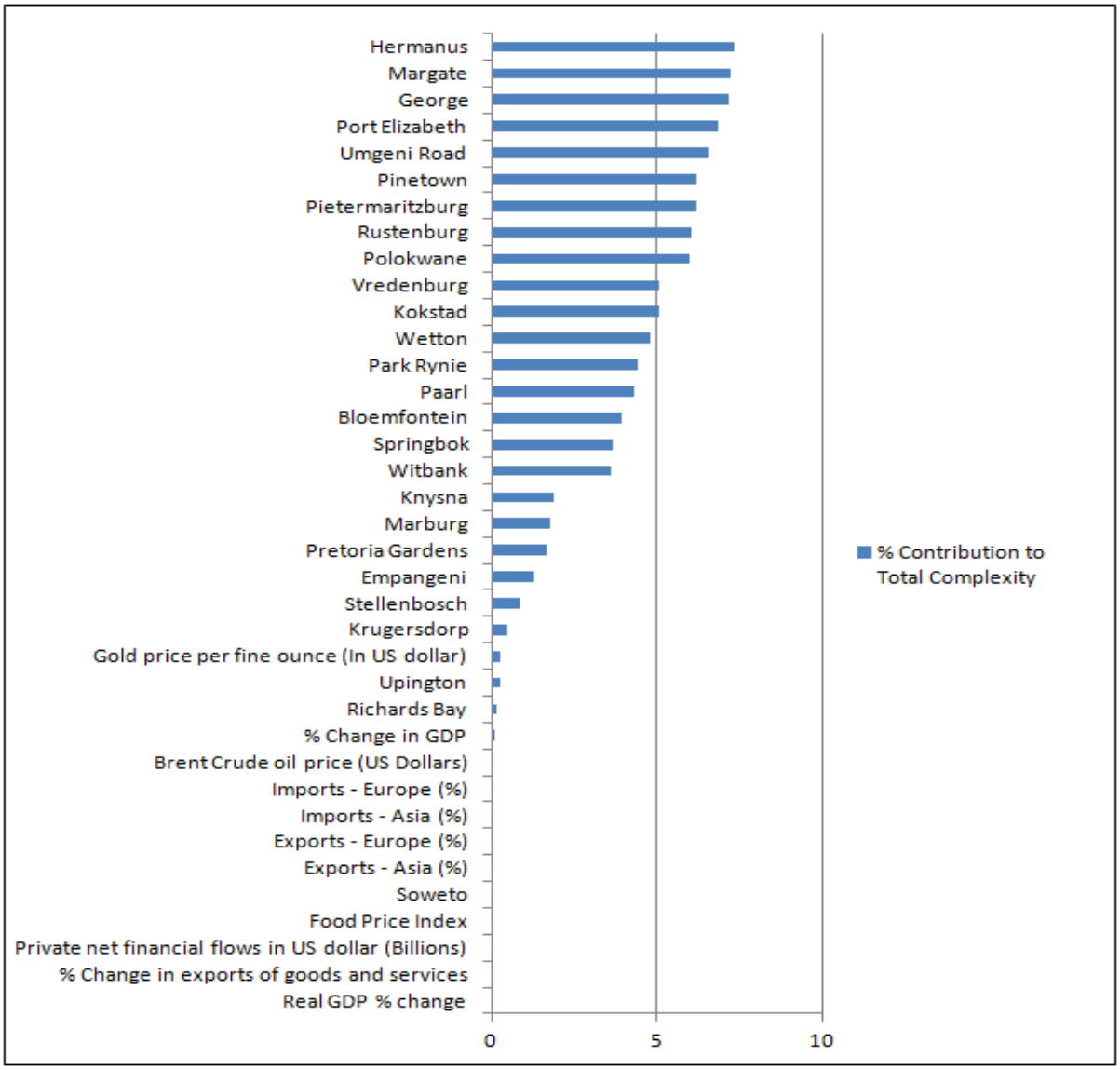
This system is very similar to the one in the previous analysis. This system is also only able to achieve a two star complexity rating and is definitely entropy-driven. Although this system receives a better robustness measurement of 60.5% compared to the previous system's 54.1%, the structure remains fragile because the system is being operated near the critical complexity value. All nodes are active but this system also receives an acceptable density measurement of 0.32 which means that it is still possible to manage and control the amount of complexity that this system possesses. The following table contains the top ten variable pairs with the highest generalized correlations for this analysis:

Table 11: The top ten generalized correlation variable pairs for the retail business and "emerging economies" segment combination

Variable 1	Variable 2	Generalized Correlation
Set 1: Port Elizabeth	Set 1: George	0.74
Set 1: Margate	Set 1: Port Elizabeth	0.7
Set 1: Umgeni Road	Set 1: Port Elizabeth	0.69
Set 1: Pinetown	Set 1: Umgeni Road	0.66
Set 1: Umgeni Road	Set 1: George	0.65
Set 1: Umgeni Road	Set 1: Hermanus	0.64
Set 1: Vredenburg	Set 1: George	0.63
Set 1: Pinetown	Set 1: Port Elizabeth	0.63
Set 3: Brent Crude oil price (US Dollars)	Set 4: Food Price Index	0.61
Set 1: Umgeni Road	Set 1: Vredenburg	0.61

The table contains almost only variables from the data set of the retail business. Four of the six identified retail business hubs, namely Margate, Umgeni Road, Port Elizabeth and George are predominantly part of the top variable pairs. The obtained complexity profile also illustrates that the business's variables contribute the most to the total amount of complexity that this system possesses.

Figure 61: The combined retail business and "emerging economies" segment complexity profile



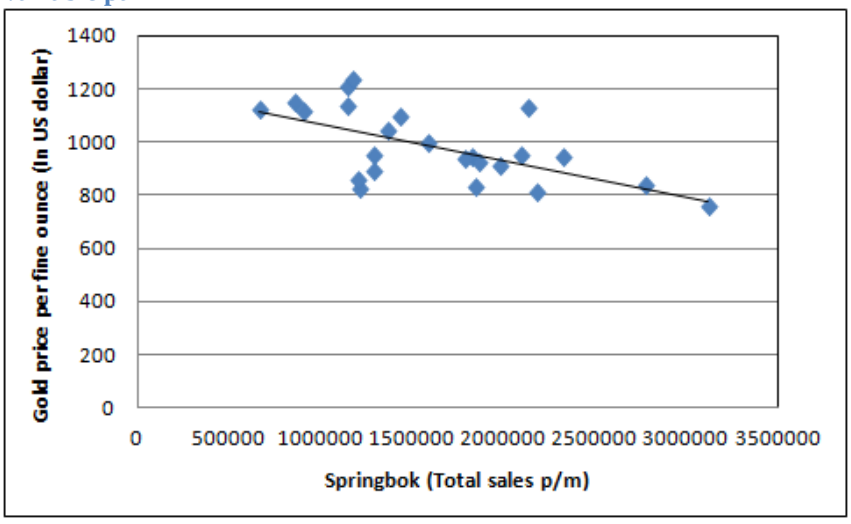
Although very small, the 'Gold price per fine ounce' variable does make a contribution to the total complexity of the system. This variable is also prominent in the top generalized correlation variable pairs table below that contains one variable from the retail business data set and one variable from the data sets of the "emerging economies" segment per pair.

Table 12: The top five generalized correlation variable pairs containing one variable from the retail business and one variable from the "emerging economies" segment per pair

Variable 1	Variable 2	Generalized Correlation
Set 1: Springbok	Set 5: Gold price per fine ounce (In US dollar)	0.461509019
Set 1: Polokwane	Set 5: Gold price per fine ounce (In US dollar)	0.338197798
Set 1: Witbank	Set 5: Gold price per fine ounce (In US dollar)	0.32081899
Set 1: Soweto	Set 3: Brent Crude oil price (US Dollars)	0.312273711
Set 1: Pietermaritzburg	Set 5: Gold price per fine ounce (In US dollar)	0.265760273

Springbok, Polokwane, Witbank and Pietermaritzburg are just a few of the retail business variables that, although not very strong, have a generalized correlation with the 'Gold price per fine ounce' variable. The scatter plot of the 'Springbok/Gold price per fine ounce' variable pair can be seen below:

Figure 62: The scatter plot of the 'Springbok/Gold price per fine ounce' variable pair



Data from the retail business data set and the 'Gold price per fine ounce' data set were used to create charts that illustrate these generalized correlations.

Figure 63: Monthly gold price per fine ounce

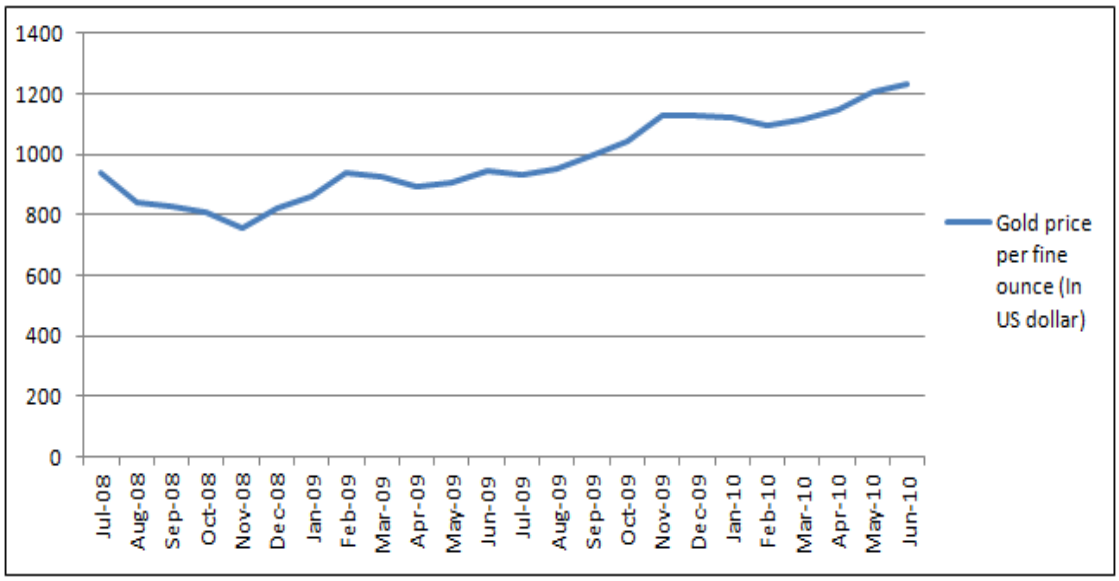
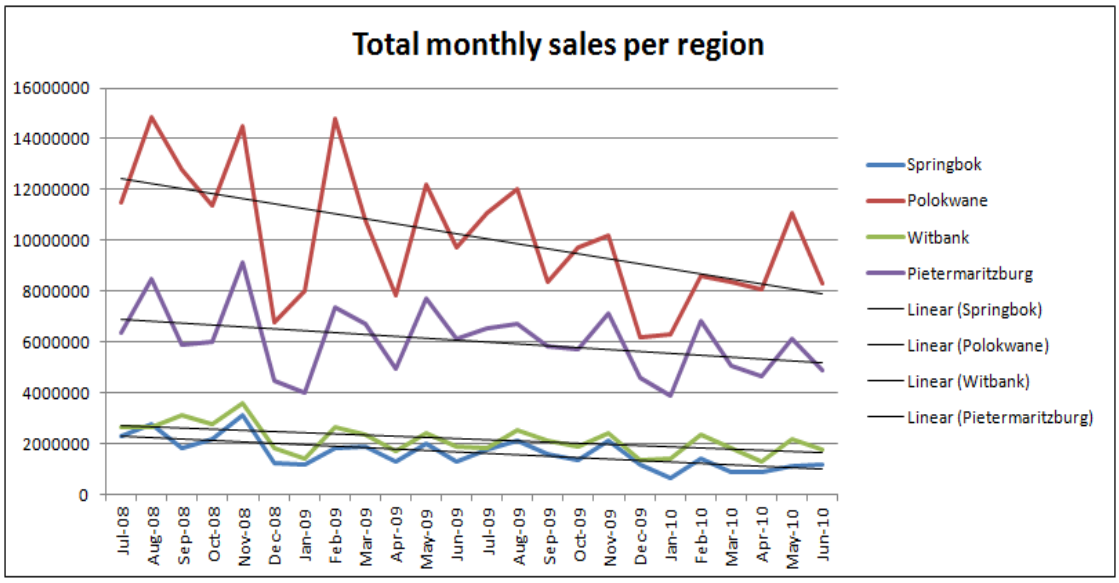


Figure 64: Total monthly sales of respective regions of the retail business



The comparison of these two charts shows that the sales of the respective retail business regions are linearly decreasing as the gold price per fine ounce increases.

A window size of 12 and overlap of 11 were used for this analysis. The system receives a very low stability index value of 48.96% for the time period analysed.

