Agribusiness value-chain risk, fragility and coordination strategies: Case studies of South African value chains

by

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In honour of my parents

Danie and Lorraine Jordaan

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Legend has it that Emperor Augustus thought nothing less becoming in a well-trained leader or officer than haste and rashness and, accordingly, one of his favourite sayings was supposedly “That which has been done well has been done quickly enough”. This thesis was not done quickly, but a concerted effort was made to do it well. Therefore, the opportunity and privilege to take the journey is recognised with gratitude.

Arrival at the concluding moment of this thesis and the doctoral programme allows for some reflection on the enthralling expedition that culminated in a “hasten slowly” sort of way. Undertaking doctoral studies has certainly been extremely captivating and packed with suspense, intrigue, adventure, drama, challenges and exhilaration on an unparalleled and grand scale – most likely never to be experienced again. The evolution from thinking about enrolling to eventually submitting bound copies of the final thesis undoubtedly contributed immensely to both my professional and personal development, and I am the better for it.

The successful completion of this thesis and doctoral programme is a very specific and tangible result of the involvement, support and encouragement of a number of individuals and institutions who have shared and enabled this journey. Foremost, I acknowledge Prof Johann Kirsten for his passionate supervision, guidance and interest, and for the colossal opportunities to develop personally and professionally as a student and colleague. It was my pleasurable privilege to be supervised and mentored by Prof Kirsten and I’ll treasure this source of pride fondly. In fact, Prof Kirsten’s gravitas and grace in supervision and mentorship is no less parallel to Emperor Augustus’ declaration that he’d “found Rome a city of clay but left it a city of marble”.

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contributes to the goals of each of these institutions and that the capacity developed in the process can be multiplied in a number of spheres, particularly in the South African agribusiness sector, in the future.

Significant gratitude is also due to the stakeholders who made generous contributions of their time to the research through the sharing of their actual experiences. In this regard, these stakeholders were indispensable to the convergence between the academic and the practical domains of the specific value chains being researched. Gratefully, the research incorporated inputs across the respective value chains, including input providers, producers, a score of value-adding entities, wholesalers, and retailers for the specific chains. It is certainly a significant privilege to be placed in a position to analyse extensive value chains like the South African lamb chain and export fruit chains through the cooperation of the various sequential stakeholders in these chains. Specific mention is becoming of the many producers whom I visited on their farms, the range of value-adding enterprises in between and the large, and oftentimes multinational, retail companies for their enthusiastic and willing participation. I certainly learnt a great deal from these stakeholders and I hope that the interaction inspires everyone to consider their value chains with even more fervour.

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My appreciation is also extended to my South African and European doctoral friends, colleagues and acquaintances with whom I've shared offices, advanced classes, exam stress and success, proposal development and defences, workshops, conferences, travels, apartments, encouragement and enjoyable times. I salute you as esteemed fellow candidates and look forward to when our paths meet from time to time.

Personally, I also recognise and salute my family, friends, confidants, colleagues and acquaintances who've remained engaged and interested in the progress of this thesis and the concurrent journey. I appreciate everyone's heartfelt encouragement and support along the way. I specifically salute my family with whom I've endured much and achieved much – no more and no less to be said.

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ABSTRACT

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Accelerating volatility, complexity and scrutiny will be the norm in the landscape for agribusiness value chains as the future unfolds. Evidence of this new landscape is clear from the extent and intricacy of global food and fibre value chains, the rise of consumerism, and the prominence of the sustainability and responsibility narrative. As a result, agribusinesses and their value chains are compelled to evolve to meet the challenges and opportunities that this new landscape presents. However, agribusinesses and their value chains generally seem lethargic to adapt to this new environment and are consequently every so often ensnared by a cascade of effects that highlight the volatile, complex and scrutinising challenges for these value chains. Confirmation of these cascading effects is evident from the range of food scandals, product recalls, instantaneous bankruptcies, and reputation and brand devastation, where unexpected events lead to these, and other, non-linear payoffs that ripple through these chains. The conspicuous occurrence of these events with non-linear impacts is indicative of fragility in these chains and specifically highlights the rationale for detailed exploration of fragility, as a phenomenon, in agribusiness value chains. This thesis addresses this overlooked phenomenon by threshing out the factors that cause fragility, by developing a framework to quantify fragility, and finally by exploring the interaction between fragility and the coordination of agribusiness value chains.

Through a normative Delphi approach with key stakeholders and a principal component analysis, this thesis explored the factors that contribute to agribusiness value chain fragility in selected meat, fibre and fruit chains and found that those factors that contribute to the efficiency of value chains are also the factors that drive the fragility of these chains. This finding exposed a juxtaposition between value chain efficiency and fragility and the need to find a measured balance between these approaches to achieve and sustain chain goals. The thesis develops a framework to measure agribusiness value chain fragility and applies this framework to the South African lamb value chain through a modified value chain analysis methodology. This framework exhibits the detection and quantification of fragility at the factor, stakeholder and chain level in the particular chain. The thesis finds a golden thread of specific factors that are critical to the fragility of the particular chain. The whole chain of actors is fragile to the actual quality and safety performance and the cash flow position of actors in the chain. Likewise, the thesis also finds nuances in specific factors that are critical to the fragility of the particular actors in the chain due to the activities' unique techno-economic characteristics. Producers are uniquely fragile to buyer and operational reliability, abattoirs to the quality and training of human resources, and the quality and adequacy of infrastructure, packers to regulations and supplier reliability, and retailers to the management information and supplier relationship and alignment. The idiosyncrasy is that activity-specific fragilities could, unpredictably, cascade into the rest of the chain due to sequential interdependencies in a typical chain. Quantification of the fragility of the South African lamb chain also establishes that increasing coordination intensity and interdependency in the chain increase the fragility of the chain. Hence the thesis argues that traditional transaction costs economising model that guides the coordination strategies of successive exchanges in value chains may, in fact, contribute to chain fragility in the effort to economise on the costs of exchange.

Conscious of the findings of the analyses the thesis argues that complex systems like value chains are unavoidably exposed to human limitations in their design and management. Humanity appears challenged in coping with complexity, and as a result, the coordination of value chains oscillates between hubris and nemesis in pursuit of coordination precision – sailing too close to the wind and then crying foul when the inevitable happens. Therefore, the thesis makes a case for a more mindful and less

'fragilising' approach to the coordination of value chains by arguing that both fragility and the cost of exchange be considered in the governance of chains. The shortcoming of the traditional approach is laid bare by the growing frequency and impact of events with cascading consequences that ripple through chains. Hence the thesis' argument is contrary to the traditional transaction costs economising model that only considers economising on the costs of exchange, at all cost, in the coordination of value chains.

Principally the thesis reasons that the need to deal with fragility becomes increasingly pressing for agribusiness value chains in a landscape of expanding uncertainties, concatenation and complexity. The argument is particularly seminal because the lean and efficient chains that are rationally justified and pursued should not be considered desirable because of their hidden and devastating vulnerabilities. The substantial, logical, argument for the design and management of agribusiness value chains should be survival first before performance, particularly because everything that is fragile will eventually be ruined. Publilius Syrus notes, "Nothing can be done at once hastily and prudently".

The thesis concludes by offering recommendations to reduce vulnerability in agribusiness chains in general and in the South African lamb chain in particular. These recommendations include decentralisation and layering of activities and decision making in chains aligned to the principle of subsidiarity, incorporating redundancy and spare capacity in the design and management of chain operations to provide for optionality, operating chains with simple rules to avoid cascades of unintended consequences, resisting over-intervention in systems that are naturally uncertain, and finally ensuring that stakeholders have real exposure to both rewards and penalties for their actions in the design and management of chains. The essence of the thesis is that mitigating fragility should not be optional but indispensable to chain sustainability, particularly, given the harsh, irreversible and terminal consequences of fragility on the durability of chains and their goals.