Figure 65: Evolution of complexity chart for the "emerging economies" segment

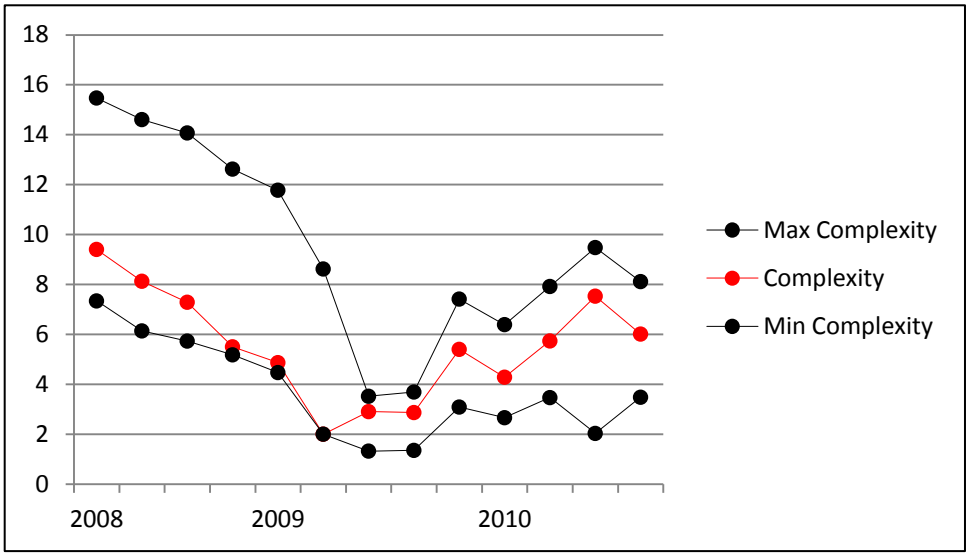


Figure 66: Evolution of entropy chart for the "emerging economies" segment

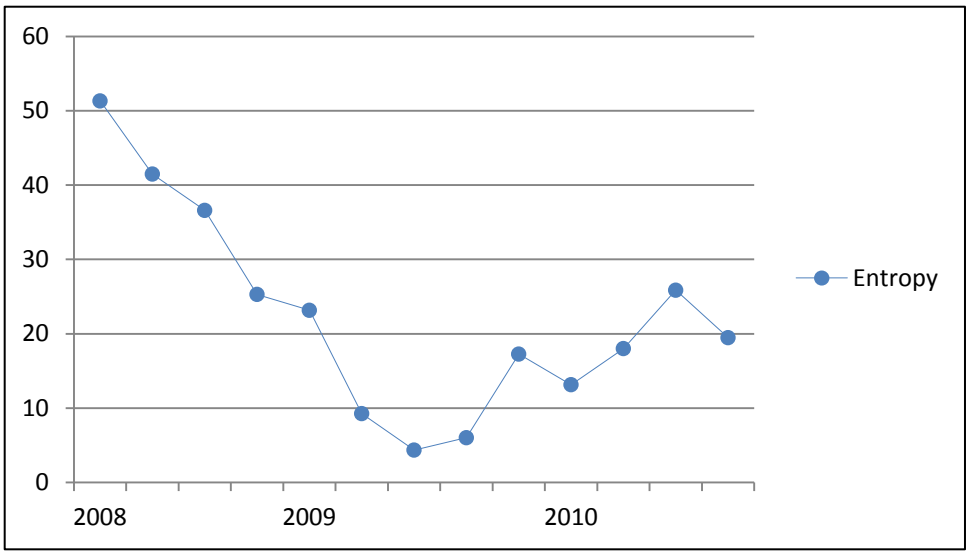
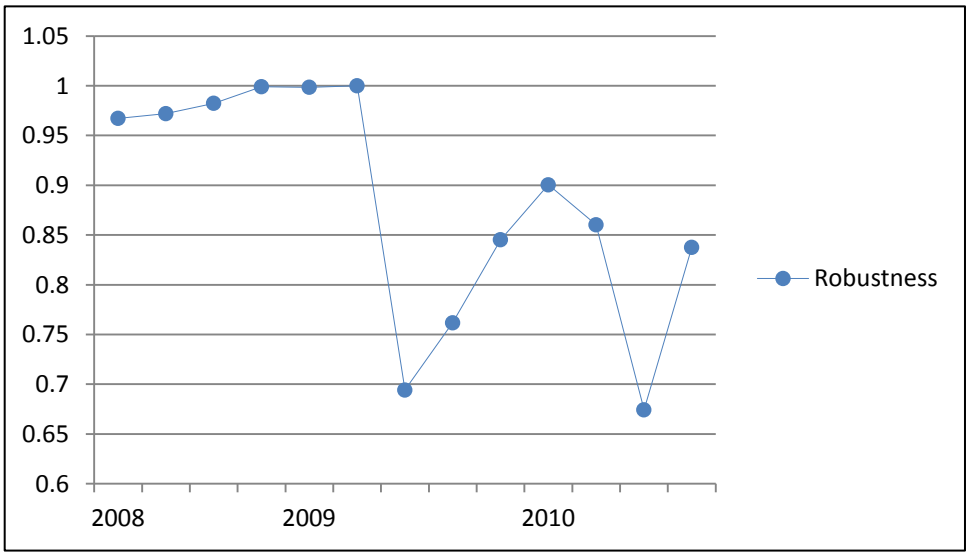


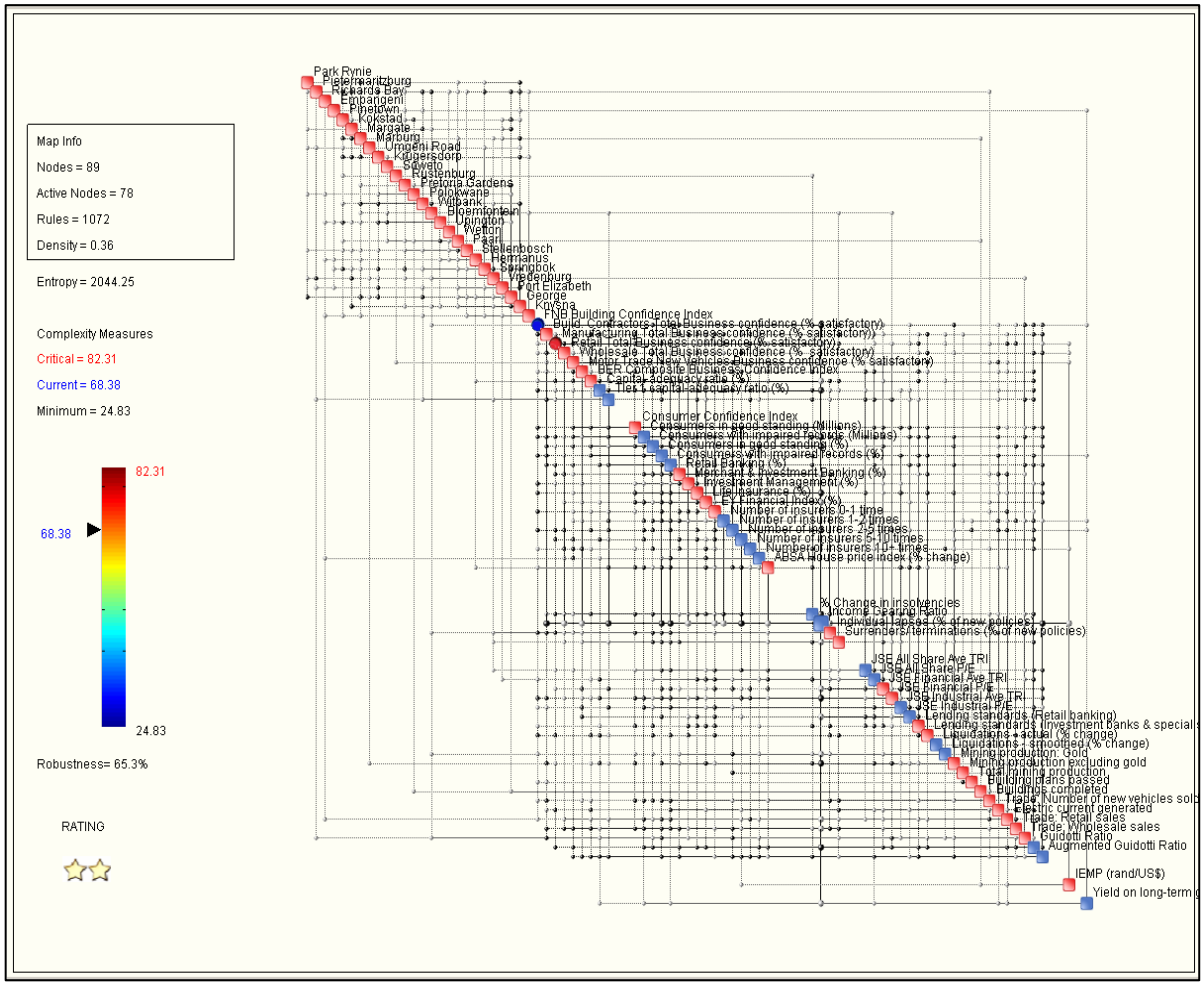
Figure 67: Evolution of robustness chart for the "emerging economies" segment



From the static analysis it is clear that the "emerging economies" segment do not have a significant impact on the retail business, although stronger than that of the "advanced economies" segment. Comparing the evolution of complexity charts of the "emerging economies" segment with that of the retail business illustrates that the complexity of the retail business remained stable while the complexity of the "emerging economies" segment decreased drastically and then increased again during late 2009. The "emerging economies" segment also began to operate very closely to its critical complexity. This was not the case with the retail business. The respective evolution of entropy and robustness charts shows a small resemblance of an identical linear pattern that was followed for the time period.

For the final retail business analysis the data set of the retail business were combined with the data sets of the "domestic economy" segment. The following process map was obtained from OntoSpace:

Figure 68: The combined retail business and "domestic economy" segment process map



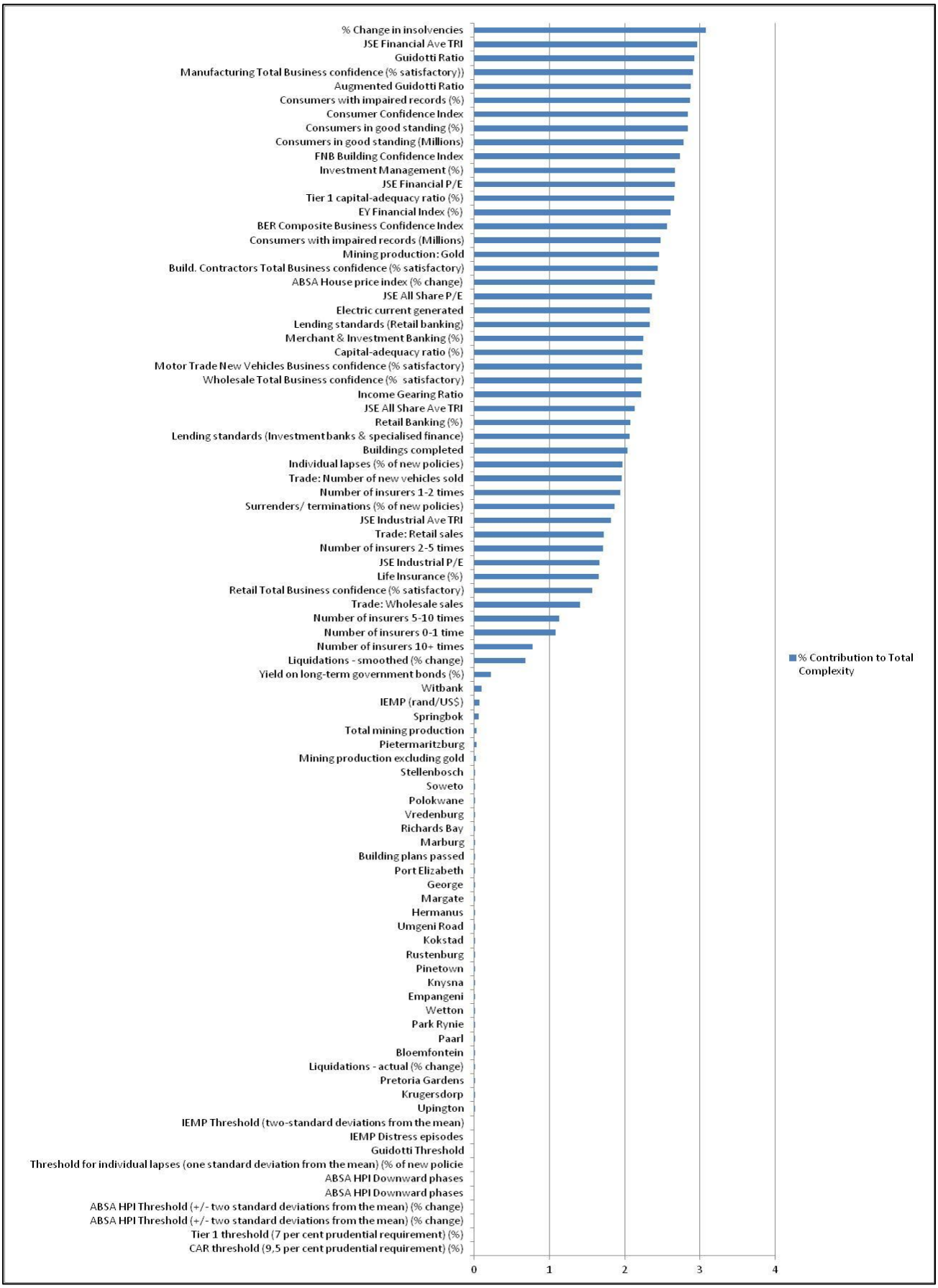
Once again the system is only able to achieve a two star complexity rating. This system is functioning non-deterministically due to the high amount of entropy that the system possesses. This system receives a robustness measurement of 65.3% which means that the system may be severely affected by a crisis. The system is operated near the critical complexity measurement. Although there is a total of 1072 rules (relationships) between the nodes in the system, the system still manages to receive an acceptable density measurement of 0.36 which means that it is still possible to manage and control the amount of complexity that this system possesses. The top ten generalized correlation variable pairs can be ranked as follows:

Table 13: The top ten generalized correlation variable pairs for the retail business and "domestic economy" segment combination