DECLARATION

I, **D. du P. S. Jordaan**, declare that the thesis, which I hereby submit for the degree **PhD (Agricultural Economics)** at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

SIGNATURE:…….

DATE: 8 December 2016

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CHAPTER 1
INTRODUCTION

1.1 THE AGRIBUSINESS LANDSCAPE

Globally, consumers' expectations of agricultural products have become, and continue to become, increasingly complex, nuanced and demanding. As a result, the global agribusiness value chain is presented with an opportunity and an obligation to meet the needs of new, more sophisticated and more demanding consumers, while satisfying shareholders' demands for returns – and in doing so, to create a sustainable food supply for the new millennium (Brenner, 2015; Deloitte, 2013b; Fearne *et al.*, 2001; Hornibrook & Fearne, 2001). The future food system will have to bring together resilience, sustainability, competitiveness and the ability to meet and manage consumer expectations, combined (Ambler-Edwards *et al.*, 2009). Consequently, the landscape and prospects for the agribusiness value chain are influenced by prominent themes that are expected to shape the structure and strategies employed in these chains in capturing the opportunities and fulfilling the obligations that are offered and faced. These themes are broadly grouped into two main streams – an increasingly demanding consumer environment, and an increasingly complex and risky operating environment (Figure 1-1 below).

With these broad themes embedded in the agribusiness context, the increasing incidence of adverse events and the impacts of such events on value chains represent a distressing development in delivering consumer value and in offering returns on the investments for stakeholders. As a result, understanding and managing adverse events and their impacts on value chains is an emerging theme in practice and in academia. Inevitably, this theme is also just as relevant in the agribusiness landscape as it is for other sectors and their landscapes.

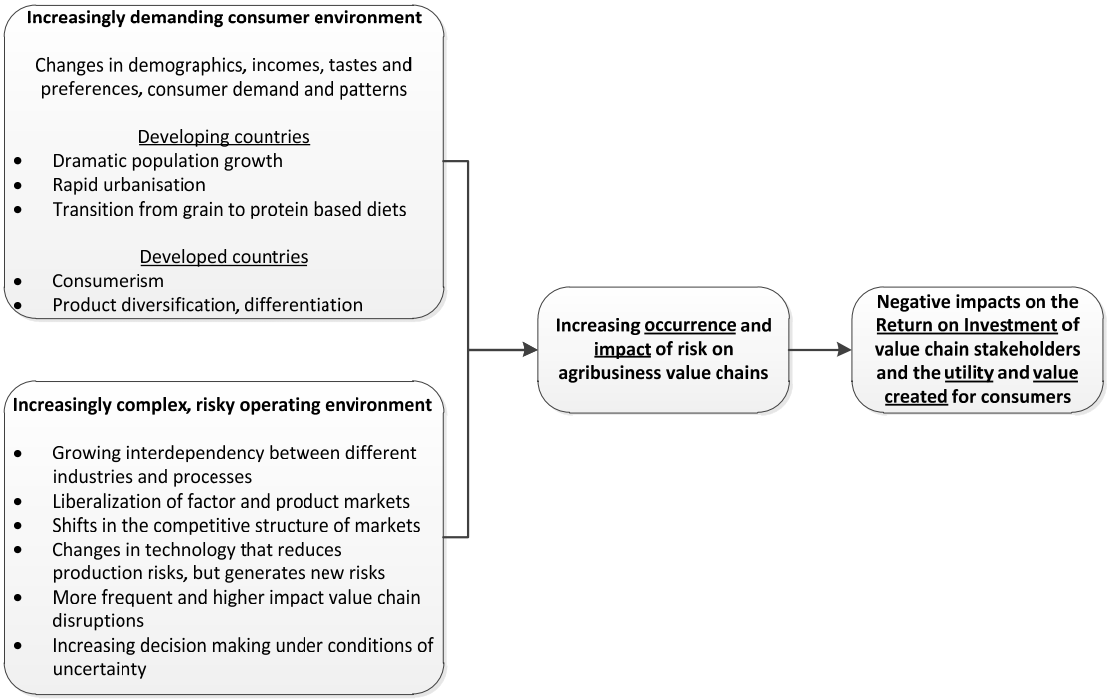

Figure 1-1: Prominent themes in the current agribusiness landscape

The evolving consumer context contributes to the increasing occurrence and impact of risk and uncertainty in agribusiness chains. Population growth estimates indicate that current food production must increase by 70 % by 2050 to meet the needs of a projected global population of 10 billion (Tilman *et al.*, 2002; Tilman & Clark, 2015). This growth is anticipated to stem, primarily, from developing countries, and particularly within their cities, metropolitan areas and towns. Developing countries traditionally have "agriculture-based economies, but in recent years they have witnessed explosive growth of the middle class, driven by greater industrialisation and urbanisation in these economies". The emergence of the middle class in these developing countries changes dietary habits, with increased consumption of meat, milk and eggs at the expense of staple foods. The shift of food consumption in developing countries to animal-based products, which are more resource intensive, is expected to put supply chains under greater pressure and to significantly strain global food supply. Consequently, the production and distribution of food is becoming an increasingly precarious issue for the global agribusiness value chain (Deloitte, 2013b; Schneider *et al.*, 2011; Trienekens *et al.*, 2012).

While the changes in emerging markets are dramatic, consumption in developed economies also remains dynamic. Globalisation and the rise of consumerism mean that product differentiation has become the new "normal" in the realm of consumer needs. Consumerism in terms of food products has also become multidimensional, with prominence given to food safety and quality features of products. Consumers in the developed world are more health conscious than ever before. They are worried about the content of their food, its origin, freshness, and safety (Deloitte, 2013b; Trienekens & Wognum, 2013; Trienekens *et al.*, 2012). Increasing consumer consciousness in terms of the safety of food products is highlighted by Bánáti (2011) who notes that "the series of food scandals and scares during the last decade resulted in a melting consumer confidence and the European food policy, the food legislation and the food safety system have changed consequentially". Snowballing consumer consciousness is also emphasised by Bánáti (2011) who points out that "despite the fact that food has never been safer, it seems that consumers are considerably uncertain, anxious and increasingly critical about the safety of their food". Food product recalls have also "become more frequent over time and operational hazards, rather than biological and chemical hazards, are the most frequent recall type within the agri-food industry" (Potter *et al.*, 2012).

The rise of consumerism is also evident in the increasingly dynamic, complex and differentiated demands of consumers. It is expected that in a globalised food market, where consumers are more educated in terms of product attributes, the demand for differentiated attributes and qualities is on the increase. Food is no longer just food and consumers' food choices have become more complex than ever before. Credence characteristics, like health, organic, origin, brand, production methods, ethics and descriptive food names and ingredients, play an important role in the modern food marketing system (Fernqvist & Ekelund, 2014; Font-i-Furnols & Guerrero, 2014; Grunert, 2005; Hussein *et al.*, 2015; Lassoued & Hobbs, 2015; Lassoued *et al.*, 2015).

In essence, agricultural supply chains are increasingly being required to deliver more food, and more food with more nuanced and complex requirements, sustainably, as the global consumer environment evolves. The consequence is that, citing Manikandan *et al.* (2011), "the risk of delays, disruptions, forecast inaccuracies, systems breakdowns,

intellectual property breaches, procurement failures, inventory problems and capacity issues" are exacerbated as a result.

Over and above the evolving consumer landscape, the global business and risk scene also continues to evolve rapidly and is becoming increasingly complex because of the growing interdependency of different industries and processes. Inadvertently, this shift in the operating environment also increases the occurrence and impact of risk and uncertainty in agribusiness chains. In the agribusiness context Jaffee *et al.* (2008) note that "broad structural, demographic and institutional changes, some associated with globalization and the uptake of new technologies, will continue to alter the risk landscape, risk management practices, and their efficacy for different agri-food supply chains".