Variable 1	Variable 2	Generalized Correlation
Set 6: Consumers in good standing (Millions)	Set 6: Consumers in good standing (%)	0.86
Set 6: Consumers in good standing (Millions)	Set 8: Number of insurers 1-2 times	0.84
Set 3: Motor Trade New Vehicles Business confidence (% satisfactory)	Set 15: Lending standards (Retail banking)	0.78
Set 17: Mining production excluding gold	Set 17: Total mining production	0.77
Set 3: Retail Total Business confidence (% satisfactory)	Set 15: Lending standards (Investment banks & specialised finance)	0.77
Set 6: Consumers with impaired records (Millions)	Set 8: Number of insurers 1-2 times	0.75
Set 14: JSE Industrial Ave TRI	Set 14: JSE Industrial P/E	0.74
Set 3: Build. Contractors Total Business confidence (% satisfactory)	Set 6: Consumers in good standing (Millions)	0.74
Set 1: Port Elizabeth	Set 1: George	0.74
Set 4: Capital-adequacy ratio (%)	Set 6: Consumers in good standing (Millions)	0.73

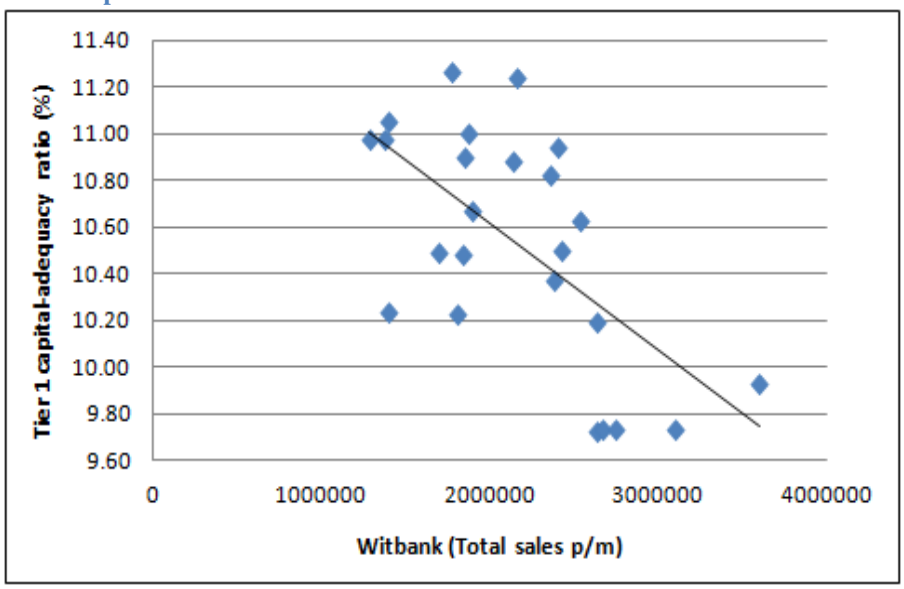
By inspecting the table above and the complexity profile of the system below, it is evident that this system is dominated by the “domestic economy” segment. Almost none of the retail business variables make a significant contribution to the total complexity of the system.

Figure 69: The combined retail business and "domestic economy" segment complexity profile



The strongest generalized correlation between a retail business variable and a "domestic economy" segment variable is that of the 'Witbank/Tier 1capital-adequacy ratio' variable pair. The pair has a generalized correlation value of 0.43. The following scatter plot illustrates the relationship between these two variables:

Figure 70: The scatter plot of the 'Witbank/Tier 1capital-adequacy ratio' variable pair



It can be noted from the scatter plot that a lot of broken structure is present between these two variables. The data points of the variable pair are not clustered closely together in groups and also not near the linear trend line and therefore their generalized correlation are not that strong.

A window size of 12 and an overlap of 11 were also selected for this dynamic analysis. The "domestic economy" segment receives an acceptable stability index value of 73.11% due to the stability in complexity and the linear increase in robustness of the system in the period of analysis.

Figure 71: Evolution of complexity chart for the "domestic economy" segment

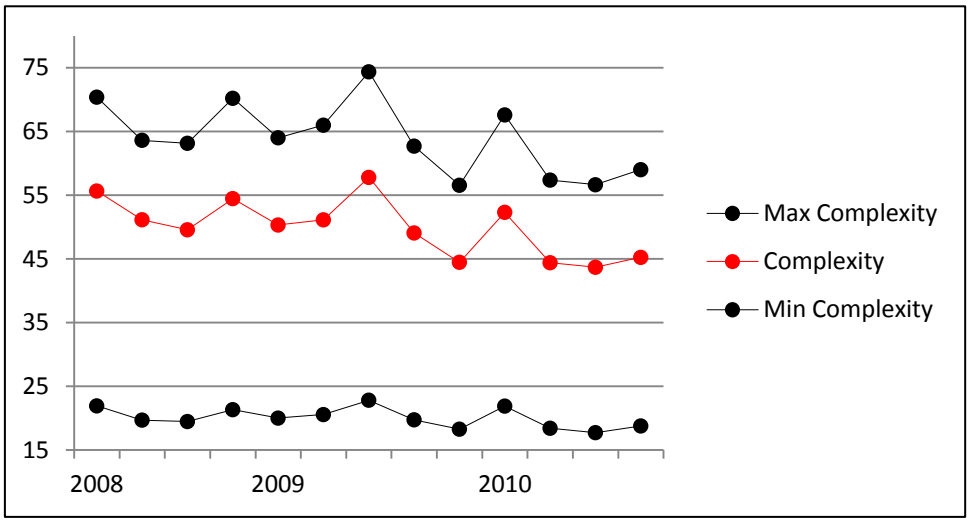


Figure 72: Evolution of entropy chart for the "domestic economy" segment

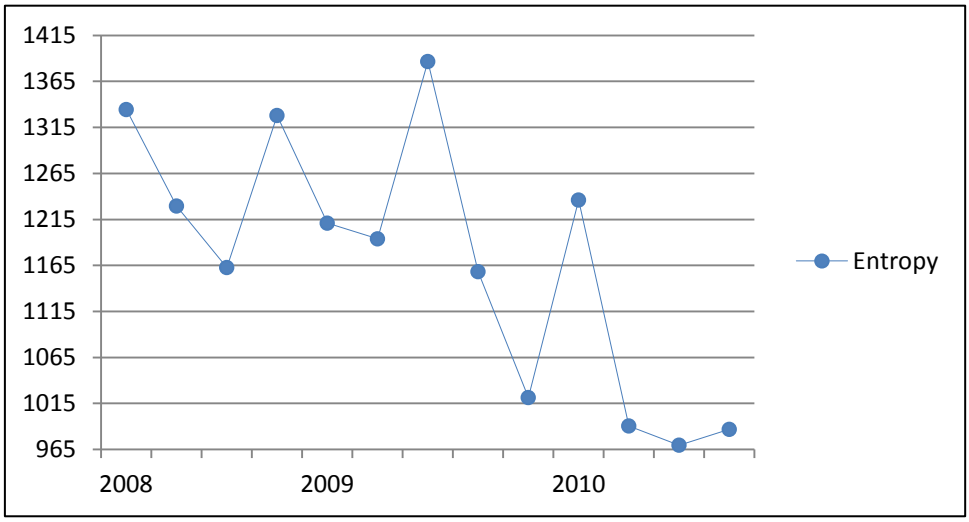
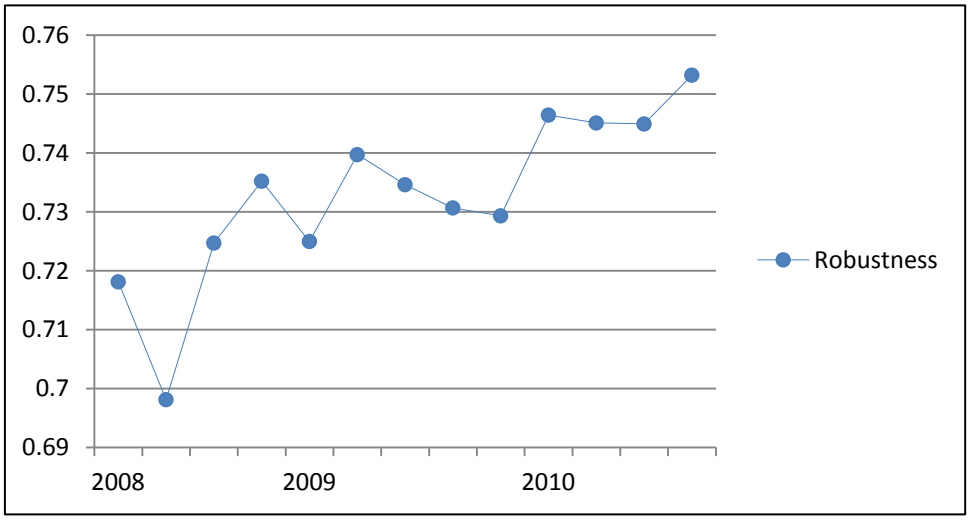


Figure 73: Evolution of robustness chart for the "domestic economy" segment



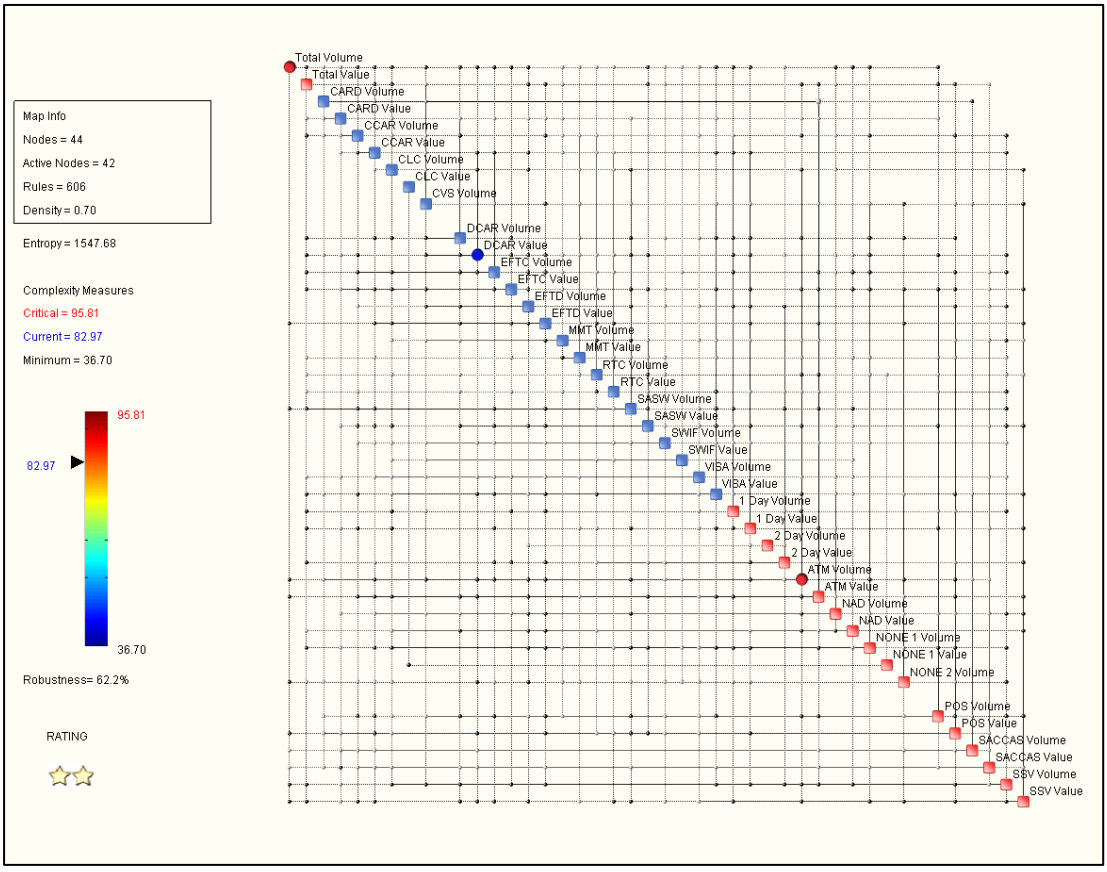
From the static analysis it is clear that the "domestic economy" segment is the main contributor of complexity to the system. Relationships between the retail business variables and variables of the "domestic economy" segment are not that strong, but if the amount of complexity that the "domestic economy" segment contributes is not managed or reduced it most may probably affect the retail business's performance. The segment's complexity as well as the business's complexity remains stable throughout the period of analysis. Both evolution of entropy charts show a linear decrease and may be the reason for the few strong generalized correlations between business variables and the segment variables. The segment illustrates a much more stable increase in robustness as opposed to the retail business's robustness that is drastically fluctuating. This can be an indication of regulatory issues for example within the business itself.

8.3.6 An electronic payment service provider within the three main segments

An industry leading electronic payment service provider (name will not be disclosed for privacy reasons) was used for this case study. Three data sets were populated for this case study, namely the total volume and value of all electronic transactions per month, the total volume and value for specified services per month and the total volume and value of subservices per month that was used for a specific service.