Globally, executives recognise the "reality of the growing scope of risk in [value] chains" (Deloitte, 2013b). This phenomenon is also evident in the global value chain context (Altomonte *et al.*, 2012; Gereffi, 2014). Reportedly, supply chain "disruptions are not only more frequent, they are also having a larger impact" (Deloitte, 2013b). These global business trends are echoed in the agribusiness environment (Boehlje *et al.*, 2011; KPMG, 2013). The global food and agribusiness sector is in the midst of major changes and, seemingly, the pace of these changes is increasing. Three fundamental issues in the future of the agribusiness sector are tangible (Boehlje *et al.*, 2011). These are that " decisions must be made in an environment of increasing risk and uncertainty, developing and adopting technology and new innovations is critical to long-term financial success, and responding to changes in industry structure and the competitor landscape and industry boundaries is essential to maintain market position" (Boehlje *et al.*, 2011)

The gravity of risk in an economic context is highlighted by Wever *et al.* (2012) when noting that the subprime crisis of 2008 "showed how risks can be transferred and amplified in the interdependent business networks and economies which exist today". These authors note that "Insufficient monitoring by mortgage providers of the creditworthiness of borrowers in a relatively small sector of the American housing economy contributed to the bankruptcy of banks and other financial institutions at the

other side of the world". The transferability and amplification of risks is equally evident in a range of other contexts, including in the financial and agriculture and food systems (Adelson, 2013; Colander *et al.*, 2009; Rosin *et al.*, 2013; Rötheli, 2010). Pertinent recent examples include the cascading effects of the 2014 Russian embargo of European Union food on trade (Boulanger *et al.*, 2016), the severity and compounding effects of the 2013 whey protein concentrate contamination scare on Fonterra, a dairy company, (Stojkov *et al.*, 2016) and the consequences of the 2017 tainted beef scandal on the export of Brazilian beef. Disruption of one or more of the primary flows that constitute value chains, i.e. the flow of goods and services, the flow of information and intelligence and the distribution of retained value exacerbates the exposure of value chains to the consequences of risk and uncertainty.

1.2 RESEARCH PROBLEM

Agricultural value chains are compelled to deliver customer value, profitably and sustainably (Boehlje *et al.*, 2011; Lamine, 2015). Value, profitability and sustainability must also be brought about in an environment where consumer demands are increasingly complex and demanding, and the operating condition is progressively challenging. In the current setting, agricultural value chains are also confronted with increasing competition in a globalised market and where informal value chains often times exist parallel to formal ones (Crush & Frayne, 2011; Vorley *et al.*, 2016).

Moreover, the transformation of agribusiness chains into more tightly aligned governance mechanisms is expected to "introduce new strategic risks which will require additional analysis and/or skills to manage or mitigate those risks" beyond what has traditionally been the norm (Gray & Boehlje, 2005). In the context of value chains, the premise is that a "break" or "event" in one link in the chain results in an accelerating impact in the whole chain. This accelerating phenomenon is termed "fragility" and points to the sensitivity of the chain to the specific event (Taleb, 2007; Taleb, 2012). Fragility, in this context, is defined as accelerating vulnerability to a harmful stressor (Taleb, 2012). The gravity of the phenomenon is that adverse events increasingly have a multiplicative, rather than an additive, impact on value chains and their goals (Elms & Low, 2013; Gereffi, 2014). There is also a certain irreversibility to fragile systems,

such as value chains, where rare and high-impact events result in irreversible, ruinous consequences to the sustainability of businesses and their value chains.

Since the production and distribution of food is becoming an increasingly precarious task for agribusinesses chains, challenges arise as these chains continue to evolve. Four specific problems are:

- Value creation and returns on investment in agricultural value chains are increasingly influenced and impacted on by risk and uncertainty as these events become more frequent, more significant, less repetitive, and less predictable.

- Agricultural value chains are increasingly vulnerable to the impacts of risk because of the cascading effects of risks which are increasingly extending beyond the boundaries of firms to affect the extended chain.

- Increasing vertical integration in agricultural value chains is leading to increasing fragility of these chains, with risks becoming progressively more hidden as chains become more vertically integrated. Essentially the governance structure of the chains themselves become the source of the exposure (Gray & Boehlje, 2005). The general result is more efficient, but also more fragile, chains as a result of the growing interconnectedness and interdependency that coincides with increasing coordination.

- The fragile is that which is harmed a lot more by extreme events than by a succession of intermediate ones, and what is fragile will eventually break, both being undesirable outcomes for value chain investors. Conversely, what is anti-fragile is what benefits from the "chance factors" generated by disruptive events (Porter, 1990; Taleb, 2012). The fragile breaks, the resilient stays the same and the anti-fragile thrives as a result of disruptive events (Taleb, 2012). The logic that follows is that anti-fragility is preferable to fragility because of the irreversibility of harm associated with the exposure and vulnerability of all that is fragile.

Considering that chain vulnerability concerns the exposure of the chain to harmful stressors (Christopher *et al.*, 2002) and that the fragility of chain relates to the

accelerating vulnerability and harm of the chain to a harmful stressor (Taleb *et al.*, 2012) the challenge to the sustainability of agribusiness value chains is clear.

Therefore, considering the challenges that agribusiness chains face, the research problem is that the causes, nature, and extent of fragility in agricultural value chains are ill defined. Consequently, measures to analyse, measure and manage fragility in agribusiness chains are also not well established. The research consequently aims to (1) Define value chain fragility, (2) identify the causes, nature, and extent of fragility, (3) develop a framework to analyse fragility and (4) argue a theoretical case to influence public policy and private strategy in relation to the fragility of agricultural value chains. The research question is justified, considering how little risk and its impact in value chains is understood, how little coordination strategies in chains manage these risks, and more specifically, how ineffective governance structures are in creating value and dealing with the effects of coordination errors in chains (Brenner, 2015; Peterson *et al.*, 2001; Wysocki *et al.*, 2003). The question is that if value chain stakeholders are aware of the increased risks, how does this influence value creation, and for those who are aware, how have they managed these risks? The relevance of these problems is resonated in a statement by Slezak (2014) who notes that the management of risks in the overwhelmingly complex agribusiness system is ultimately indispensable to "the world's well-being and peaceful economic development". An argument is also made that the design of value chains and their governance structures should incorporate provisions for resilience (or measures against fragility) of the chain (Leat & Revoredo-Giha, 2013). In the case of the Scottish pork value chain, Leat and Revoredo-Giha (2013) make the case that both vertical and horizontal coordination mechanisms can be employed to fortify value chains against fragility.

1.3 CONCEPTUAL FRAMEWORK

The agricultural value chain system is particularly unique and a range of characteristics sets it apart from other industrial manufacturing and service supply chains (Sporleder & Boland, 2011). The biological nature and the globalised character of agriculture and agribusiness value chains are two well-known and distinguishing features of the system. Due to these unique characteristics, greater coordination of agribusiness value chains is

a growing phenomenon, pushed forward by technological, regulatory and socio-economic factors (Hobbs & Young, 1999; King *et al.*, 2010; Sexton, 2013). Increasing coordination intensity in agricultural value chains (Gereffi, 2014; Handayati *et al.*, 2015; Swinnen & Maertens, 2007) is also unabatedly propelled by principles from the transaction cost economics script to economise on the costs associated with transactional frequency and uncertainty and investments in relationship specific assets. This narrative is rationally palatable because of the cost economising benefits and the efficiency that it introduces to the unavoidable relational alignment in a value chain. This narrative, however, also conceals a surge of new, less tangible, hazards as a result of the growing interconnectedness and interdependency that coincides with increasing coordination within a chain context (Brenner, 2015; Christopher *et al.*, 2002; Liu *et al.*, 2015; Peck, 2005; Wagner & Bode, 2006). The result of growing interconnectedness and interdependencies laden with systemic risks and payoffs is that complex systems, like optimised value chains, tend to become very prone to 'convexity effects' (non-linear consequences) where uncertainty is inherent in the system (Kinsey, 2001; Sexton, 2013) and the chains are fragile, by definition (Peck, 2005; Waters, 2011).

As the consequences of risk and uncertainty become less and less tractable and increasingly reach beyond firm boundaries, the need to improve the risk management capabilities within chains accelerates. This is the domain for this conceptual framework (Figure 1-2 below), given the essential consideration of business continuity and sustainability (Leat & Revoredo-Giha, 2013) in potentially fragility systems like value chains. Here, the strategic imperative is for enterprises and their value chains to deal with the trade-off between the high performance and the fragile value properties of value chains (Duarte *et al.*, 2011). The purest form of this argument is made by Taleb (2012) who makes the point that fragility is brutally punishing, has ratchet-like properties considering the irreversibility of damage and is path dependent. Citing Taleb (2012) "A package doesn't break under adverse conditions, then manage to fix itself when proper conditions are restored". Mindfulness of this trade-off is argued to be increasingly central to the coordination of value chains. Especially where the pursuit of chain performance is juxtaposed against the inevitable ruin of any vulnerable system. Bearing this trade-off in mind, this conceptual framework gives a means to examine

fragility as a phenomenon in value chains and as a tool to design and manage the coordination of such chains, mindful of the trade-off.

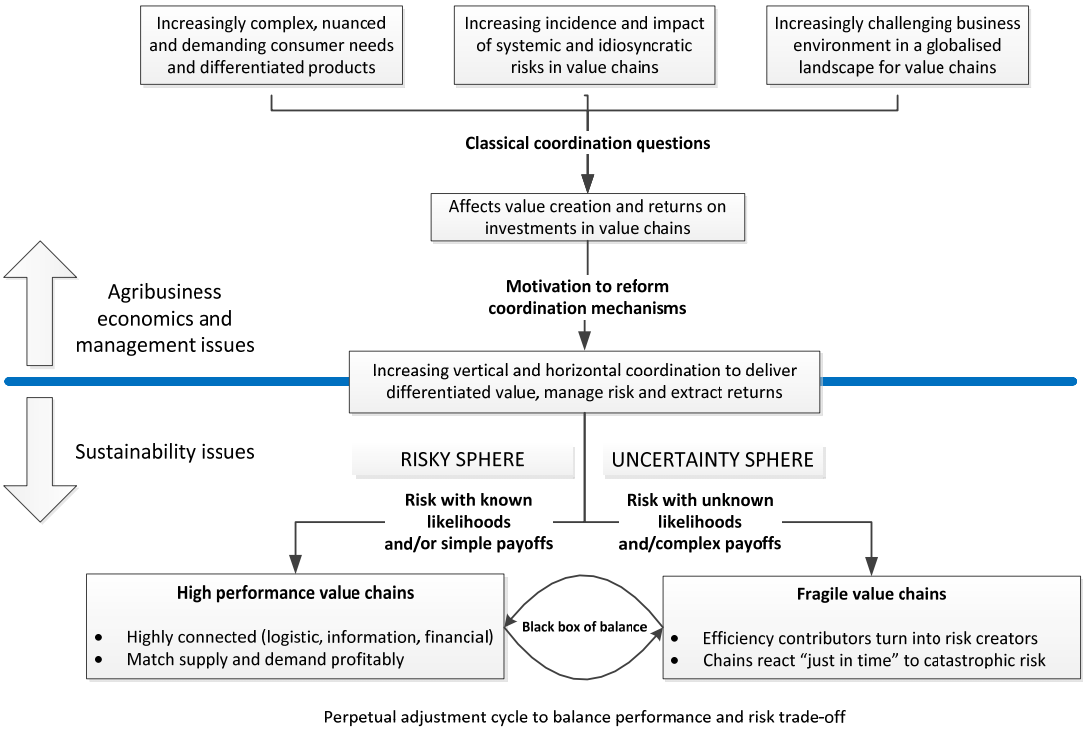

Figure 1-2: Conceptual framework of vertical coordination and fragility

The unadulterated pursuit of profit is generally considered to be the principal objective of economic activity. Risk control and survival generally seem to be subservient objectives and at most something to reflect upon in undertaking profit generating economic activities. "What is missed is the strong logical precedence of survival over success" (Taleb, 2012). Mitigating fragility is, therefore, not an option but an essential condition to undertaking economic activity. While this point sounds obvious, it is certainly underemphasised. The various chapters in this thesis contribute to, and lean upon, this conceptual framework where fragility, as a phenomenon in agribusiness value chains, is explored. As such, the conceptual framework is central to the notion of the thesis and to the research objectives, and propositions that flow from its constructs.

1.4 RESEARCH OBJECTIVES

The thesis addresses specific research objectives by developing a framework to characterise the fragility of agricultural chains and then assessing the vertical coordination strategies of selected value chains against theoretical constructs of risk, fragility and vertical coordination.

The specific objectives of the thesis are:

- To contextualise and define fragility in the context of agribusiness value chains;
- To develop a systematic framework with which to identify the causes of fragility and to characterise fragility in the context of agricultural value chains;
- To assess the usefulness of the framework by validating it through an application to three South Africa case studies – the lamb, pear and mohair value chains;
- To develop a framework to detect and measure value chain fragility in order to prioritise key factors so that acceptable decisions can be made under conditions of uncertainty;
- To showcase the quantification framework by measuring value chain fragility in the South African lamb value chain;
- To conduct a comparative value chain fragility analysis within the South African lamb value chain to compare vertical coordination regimes; and
- To review the theoretical constructs that contribute to fragility in value chains and to explore recommendations to address fragility in theory and practice.

These objectives will be pursued in the respective chapters of this thesis which deal with the various elements of developing fragility as a phenomenon in value chains.

1.5 RESEARCH PROPOSITIONS

The thesis addresses the research problem with a constructivist approach and consequently a number of propositions have been formulated to contextualise and

structure the arguments in the study. The premise of the propositions is that agricultural value chains continue to reorganise their vertical and horizontal coordination mechanisms (particularly away from spot markets to increasingly coordinated chains) in reaction to their internal and external requirements and the operating environment. This reorganisation is fuelled by:

- the globalisation of food chains and the resultant competition between chains which requires increasing efficiencies and effectiveness;
- increasingly diversified and complex consumer needs and the safety requirements placed on these chains;
- requirements to comply with private and regulatory standards, while at the same time having to maintain the required economic outcomes; and
- increasingly volatile and uncertain operating environments.

In light of this context and the uniqueness of agricultural value chains, the thesis engages the dimensions of risk, fragility and coordination mechanisms in value chains by considering specific propositions. These propositions address the research objectives and questions, and are:

Proposition 1 – The fragility of agribusiness value chains is influenced by a range of variables which vary in their relevance and influence. These variables include the typical internal and external factors that are indispensable to the value creation process and the classic chain factors that are critical to the sequential interdependencies that characterise a chain of activities in a construct such as a value chain (Gray & Boehlje, 2005; Porter, 1980; Stonebraker *et al.*, 2009; Wever *et al.*, 2012). The exploration of this proposition is also a vital component of this thesis's conceptual framework for gaining an understanding of the causes and catalysts of value chain fragility. This proposition is explored in Chapter 3 which details the determinants of value chain fragility in an agribusiness context.

Proposition 2 – An analysis of value chain fragility offers interpretations to prioritise potential perils to value chain continuity in a similar fashion to a traditional risk

analysis. The primary goal of risk management is, after all, to reveal, assess and prioritise hazards so that acceptable decisions can be made under conditions of uncertainty (Aven, 2015; Jüttner, 2005; Manuj & Mentzer, 2008). Traditionally, risk analysis approaches the scrutiny of risk and uncertainty by considering the probabilities and impacts of perilous events, while fragility analysis considers the sensitivity to perilous events. Given these different approaches, Taleb (2012) argues that "fragility can be measured", while "risk is not measurable" (or at least as measurable as is thought, especially in complex systems). In the context of this thesis, a framework to detect and measure fragility in an agribusiness value chain setting is developed to reveal, assess and prioritise fragility factors analogous to the type of outcomes from a traditional risk analysis. The rationale is that, as Taleb (2012) notes, "sensitivity to harm from volatility is tractable, more so than forecasting the probability or impact of the event that would cause the harm." The exploration of this proposition is an equally vital component of this thesis's conceptual framework for detecting and quantifying value chain fragility and for employing this capability in an analytical context. This proposition is explored in Chapter 4, which details the detection and measurement of value chain fragility in an agribusiness context.