The first analysis was conducted to establish all possible relationships between the volumes and values of the three data sets and obtain a relevant process map from OntoSpace. After this analysis the three data sets were combined with the data sets of the three main segments to determine if the business's transaction performance was impacted by external parameters. The following figure illustrates the process map of the service provider:

Figure 74: Process map of the service provider



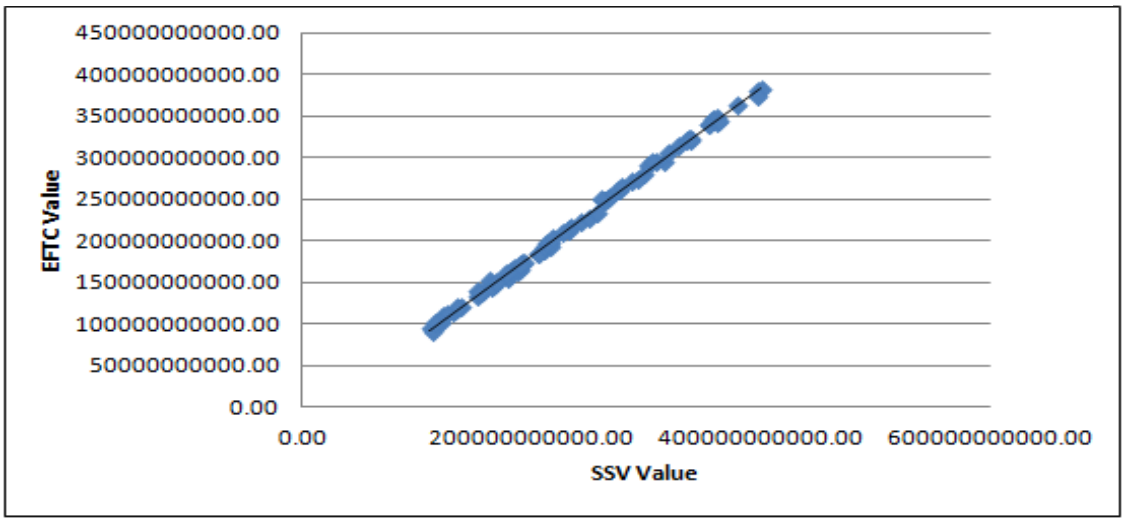
The process map illustrates that the service provider's system is very fragile. The system possesses a high amount of complexity and entropy and is therefore very volatile. The system is being operated very closely to its critical complexity measurement of 95.81 and therefore it only receives a two star complexity rating. The high density of the system indicates that it will be difficult to implement changes in the system. Credible forecasts cannot be made for this system and when a crisis occurs the system will most probably struggle to cope as indicated by the low robustness measurement of 62.2%.

Table 14: The top ten generalized correlation variable pairs of the service provider

Variable 1	Variable 2	Generalized Correlation
Set 2: EFTC Value	Set 3: SSV Value	0.95
Set 2: CLC Volume	Set 3: NONE 1 Volume	0.94
Set 2: CCAR Value	Set 3: POS Value	0.93
Set 2: CCAR Volume	Set 3: POS Volume	0.93
Set 1: Total Value	Set 3: SSV Value	0.92
Set 2: CVS Volume	Set 3: NONE 2 Volume	0.92
Set 1: Total Value	Set 2: EFTC Value	0.92
Set 2: EFTD Value	Set 3: SSV Value	0.91
Set 1: Total Volume	Set 3: SSV Volume	0.91
Set 2: CARD Volume	Set 3: SACCAS Volume	0.91

From the table it can be seen that the 'Credit Electronic Fund Transfer (EFTC)/Siteserv (SSV) Value' variable pair has the strongest generalized correlation. This correlation is depicted in the following scatter plot:

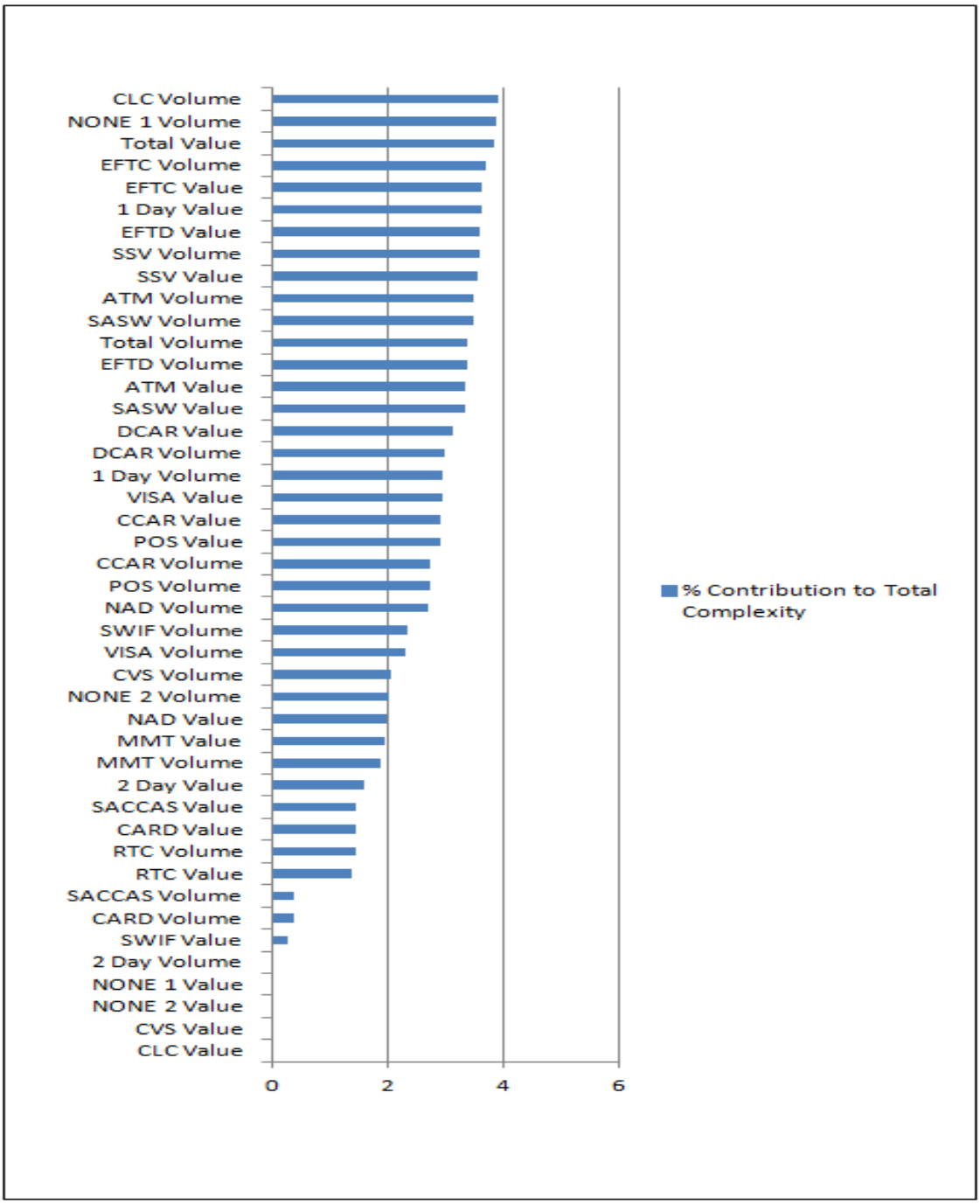
Figure 75: The scatter plot of the 'EFTC/SSV Value' variable pair



This high generalized correlation value depicts the strong relation between this service variable and subservice variable. Both of these variables in turn also have a very strong generalized correlation with the total value of all the transactions generated per month.

The following complexity profile ranks the main contributors of complexity:

Figure 76: The complexity profile of the service provider



The contribution of complexity is well balanced between service variables and subservice variables.

For the dynamic analysis a window size of 36 and an overlap of 35 were chosen. The service provider's system received a high stability index measurement of 71.48% for the analysis period which was between January 2002 and December 2008. The following respective evolution charts were obtained from OntoSpace and are compared to the evolution charts of the three main segments:

Figure 77: Evolution of complexity chart of the service provider

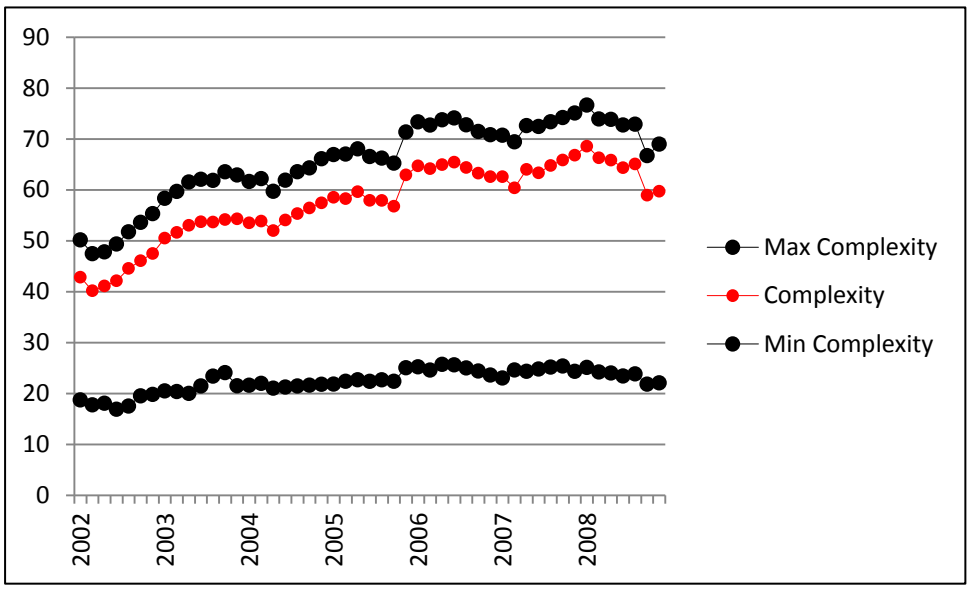


Figure 78: Evolution of entropy chart of the service provider

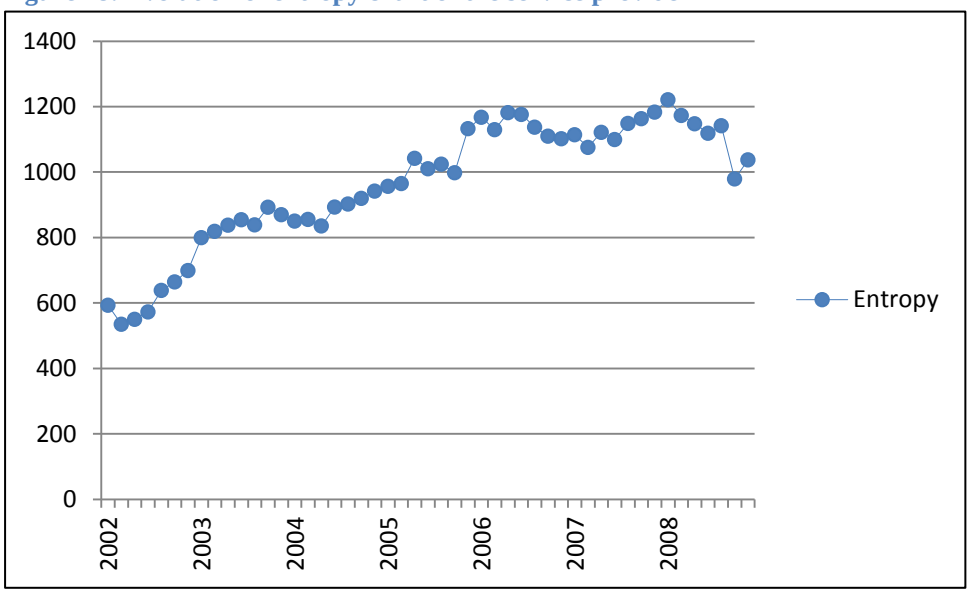
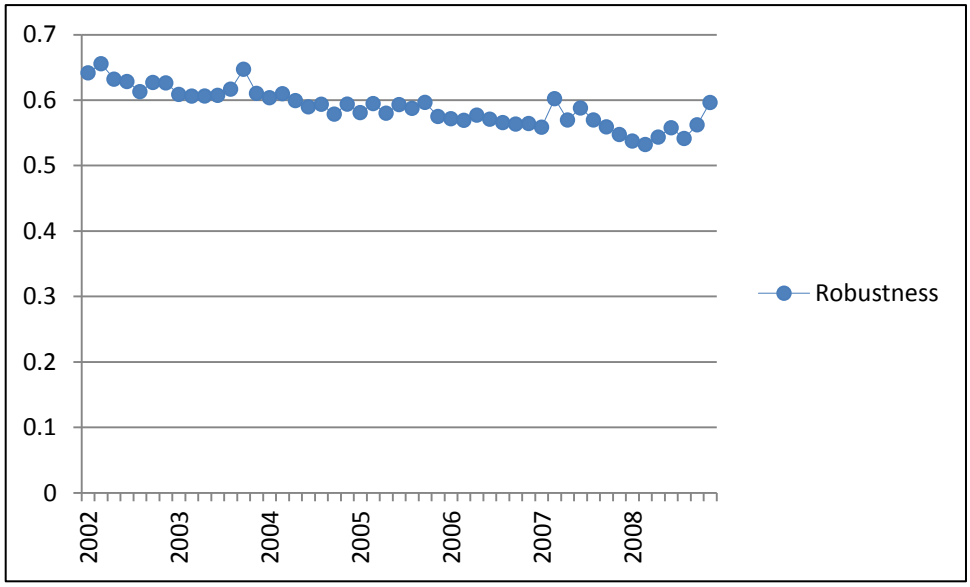
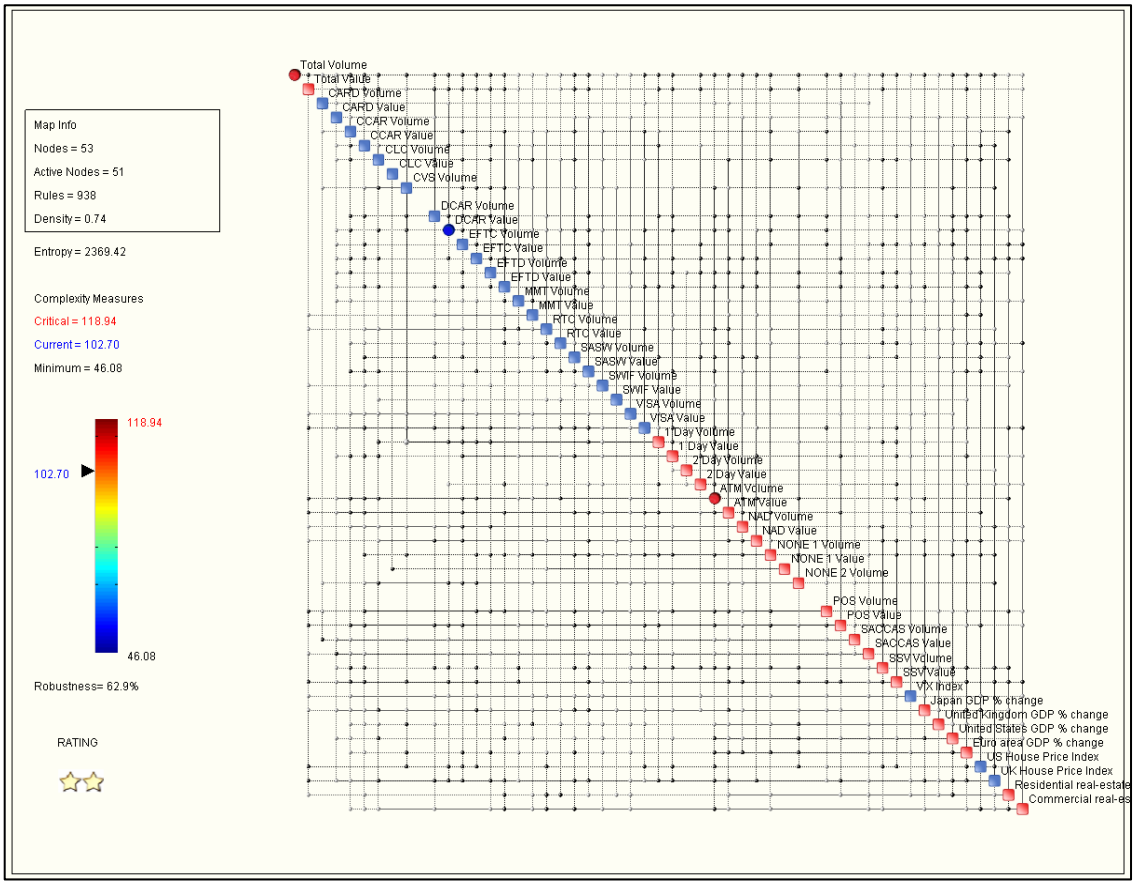