Proposition 3 – Increasingly coordinated, vertically integrated and overly optimised-strategies increase fragility in complex systems like agribusiness value chains (Brede & de Vries, 2009; Taleb, 2012). Conversely, systems that are less integrated and purposefully coordinated grant optionality and compartmentalisation properties to complex systems that ultimately curb the fragility of these systems, albeit a counterintuitive notion. This proposition and its extension is the foundational premise and apex of the conceptual framework of this thesis which aims to highlight the trade-off between fragility and coordination intensity. Conveniently, this proposition also questions the mechanical application of the dictum to ruthlessly economise on transaction cost in vertical exchanges, especially in the coordination of agribusiness value chains (Hobbs & Young, 1999; Martinez, 2002; Schulze *et al.*, 2006; Sykuta & Cook, 2001) without due consideration of the fragility that such economising introduces. This proposition is explored partly in Chapter 4 and partly in Chapter 5, which develops a framework to measure value chain fragility and applies the

framework in a comparative analysis of different vertical coordination intensities and strategies.

Proposition 4 – The generally employed approach of organising the coordination of vertical exchanges by single-mindedly economising on the costs of the exchange is ignorant of the unintended consequences of the approach. While this old-style narrative is rationally palatable because of the cost-economising benefits, it also conceals a multiplication of new, less tangible, risks as a result of the economising approach. Arguably, a more mindful approach to governing exchanges is to weigh the benefits of economising on the costs of exchange against the consequential systemic risks arising through the coordination mechanism. The point is aptly emphasised by Taleb (2012) who notes that "one can't separate financial returns from risks of terminal losses, and 'efficiency' from danger of accident because of the irreparable nature of harm in complex systems" like value chains. This proposition is explored in Chapter 5 which considers some optimisation constructs in vertical exchanges, the human factor in decision-making and the construction of fragile systems, and some proposals regarding robust and anti-fragile strategies.

The assessment of each of these propositions is achieved with specific constructs and methods as discussed in the respective methodological approaches in the different chapters of this thesis. Specific case studies, where applicable, provide the context for the assessment of these propositions.

1.6 DELIMITATIONS

The study of agribusiness value chains and their governance is diverse and covers many different and wide-ranging fields of knowledge, inquiry paradigms and fundamental questions. As a result of the wide scope of themes in agribusiness value chains, a delimitation of the elements of this thesis is necessary to provide an outline to the study and to restrict the study to a specific set of research questions.

This thesis is limited to:

- The development of systematic frameworks to characterise and measure value chain fragility in the context of agricultural value chains;
- Assessing the usefulness of the characterisation framework by validating it through an application to three South African case studies;
    - The lamb value chain
    - The export fruit value chain
    - The mohair and wool value chain
- Exhibiting the practicality of the value chain fragility detection and quantification framework through a case study application in the South African lamb value chain;
- Analysis of the interaction between value chain fragility and vertical coordination strategies in the South African lamb value chain;
- Exploration of the theoretical aspects of value chain fragility and measures to deal with the phenomenon.

This thesis has specifically not explored to the more complex chain configurations associated with networked chains in detail (Lazzarini *et al.*, 2001) having had regard for the further intricacies that simultaneous and networked activities would introduce to the initial analysis and conceptual establishment of value chain fragility as a phenomenon. This thesis deals first with fragility in the context of the basic elements of value chains – those main functions and sequential activities required for a basic chain to operate. Notwithstanding this specific delimitation the necessity to attend to the fragility of networked activities in future is unquestionable and the networked chain platform as discussed in subsequent chapters is a suitable precursor.

1.7 CONTRIBUTION

This thesis makes a distinct contribution to the discourse at the nexus between the coordination of and exposure to risk and uncertainty inherent in, and as a result of, the alignment of actors into a value chain. This thesis specifically contributes to the development of fragility, as a phenomenon, in agribusiness value chain research. The key leap forward is that the analysis of the sensitivity to harm is a more workable approach to managing and dealing with risk and uncertainty than attempting to forecast an event or exposure to the event.

The study of risk and methods of managing it has a long history and, although risk analysis and management is well understood in some disciplines (finance, engineering, project management, etc.), it is only relatively recently that risk and its management has emerged as an important issue in value chains (Khan & Burnes, 2007; Manuj, 2013; Manuj & Mentzer, 2008). Nevertheless, it appears that there is a general consensus that risk and its consequences are increasingly relevant in the context of value chains, and consequently, its analysis and management can no longer be limited to the firm level alone (Croson *et al.*, 2014; Diabat *et al.*, 2012; Fearne *et al.*, 2001; Garvey *et al.*, 2015; Ge *et al.*, 2016; Hendricks & Singhal, 2005; Khan & Burnes, 2007; Liu *et al.*, 2015; Park *et al.*, 2016; Slezak, 2014; Tang & Musa, 2011; Wagner & Bode, 2008).

There is no doubt that understanding and managing risk and fragility in the value chain should be important for most organisations (Chacon *et al.*, 2012; Chopra & Sodhi, 2014; Khan & Burnes, 2007). Value chain risk and uncertainty are also not expected to subside in the near future, but rather to accelerate as globalisation continues to evolve, consumers' needs become more nuanced, and greater demands are placed on the extended value chain. Whether current research and advice in this regard is adequate to meet this challenge seems debatable (Chopra & Sodhi, 2014; Khan & Burnes, 2007). Comprehensive value chain risk management necessities an integration of multiple knowledge and research disciplines, and new analytical tools should aim at proactively managing supply chain risk (Tang & Musa, 2011; Wiengarten *et al.*, 2016).

Considering the significant influence of risk and fragility in value chains, the advances from this thesis should contribute to extending the value chain analysis body of knowledge, specifically in the agribusiness context. Moreover, the thesis will provide a basis from which to develop suggestions in solving the vicious circle of creating and mitigating risk, given changes induced by the environment. The thesis aims to make three specific, novel and significant contributions to the body of literature related to value chain risk and resiliency. These are:

- To define fragility in the context of agribusiness value chains;
- To develop a framework which considers risk beyond the boundaries of firms and takes into account risk in, and as a result of, the extended value chain;
- To develop a framework to measure fragility in a value chain context as a means to characterise, quantify, prioritise and managing adverse events in value chains;
- To contextualise the frameworks in the agricultural value chain milieu.

Aside from the risk and fragility considerations, the risk aversion/sharing characteristics of the players in the value chains are also important. Due to the consumer orientation of most agribusiness value chains, the role of risk and risk preferences shaping chain coordination strategies, particularly at the consumption end of the chain, have not been considered before. Product dimensions, such as safety, quality, reputation, origin, service, and brand, are becoming increasingly prominent and valuable at the consumption end of the value chain, implying that risk and risk preferences further along the value chain are equally, if not more, significant than at the production end of the chain.

At the same time, Gray and Boehlje (2005) argue that “the transformation of the industry into more tightly aligned supply chains will introduce new strategic risks which will require additional analysis and skills to manage or mitigate those risks”. The fragility of agribusiness value chains has been noted in popular literature but has not, expressly, been studied and analysed. The thesis sheds some more light on the relationship between risk, fragility and the coordination of value chains. In this regard, the thesis conceptually queries the paradigm in Transactions Costs Economics (TCE)

which posits that "Less uncertainty in a transaction suits spot market transactions while more uncertainty suits a more formal type of co-ordination strategy e.g. a strategic alliance, a contract or some form of vertical integration" (Hobbs, 1996; Hobbs & Young, 1999; Wiengarten *et al.*, 2016).

1.8 OUTLINE

This thesis comprises six chapters. Following this chapter the second chapter gives an overview of the literature related to agribusiness and value chain research, risk, risk in value chains, fragility, and the role of risk in vertical coordination strategies in value chains. The third chapter details a framework to develop a value chain fragility tool with which to assess the fragility of agricultural value chains. This chapter addresses risk and fragility in a practical context; that is, why a risk analysis is not a fragility analysis, which factors determine fragility, how fragility should be measured, and the defining of a metric for fragility. The fourth chapter operationalises the framework from Chapter 2 to measure the fragility of some South African lamb chains, which also doubles as an evaluation of the interaction between value chain fragility and vertical coordination strategies. The fifth chapter provides a theoretical discussion of value chain fragility, the need to consider fragility in agricultural value chains, the design of vertical coordination strategies that consider fragility in their design, and the frailties of actors in the process of intervention. The sixth and final chapter provides a conclusion to the study, with comments on the contribution of the research to the stream of agribusiness and value chain research, recommendations for agricultural value chains' approaches to risk, fragility and coordination strategies, and suggestions for further research.

CHAPTER 2
RISK AND UNCERTAINTY IN THE AGRIBUSINESS LANDSCAPE

2.1 INTRODUCTION

Appreciation of the risk, uncertainty and coordination mechanisms within the agribusiness and agribusiness value chain environment has evolved since the late 1900s when the governance of successive stages of the agribusiness chain was first scrutinised (Cook & Chaddad, 2000; Zylbersztajn & Farina, 1999; Zylbersztajn & Goldberg, 1996). As a point of departure, this chapter positions the thesis in the landscape of current knowledge related to risk, uncertainty, fragility and the coordination of agribusiness value chains, as a foundation for the eventual analyses in the thesis.

This chapter is arranged along common themes, including the general issues and landscape in agribusiness research; a discussion of the uncertainty landscape, value chain risk and uncertainty and risk and coordination in a chain; the basic principles of chain governance; and coordination and specific studies related to the analysis of governance choices for agribusiness and agricultural value chains, generally. The primary purpose of the chapter is to position fragility, as a phenomenon, in the agribusiness value chain landscape and to lay a theoretical foundation for the analyses that follow.

2.2 AGRIBUSINESS AND CHAIN RESEARCH

Agribusiness research has developed along two parallel pathways of analysis (Cook & Chaddad, 2000; King *et al.*, 2010). The first is the study of coordination between vertical and horizontal participants within the food chain, termed as “agribusiness economics”. The second is the study of decision-making within the alternative food chain governance structures, termed “agribusiness management” (Figure 2-1 below). Topical issues in value chain research have, however, evolved beyond the typical landscape (Cook and Chaddad (2000) (Trienekens, 2011) which has focused on chain and network performance, business strategy and institutional design. Contemporary

value chain research emphasises, among other things, the sustainability of the system – the ability for the system to endure. Evidence of the significance of the sustainability theme is noted in the popular (Cordon & Ferreiro, 2013; KPMG, 2013) and academic literature (Giannakis & Louis, 2011; Trienekens, 2015). Moreover, recent special issues of journals, including *Supply Chain Management: An International Journal* (Wagner, 2014), *Sustainability* (Wiskerke, 2013) and the *Journal of Chain and Network Science* (Omta, 2012), have emphasised the sustainability theme. Typical sub-themes of the sustainability stream include corporate social responsibility in supply chains, supply chain auditing, a green supply chain, and sustainability performance of supply chains.

The growing importance of the durability or sustainability theme in value chains heralds a shift in emphasis and the emergence of a new frontier, which is of interest to both practitioners and scholars alike. The interest in the sustainability theme is fuelled by, for example, the questionable sustainability of the global financial system which suffered the consequences of interconnectedness and the underestimation of the system's vulnerability. This attention on system sustainability is equally topical for international agricultural and food value chains (Beske *et al.*, 2014; Rosin *et al.*, 2013). In this regard, globalisation has not only offered opportunities, but also poses novel sources of uncertainty and risks (Kytle & Ruggie, 2005). Businesses now face increased uncertainties in corporate decision-making due to the greater interdependencies and hidden vulnerabilities that have developed in the global value chain system as a result of globalisation. In the agribusiness landscape, the vulnerability of the food system is probably the most frightening current sustainability question (Kytle & Ruggie, 2005).

Considering the attention that the discussion of system sustainability or vulnerability is gaining as a contemporary theme, also in agriculture and agribusiness value chains, a new frontier in agribusiness research seems inevitable. The vulnerability of the agricultural system extends the agribusiness research continuum by positioning it as "getting the sustainability of the agribusiness system right" (Cook & Chaddad, 2000). Because uncertainty weighs on the continuity of enterprises (Leat & Revoredo-Giha, 2013), dealing with the vulnerability to uncertainty is essential to the sustainability of the system.

Notwithstanding the instinctive importance of the fragility of agricultural value chains, it is unexplored and particularly underdeveloped as a theme of study. Much of the literature related to risk, uncertainty and vulnerability in the agricultural value chain context relates to risk identification, quantification, and prioritisation tools and frameworks (Jaffee *et al.*, 2008; Markmann *et al.*, 2013). The prioritisation is coupled to a risk management plan in the various stages of the chain. This shortcoming is noted by Jaffee *et al.* (2008) who point out that attention is frequently focused on addressing one type of risk faced by particular stakeholders (e.g. weather risk, facing farmers; price risk, facing traders), even though supply chain actors are interdependent and need to manage several different types of uncertainty collectively.

The fragility and hidden vulnerabilities of agricultural-based chains is evident from a multitude of events which reveal the phenomenon. An example is the Belgian pear chain where an abrupt closure of the Russian Federation market for European fresh produce caused significant difficulties for the world's largest pear exporting country. At the time, up to 40 % of Belgian pear exports were destined for the Russian Federation market when this particular chain's fragility was revealed (European Commision, 2014). A further example is the dramatic decline in operating profits at the French spirits group, Remy Cointreau, which fell 40 % following a crackdown on corruption in China (Williams-Grut, 2015).

Food scares or scandals also highlight the vulnerability of agricultural or food chains. Because of the concerns for public health and wellbeing, and the link with food safety and quality, these scares are often highly public and widely broadcast. The almost disproportionate response to these scares and scandals highlights the sensitivity of value chains to adverse events and to the severe impact that events have on the proper functioning of value chains. Such events include the British meat adulteration scandal (Abbots & Coles, 2013; Barnett *et al.*, 2016) and the Bovine Spongiform Encephalopathy (BSE) crisis (Jones & Davidson, 2014). Value chains evidently remain vulnerable despite the emergence of labelling and traceability systems aimed at limiting the risk of bad publicity, liability and product recalls associated with food scares and scandals (Aung & Chang, 2014).

Although food scandals offer some insights into the sensitivity of food chains to adverse events, there is limited data on the actual impact of these events, which are often less public (Brenner, 2015). Although the fragility of systems has been on the radar in a range of contexts, it has hardly been explored in agricultural value chains. This seems an oddity because there is ample evidence of the sensitivity of agricultural value chains to disturbances and their propensity to disproportionate responses because of their unique techno-economic attributes. This study is therefore opportune to address the evident need to explore value chain fragility and getting the sustainability of agricultural value chains right.