Figure 79: Evolution of robustness chart of the service provider



For the second analysis the data sets of the service provider were combined with the data sets of the "advanced economies" segment to determine whether variables of this segment had an impact on the business's performance. The following process map for this system was obtained from OntoSpace:

Figure 80: The combined service provider and "advanced economies" segment process map



The process map illustrates a complex system. The system possesses a high amount of complexity and entropy and therefore it has a fragile structure. The system's current complexity measurement of 102.7 is very close to the critical complexity measurement of 118.94. The system is only able to achieve a two star complexity rating. The high density of the system (only two nodes are inactive) indicates that it will be difficult to manage this system and also to implement changes in the system. The system receives a low robustness measurement of 62.9%.

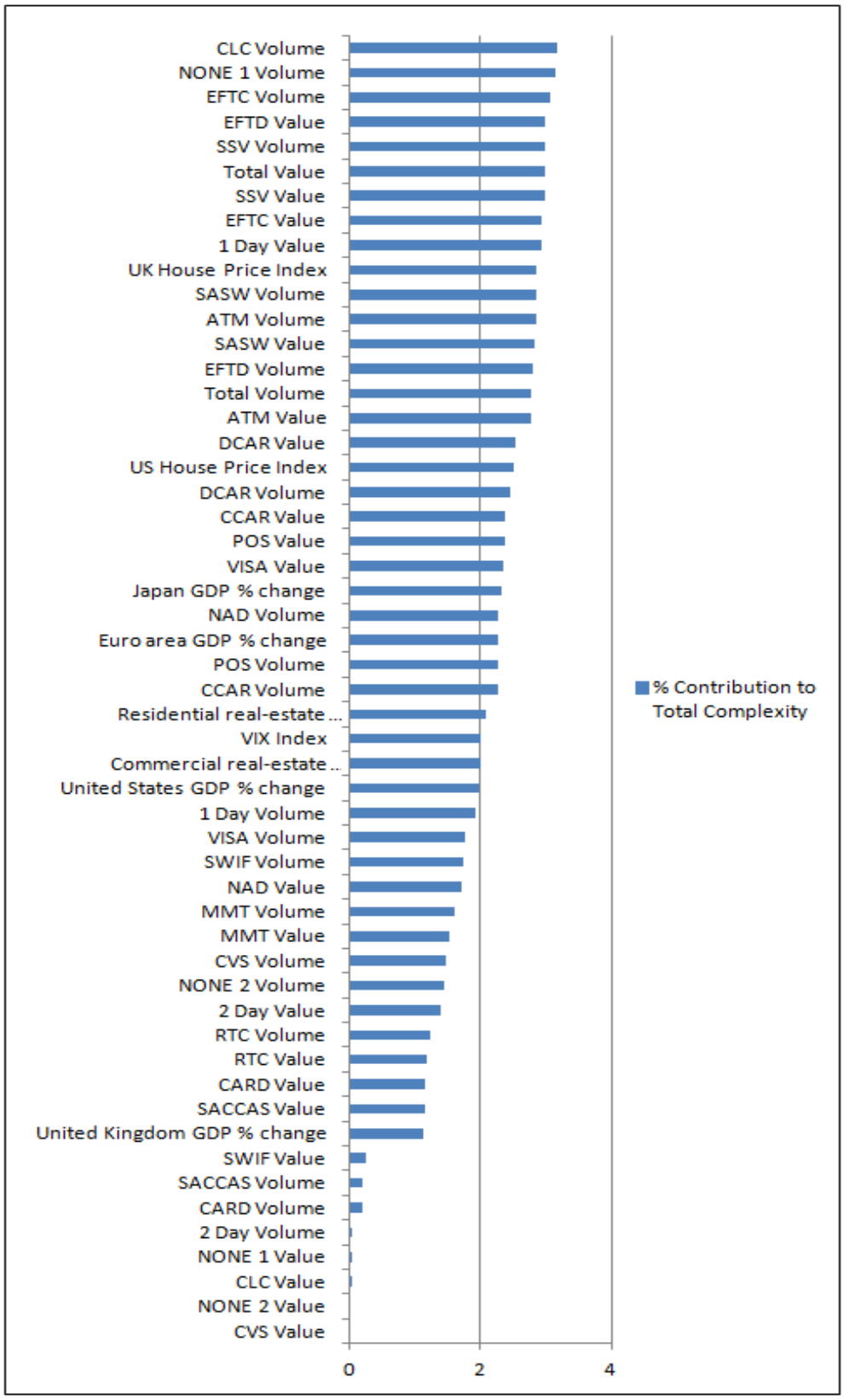
The following table contains the top ten generalized correlations for this analysis:

Table 15: The top ten generalized correlation variable pairs for the service provider and "advanced economies" segment combination

Variable 1	Variable 2	Generalized Correlation
Set 2: EFTC Value	Set 3: SSV Value	0.95
Set 2: CLC Volume	Set 3: NONE 1 Volume	0.94
Set 2: CCAR Value	Set 3: POS Value	0.93
Set 2: CCAR Volume	Set 3: POS Volume	0.93
Set 1: Total Value	Set 3: SSV Value	0.92
Set 2: CVS Volume	Set 3: NONE 2 Volume	0.92
Set 1: Total Value	Set 2: EFTC Value	0.92
Set 2: EFTD Value	Set 3: SSV Value	0.91
Set 1: Total Volume	Set 3: SSV Volume	0.91
Set 2: CARD Volume	Set 3: SACCAS Volume	0.91

The table above does not contain one variable pair that has an "advanced economies" segment variable as one of the pairs. In fact, the top ten ranked variable pairs are exactly the same as those from the first service provider analysis. However, the complexity profile illustrates that all of the "advanced economies" segment variables do make a contribution to the total amount of complexity that the system possesses.

Figure 81: The combined service provider and "advanced economies" segment complexity profile



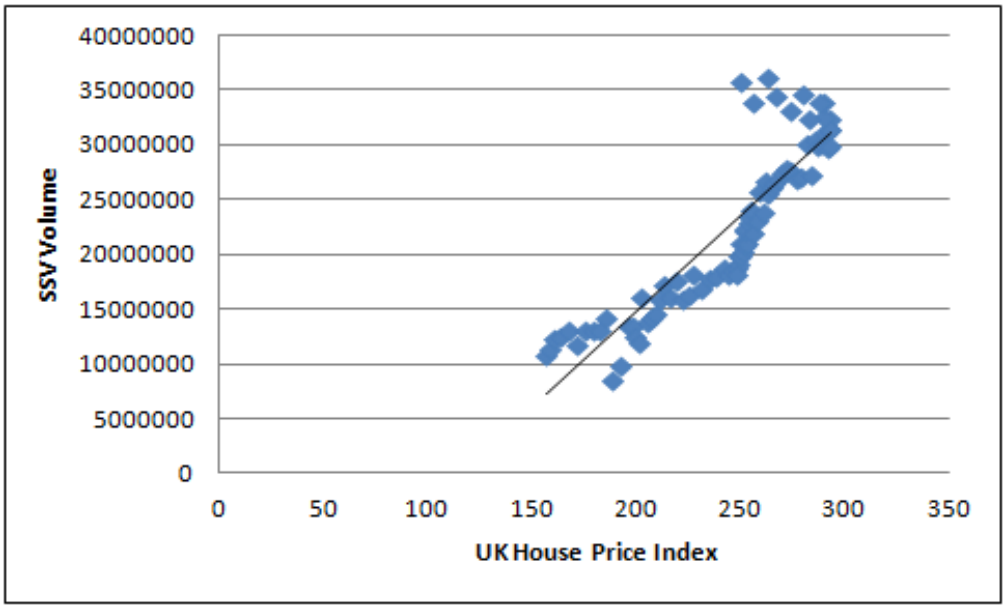
Because of the latter, further investigation was conducted to determine the top five generalized correlation variable pairs between a service provider variable and an "advanced economies" segment variable. The following table lists these top ranked variable pairs as follows:

Table 16: The top five generalized correlation variable pairs containing one variable from the service provider and one variable from the "advanced economies" segment per pair

First Variable	Second Variable	Generalized Correlation
SSV Volume	UK House Price Index	0.84621489
RTC Volume	Residential real-estate delinquencies (% cent of loans)	0.842155695
SSV Value	UK House Price Index	0.840598106
EFTD Value	UK House Price Index	0.837590337
RTC Value	Residential real-estate delinquencies (% cent of loans)	0.832724273

The table above shows that although these five variable pairs do not show in the top ten generalized correlation variable pair table, there exist extremely strong relationships between the service provider variables and the "advanced economies" segment variables. The following scatter plot illustrates the strong relationship of the 'SSV Volume/UK House Price Index' variable pair:

Figure 82: The scatter plot of the 'SSV Volume/UK House Price Index' variable pair



From the scatter plot valuable knowledge is gained. The data points from the variables are clustered together near the linear trend line that depicts why this variable pair has such a high generalized correlation value. Because of this generalized correlation the 'SSV Volume' variable will most certainly also have a strong relationship with the US House Price Index because of the high generalized correlation between the latter and the UK House Price Index as calculated previously.

For the dynamic analysis a window size of 36 and overlap of 35 were selected. The "advanced economies" segment receives a relatively high stability index of 61.13%. The following evolution charts was obtained from the analysis:

Figure 83: Evolution of complexity in the "advanced economies" segment

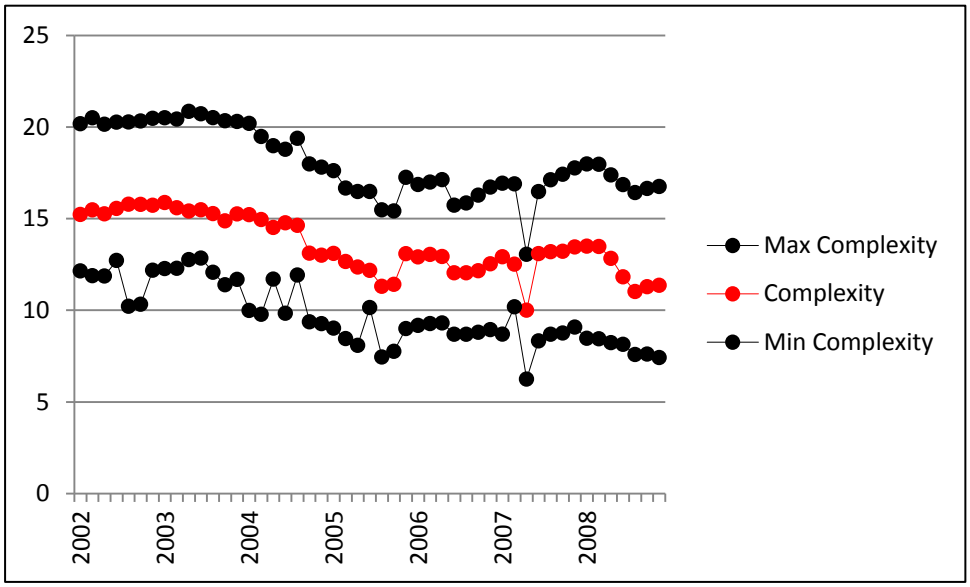


Figure 84: Evolution of entropy in the "advanced economies" segment

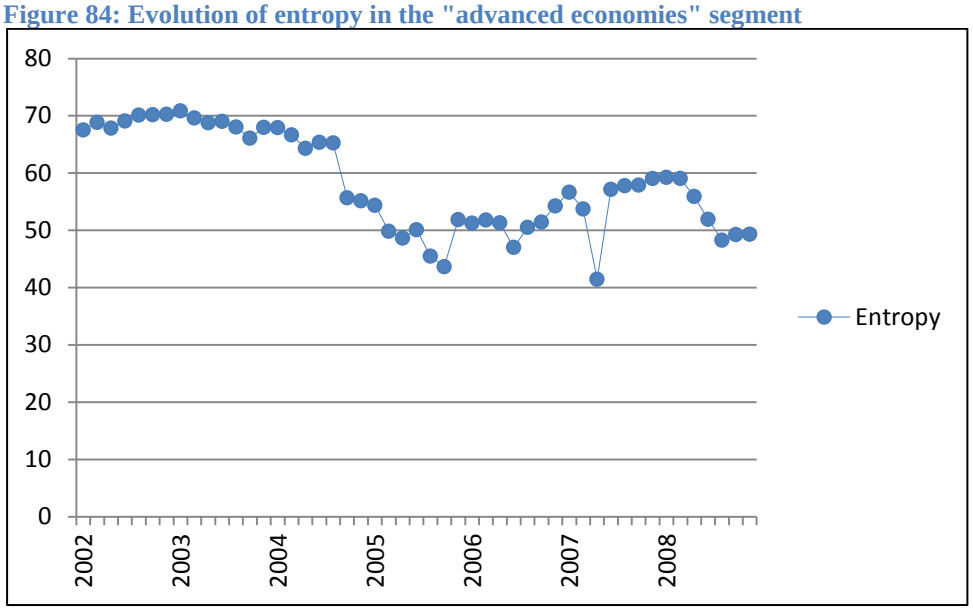
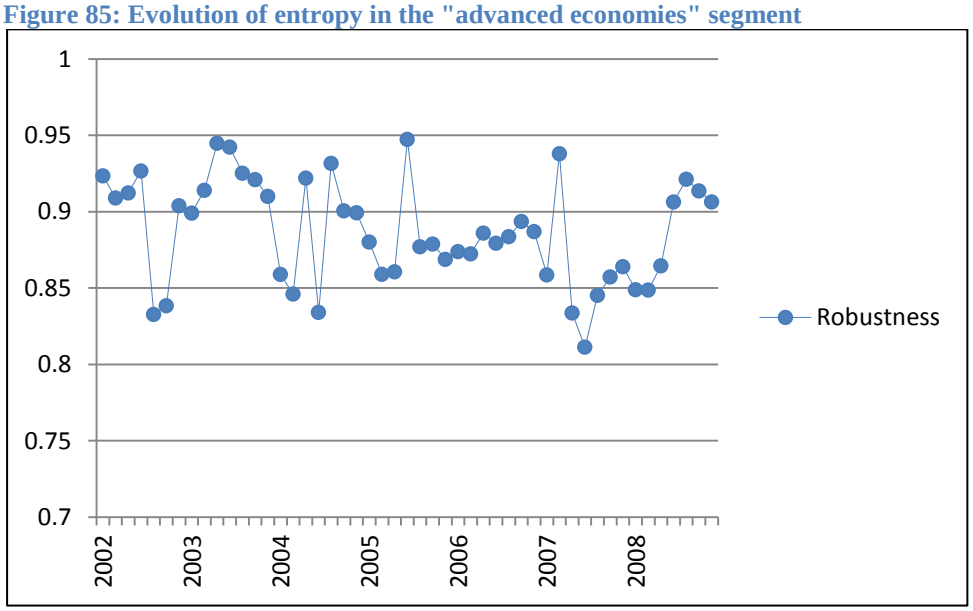


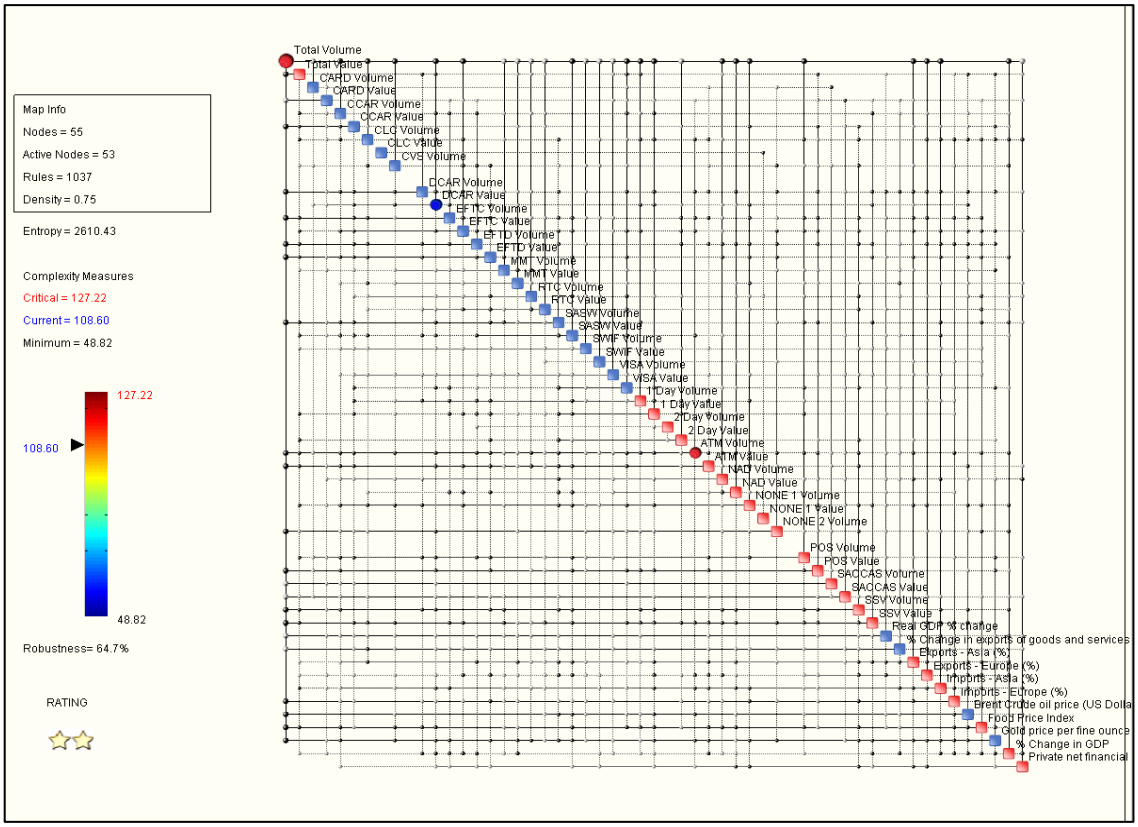
Figure 85: Evolution of entropy in the "advanced economies" segment



From the static analysis it is evident that the “advanced economies” segment does have a significant impact on the service provider performance. Even in the top twenty generalized variables pairs the values remain above 0.82. The comparison of the three respective evolution charts of the service provider (figures 75-77) with those of the “advanced economies” segment indicates a somewhat different perspective. During the period of analysis the complexity and entropy of the “advanced economies” segment remained stable until mid 2004 when the real estate bubble surfaced and the US took drastic measures to counteract financial crises. This is in contrast with the service provider’s evolution charts. For the whole period of analysis the complexity and entropy of the service provider increased while the robustness decreased. The robustness of the “advanced economies” segment continuously oscillated around a value of 0.87. The reason for this contrast may be because of the delay in transfer of the consequences of the recent economic crisis to SA.

For the third analysis the data sets of the service provider were combined with the data sets of the “emerging economies” segment. The following process map for this system was obtained from OntoSpace:

Figure 86: The combined service provider and "emerging economies" segment process map



The amount of complexity in this system is high as indicated by the two star complexity rating on the process map. The system has a very dense structure which will be difficult to manage and control. Exposure and inefficiency are high. The system is definitely entropy-driven, making it difficult to make credible forecasts. The system receives a low robustness measurement of 64.7% that is not sufficient to sustain a crisis without some system breakdown.

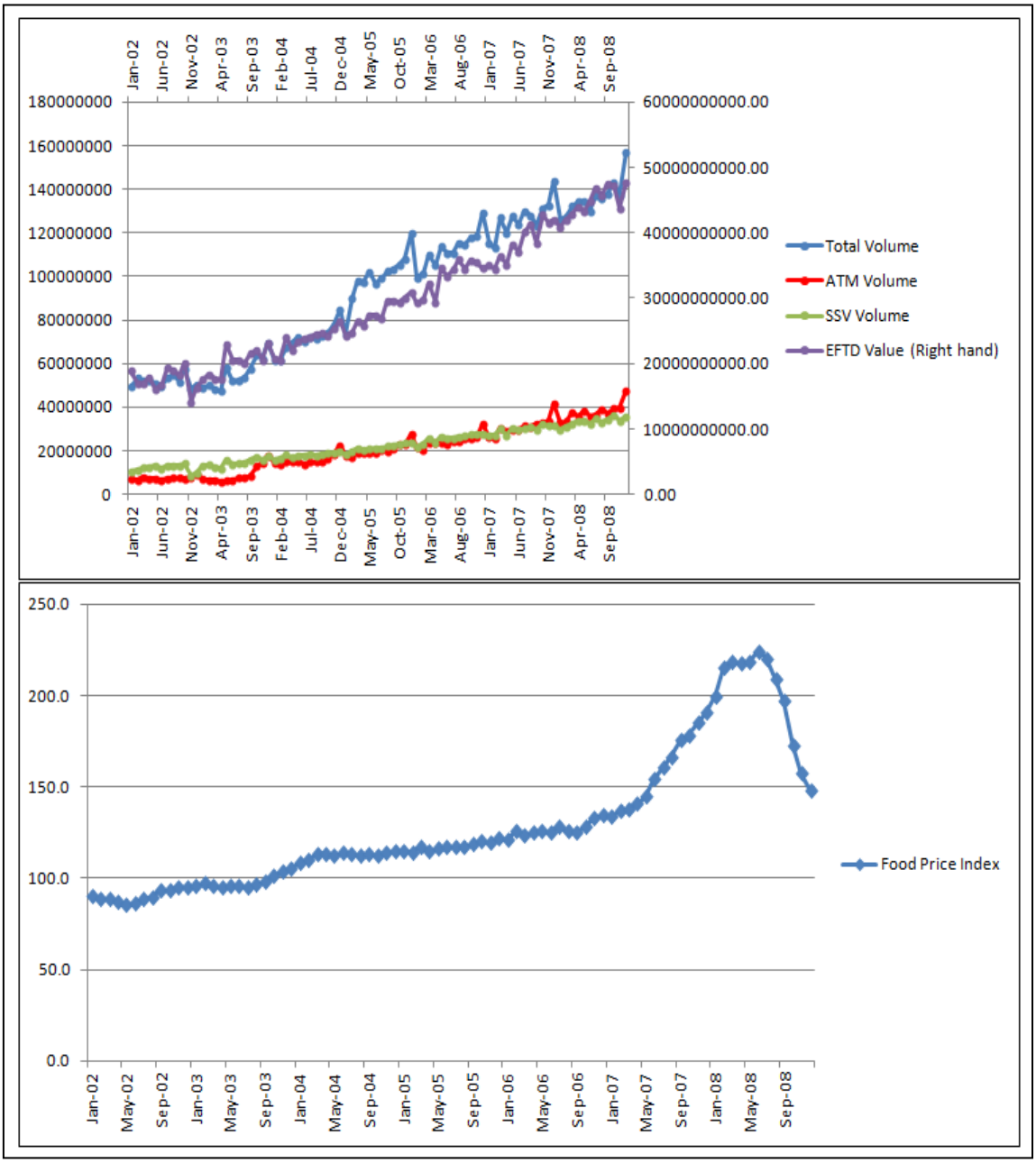
During the analysis it was found that the top ten generalized variable pairs were exactly the same as in the two previous analyses. The data sets were filtered to obtain the top generalized correlation mixed variable pairs which would be of more significant value. The following table was obtained:

Table 17: The top ten generalized correlation variable pairs containing one variable from the service provider and one variable from the "emerging economies" segment per pair

First Variable	Second Variable	Generalized Correlation
ATM Volume	Food Price Index	0.877750039
Total Volume	Food Price Index	0.862413526
SSV Volume	Food Price Index	0.857745647
EFTD Value	Food Price Index	0.857377529
EFTD Value	Gold price per fine ounce (In US dollar)	0.855843484
SSV Value	Food Price Index	0.845674098
ATM Volume	Gold price per fine ounce (In US dollar)	0.8342731
CLC Volume	% Change in GDP	0.834265172
CLC Volume	Exports - Asia (%)	0.834265113
EFTC Volume	Food Price Index	0.832876563

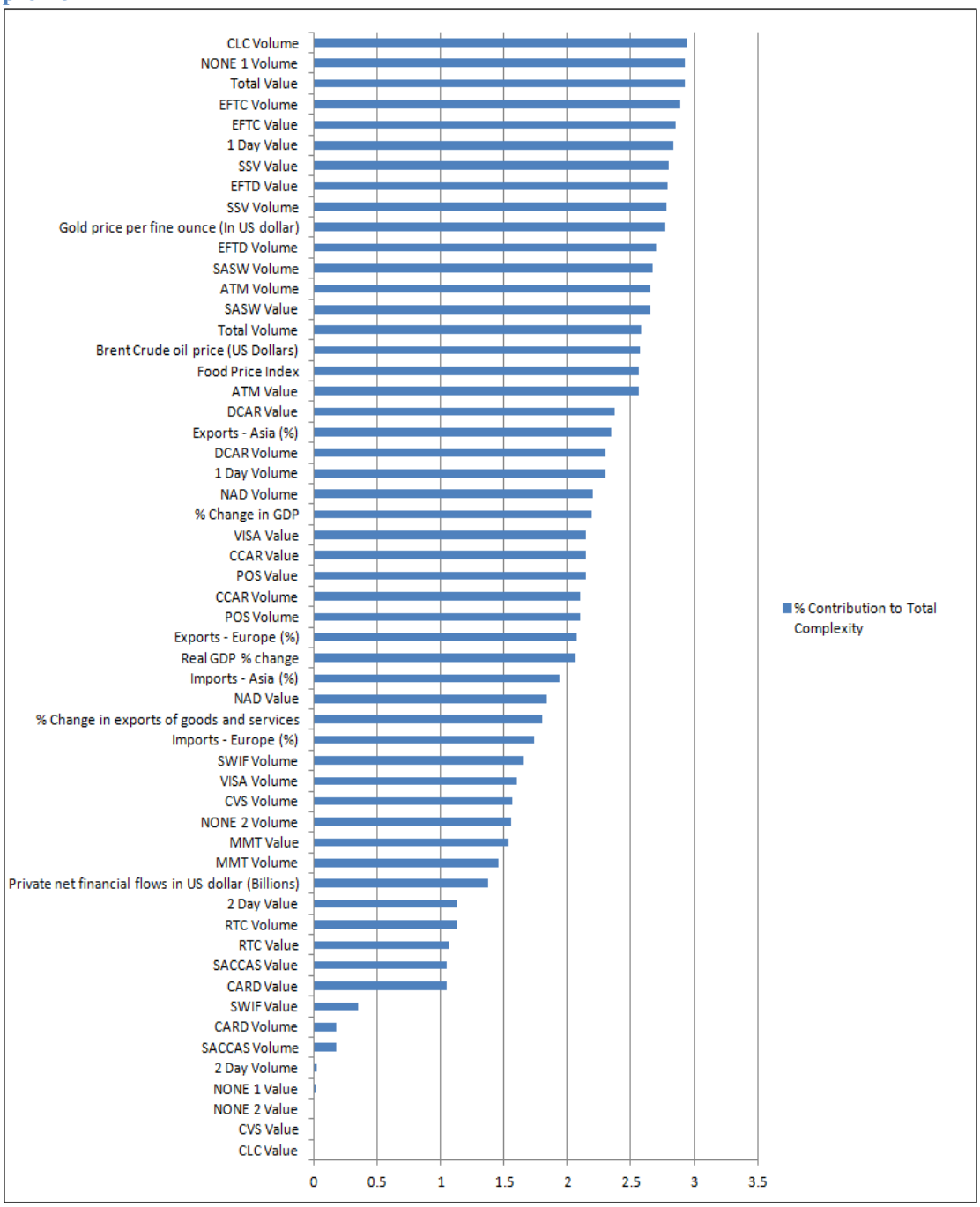
Again on further investigation it was found that there exist strong relationships between the variables of the service provider and the variables of the segment. The following two charts were constructed to illustrate the strong generalized correlation between the volume of automated teller machine (ATM) transactions per month, the total volume of electronic transactions per month, the volume of Siteserv transactions per month, the value of debit electronic fund transfer transactions per month and the segment's Food Price Index:

Figure 87: An illustration of the strong relationship between the service provider and the "emerging economies segment"



The charts above illustrate that the total volume of electronic transactions per month, as well as the volumes and value of the other respective transactions per month increased as the Food Price Index increased over most of the period of analysis. The complexity profile for this system below also illustrates a balance in the different variables that are contributing to the system's complexity:

Figure 88: The combined service provider and "emerging economies" segment complexity profile



A window size of 36 and overlap of 35 were selected for the time-dependent analysis. The "emerging economies" segment receives a relatively high stability index of 63.78% which suggests that the system was stable during the analysed period. The following evolution charts were obtained from the analysis:

Figure 89: Evolution of complexity in the "emerging economies" segment

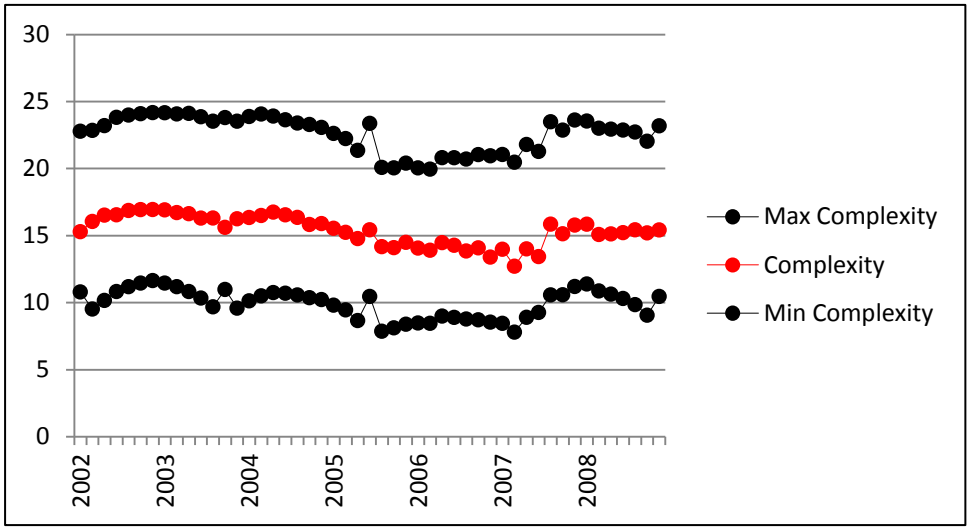


Figure 90: Evolution of entropy in the "emerging economies" segment

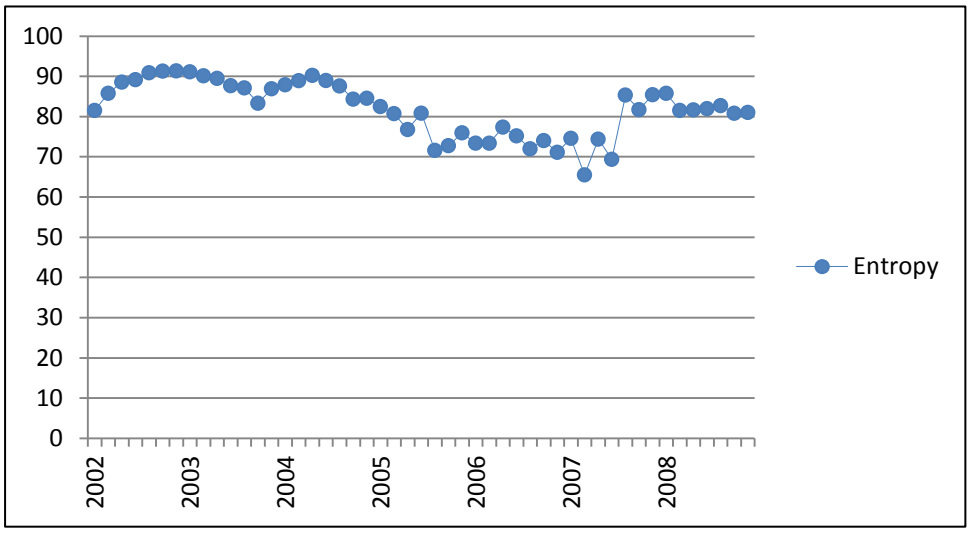
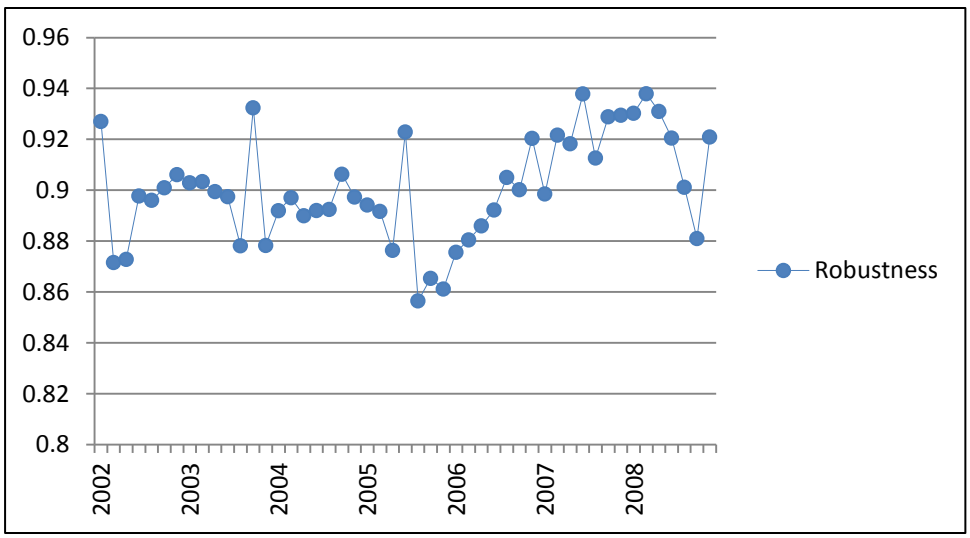


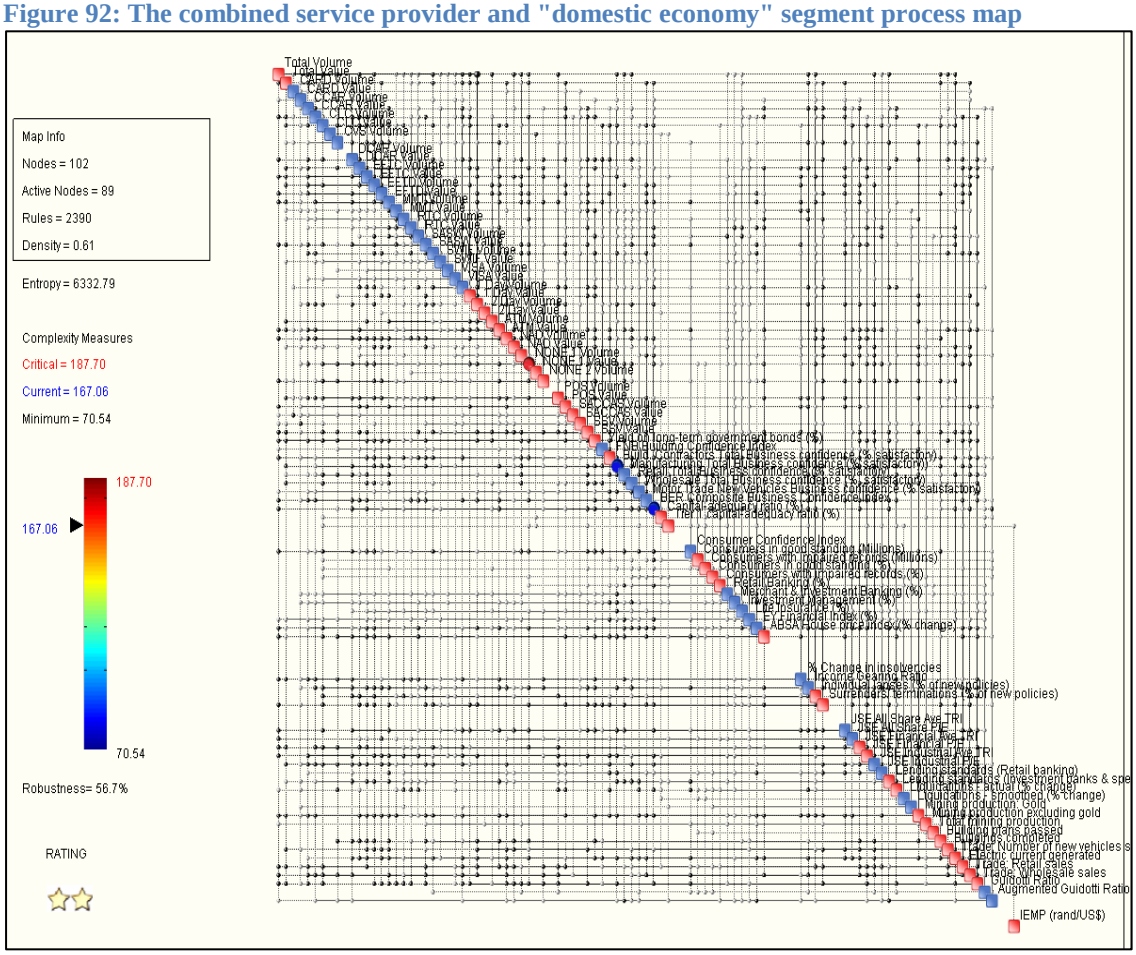
Figure 91: Evolution of robustness in the "emerging economies" segment



From the static analysis there is a strong indication of the influence that the "emerging economies" segment has on the service provider. The "emerging economies" segment does however have a more stable evolution of complexity, entropy and robustness. This is however positive for the service provider that needs to operate within this segment.

For the final analysis the data sets of the service provider were combined with the data sets of the "domestic economy" segment. The following process map for this system was obtained:

Figure 92: The combined service provider and "domestic economy" segment process map



This system is also only able to achieve a two star complexity rating. The system is very vulnerable because it is being operated near its critical complexity measurement. There is also not enough redundancy built into the system due to the fact that 102 of the nodes that are active only 4 are identified as hubs. The system has a low

robustness measurement and is highly entropy-driven. The 2390 rules in the system result in a high density value of 0.61 which is above the acceptable value of 0.5. Because the system is so dense, it will be difficult to implement changes in the system and also to manage the complexity in the system.