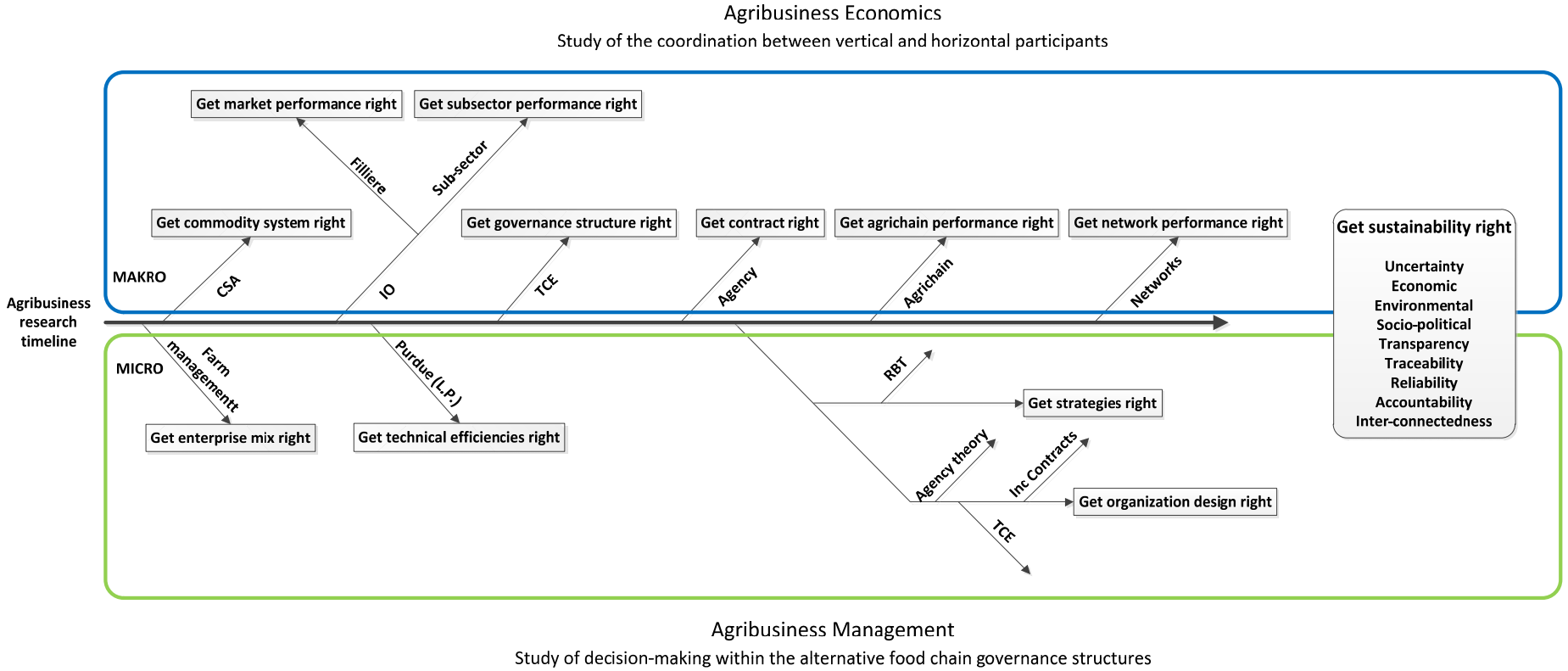

Figure 2-1: The evolution of agribusiness research[1]

Source: Cook and Chaddad (2000) (own additions)

1 CSA – Commodity systems approach, IO – Industrial organisational model, RBT – Resource-based theory.

2.3 THE UNCERTAINTY LANDSCAPE

Defining and clarifying some terms in the uncertainty landscape is particularly important because of the loose use of terminology, like risk, uncertainty, exposure, vulnerability, fragility, robustness, and resilience, each of which could mean several different or similar things. A firm grasp of the different concepts in the uncertainty landscape allows for the conceptual development of fragility as a phenomenon in the context of agribusiness value chains and the agricultural system. The following sections provide an overview of the salient constructs in the uncertainty landscape.

2.3.1 The tenability continuum

Fragility, robustness and resilience are positioned on a continuum of tenability (Figure 2-2 below). Tenability, in this instance, is defined as the capability to hold, maintain or defend continuity under uncertainty. The one extreme is a fragile state which displays an accelerating decline in tenability, and the other extreme is an anti-fragile state which displays an accelerating improvement in tenability under uncertainty. The middle ground between fragile and anti-fragile is robust or resilient terrain where tenability is, to a greater or lesser extent, unaffected by uncertainty. This continuum is also colloquially referred to as the ‘triad’ (Taleb, 2012) and is, in essence, a map of the fragility spectrum and consists of fragility, robustness and anti-fragility. This map of the fragility spectrum is seminal to the risk and uncertainty literature and extends the traditional paradigm to include the anti-fragile dimension. The novel value of the map is that it is essentially a map of exposure rather than a map of risk which Taleb (2012) argues to be preferable in a practical context.

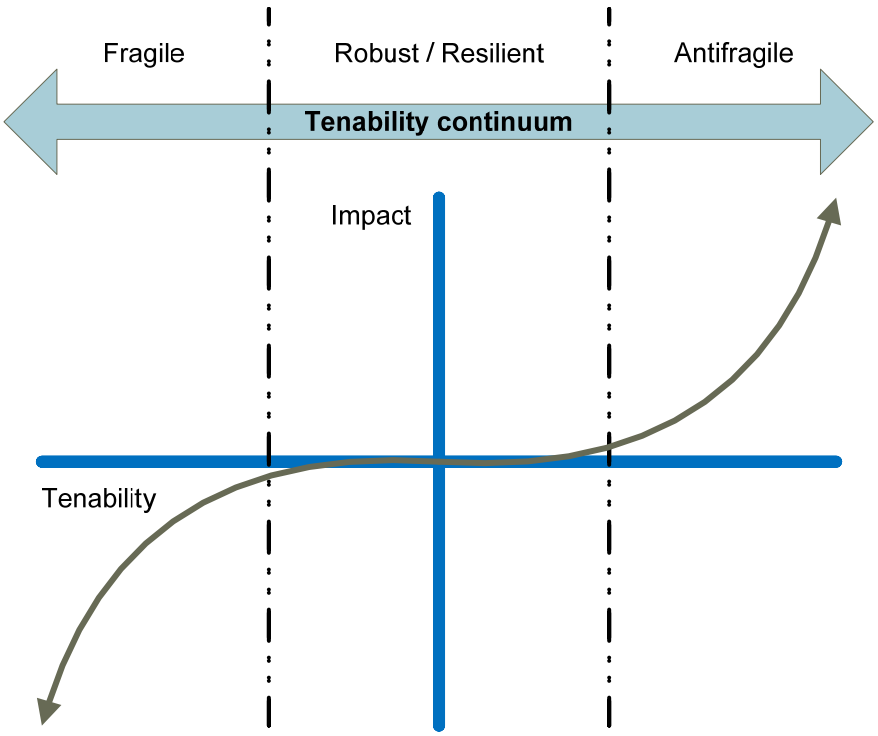

Figure 2-2: The tenability continuum or map of the fragility spectrum

Source: Taleb (2012) (own additions and modifications)

Mindful of the tenability continuum, fragility, as an idea, is counter-intuitive to the everyday language used to engage concepts related to risk, uncertainty and exposure. In this regard, Taleb (2012) makes the point that "fragile wants tranquillity, the anti-fragile grows from disorder, and the robust doesn't care too much".

2.3.2 What is risk and what is uncertainty?

The concepts of 'risk', 'uncertainty', and 'fragility' are loosely used to mean several different or several similar things. The ways in which these terms are used are very diverse, which leads to considerable confusion about what is actually meant by the one or the other. In order to avoid confusion, broad designations of risk and uncertainty are assumed in this thesis.

A general definition of risk is exposure to a proposition that is indeterminate (Holton, 2004). The premise is that people care about the outcomes. If someone has a personal interest in what happens, that person is exposed (Holton, 2004; Taleb, 2007). Also, people do not know what will happen and, therefore, in each situation the outcome is

indeterminate. Consequently, a broad definition of "risk requires both exposure and doubt dimensions about a proposition or event" (Holton, 2004).