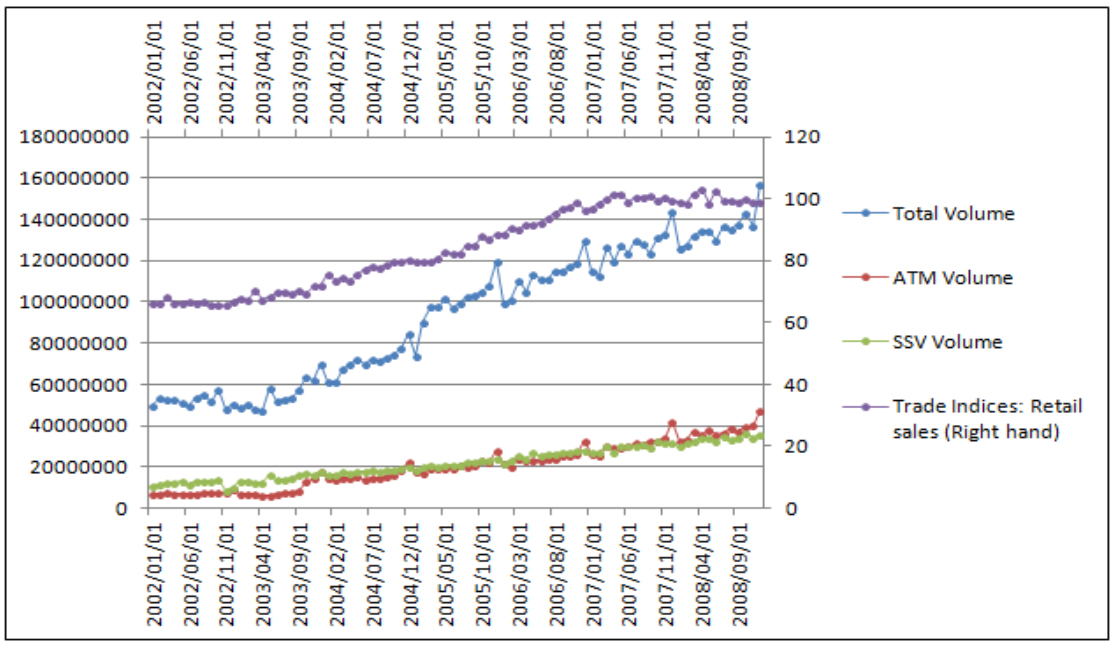
For the purpose of this analysis it was also required to filter the generalized correlation data set in order to obtain the top ranked mixed variable pairs. The following table was created:

Table 18: The top ten generalized correlation variable pairs containing one variable from the service provider and one variable from the "domestic economy" segment per pair

First Variable	Second Variable	Generalized Correlation
CLC Volume	Surrenders/ terminations (% of new policies)	0.880462885
NONE 1 Volume	Surrenders/ terminations (% of new policies)	0.877540231
EFTD Value	Mining production: Gold	0.874306619
SSV Volume	Trade: Retail sales	0.871263146
Total Volume	Mining production: Gold	0.866935968
ATM Volume	Mining production: Gold	0.866689265
SSV Volume	Surrenders/ terminations (% of new policies)	0.864626348
ATM Volume	Trade: Retail sales	0.861287594
Total Volume	Trade: Retail sales	0.858481824
SSV Value	Trade: Retail sales	0.85443455

From the table above a self explanatory generalized correlation stands out, namely that of the volume of electronic transactions made per month and the effect that it has on the retail sales real economic indicator. The following chart illustrates these strong generalized correlations:

Figure 93: An illustration of the strong relationship between the retail sales real economic indicator and the volume of electronic transactions



It is evident that when the volume of ATM transactions increases, for example, the total volume of electronic transactions will also increase which will in turn result in an increase in the retail sales real economic indicator.

The complexity profile (Appendix A) for this system also illustrates a balance in the amount of variables from the service provider and the segment respectively contributing to the total complexity of the system.

For this dynamic analysis the same window size and overlap of the previous analysis were chosen. The system received a very high stability index value of 73.62% meaning that there was very little fluctuation in the system's structure. The following evolution charts were obtained from OntoSpace:

Figure 94: Evolution of complexity in the "domestic economy" segment

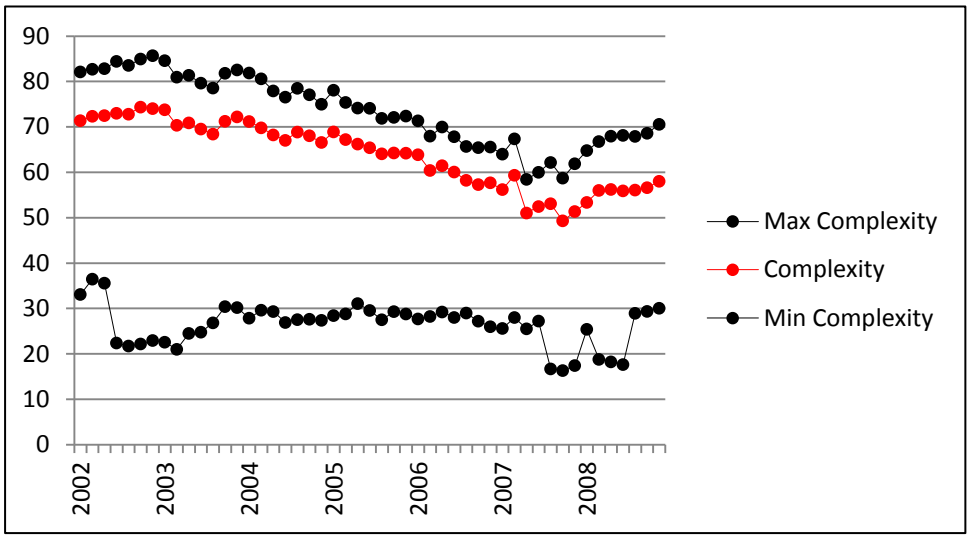


Figure 95: Evolution of entropy in the "domestic economy" segment

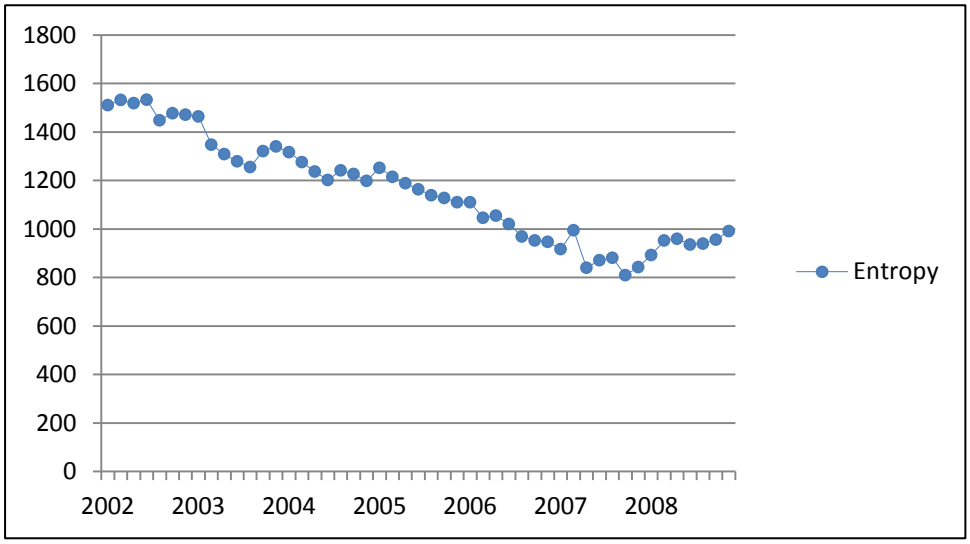
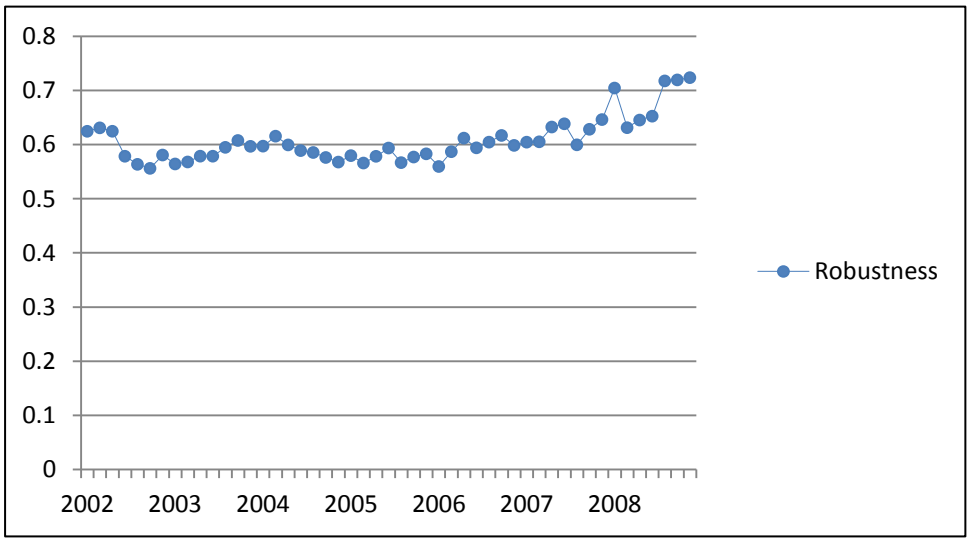


Figure 96: Evolution of robustness in the "domestic economy" segment



From the dense process map and the generalized correlation table in the static analysis it can definitely be concluded that the "domestic economy" segment and the service provider influence each other strongly. Although the evolution charts from the service provider and the segment respectively evolve in opposite directions for the analysed period, it can still be said that there is a strong correlation. The changes in the respective evolution charts remain steady and therefore the decrease in complexity and entropy and the increase in robustness of the segment can only influence the service provider positively.

9. Conclusion

The aim of the research project was to develop a systemic macro-prudential instrument (MI) that will aid an industrial engineer (IE) in evaluating and analysing the macro-economic ecosystem within which a business operates and the impact it has on business performance.

It can be concluded from the various analyses that were conducted that OntoSpace does give accurate results. OntoSpace is able to correctly display a specific crisis that occurred at a given time as was seen from the interpretation of the respective evolution charts. The static analyses also provided valuable information regarding the interconnectedness of businesses and markets in a macro-economic ecosystem. Although the impacts of the three main segments on the retail business and vice-versa were not that significant, there were still notable interactions within the macro-economic ecosystem. There was however very strong relationships between the service provider's performance variables and the three main segments as were indicated by the strong generalized correlations of mixed variable pairs.

It can therefore be stated that an IE can definitely use OntoSpace as a macro-prudential instrument to determine which applicable strategies to implement under certain circumstances in order to create a sustainable business system that continues to create value for its shareholders.

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Appendix A: The combined service provider and "domestic economy" segment complexity profile
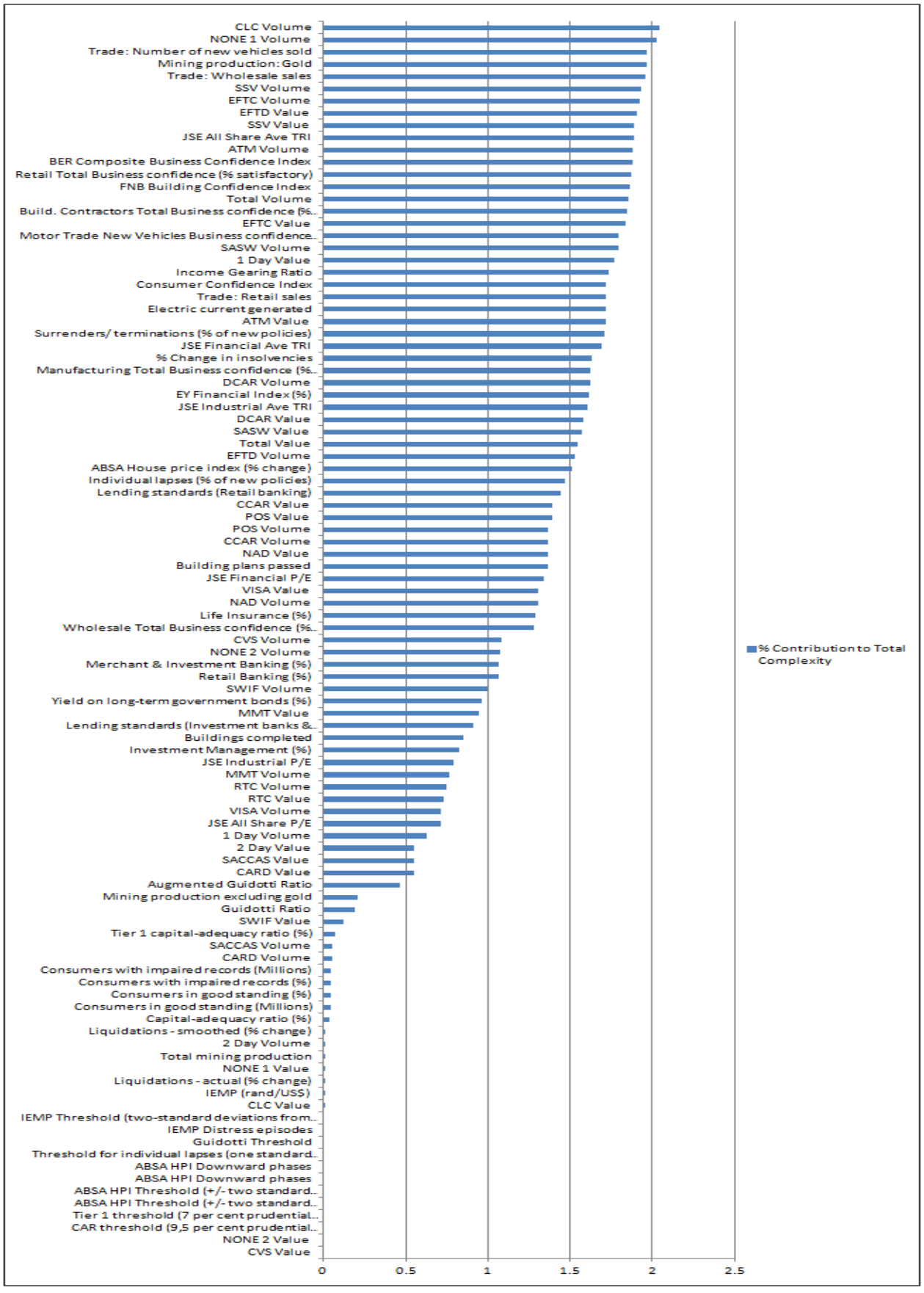
Figure 97: The combined service provider and "domestic economy" segment complexity profile