While these terms are mindlessly used, both colloquially and academically, Knight (1921) provides a sensible categorisation. Risk, or "Knightian risk" is measurable, and uncertainty or "Knightian uncertainty" is not measurable (Taleb, 2005). Here, the measurability relates to both the probability distributions, the exposure and, the interconnectedness of the exposure (Taleb, 2005; Taleb, 2009b). In a further attempt to deconstruct these concepts, Taleb (2008) proposed a map of risk and uncertainty, the 'triad', with due consideration of the nature of the probability distributions and exposure. Within this broad definition of risk and uncertainty Kleindorfer and Saad (2005) note that "there are two broad categories of risk affecting value chain design and management: (1) risks arising from the problems of coordinating supply and demand; and (2) risks arising from disruptions to normal, operational, activities."

2.3.3 What is fragility

Much of the history of the financial crisis of 2008 Taleb *et al.* (2012) interpret broadly as "an underestimation of risks, not only of the probability of large impact, unforeseen random events, but of the financial system's fragility" to these events. A similar argument is made by Thurner *et al.* (2012) in the context of investment funding, noting that "the very effort to control risk at the local level creates excessive risk at the aggregate level" for the investment and banking dyad. The consequence is non-linear feedback which amplifies negative impacts. Non-linear feedback or accelerating sensitivity to a harmful stressor implies a vulnerable or fragile system. The word "fragility" was adopted by (Taleb *et al.*, 2012) to refer to this phenomenon of non-linear feedback or accelerating impact. As such, fragility is observed as a concave curve in gains or losses in reaction to random events and mathematically culminates in more losses than gains from random risky events (Figure 2-3 below). The concept of fragility is also relevant to value chains and, like businesses, chains can be fragile, robust/resilient or even anti-fragile. A fragile chain implies that a "break" or "adverse event" in one link in the chain results in an accelerating impact or non-linear feedback into the rest of the chain.

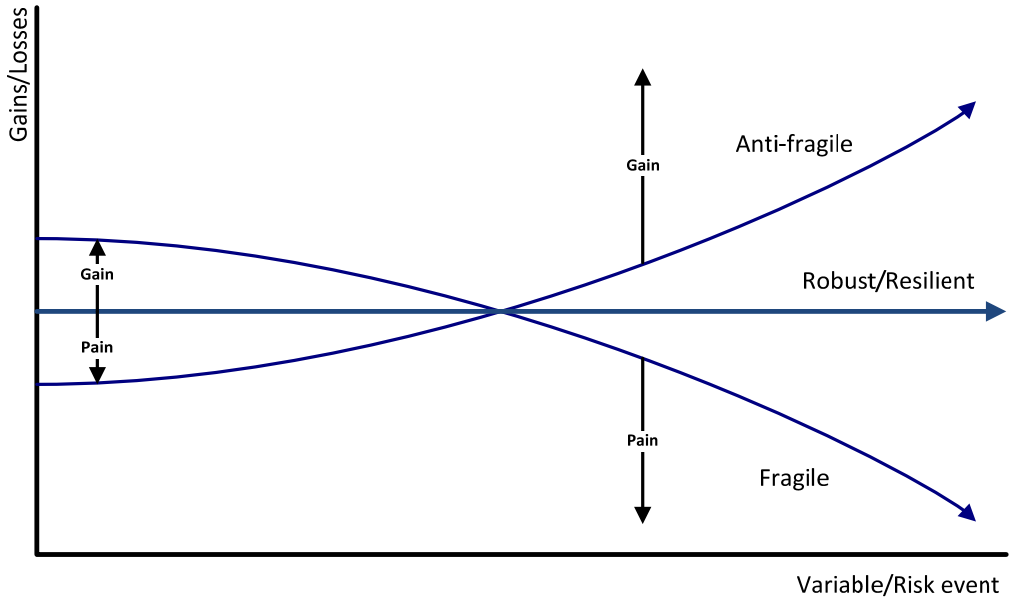

Figure 2-3: Concepts of convexity and concavity as they relate to fragility
Source: Taleb *et al.* (2012)

In the interest of avoiding doubt, (Taleb, 2012) makes the point that fragility and anti-fragility mean potential harm or gain from exposure to something related to adverse or beneficial occurrences. The 'something' in this context is "any one of the members of the extended disorder family including uncertainty, variability, imperfect, incomplete knowledge, chance, chaos, volatility, disorder, entropy, time, the unknown, randomness, turmoil, stressor, error, dispersion of outcomes, unknowledge" (Taleb, 2012).

2.3.4 Why is risk and uncertainty in value chains important?

Consideration of risk and uncertainty in the analysis of value chains and their coordination is important. Risk and uncertainty, as noted earlier, have a direct and dramatic impact on the potential to create value and returns on investments in chains. Moreover, risk and uncertainty are always present and diverse within agricultural value chains (Jaffee *et al.*, 2008). Moreover, Jüttner *et al.* (2003) affirm the notion by noting that "despite increasing awareness among practitioners, the concepts of supply chain vulnerability and its managerial counterpart supply chain risk management are still in their infancy."

A broader view of risk and uncertainty is also required in the context of agricultural value chains because more often than not, attention is focused on "addressing one type of risk faced by particular stakeholders (e.g. weather risk facing farmers; price risk facing traders), even though supply chain actors are typically inter-dependent and need to manage several different types of risk" in a coordinated way (Jaffee *et al.*, 2008; Jaffee *et al.*, 2010).

Risk or the degree of uncertainty in transactions, such as in value chains, is also a key determinant in the transaction cost economics (TCE) paradigm that influences the choice of coordination mechanism (Martinez, 1999; Martinez, 2002). Risk or uncertainties in exchange arise from three basic sources (Koopmans, 1959; Sutcliffe & Zaheer, 1998; Williamson, 1985; Williamson, 1996). First, uncertainties arise as a result of technological changes, unpredictable changes in consumer preferences, and random acts of nature. Second, uncertainty may arise as a result of a lack of well-timed communication or the incapacity to determine concurrent decisions and plans made by others. Third, uncertainty may arise due to behavioural uncertainty between transacting parties regarding nondisclosure, disguise or distortions of information – the typical complications of information asymmetry.

2.4 VALUE CHAIN RISK AND UNCERTAINTY

Interest in risk and uncertainty in value chains has grown in prominence in the past two decades. Fears of major disruptions to systems from the widely considered "millennium bug" captivated society at the time and focused the attention influence of risk and uncertainty on complex and interdependent systems like value chains (Jüttner *et al.*, 2003). Subsequent events and their consequences also continuously and regularly accentuate the fragility of many contemporary value chains. This section reviews risk and uncertainty in a global setting and contextualises it to agribusiness and food value chains.

2.4.1 Chain risk and uncertainty in the global context

While business strategies, such as outsourcing, just-in-time inventory, and lean manufacturing, can be useful to reduce costs and to allow specialisation, these very

strategies may also stretch the capability of chains to breaking point (Bosman, 2006). Risk and uncertainty in chains can reduce revenue, deplete market share, inflate costs, cause budget overruns, and jeopardise business' production and distribution (Bosman, 2006; Brede & de Vries, 2009). Together, these risks or disruptions harm credibility with investors and stakeholders, which, in turn, pushes up the cost of capital to compensate for the risk.

Emerging from the Deloitte (2013b) research a study of "executives at manufacturing and retail companies was conducted to understand their perceptions of the impacts and causes of risks, the actions they take to address them, and the continuing challenges they face". The key findings from the research include (Deloitte, 2013b):

- "Chain risk is a strategic issue for the majority of executives
- Margin erosion and sudden demand changes often cause larger impacts
- Concern is also expressed about extended value chains
- Chain risk management is not normally considered effective
- Companies face a wide variety of challenges
- Many companies lack the latest tools to analyse and manage risk"

The categories of chain risks that were identified by Deloitte (2013b) include (Figure 2-4 below):

- "Macro-environment risk – Risk that can have an impact on any portion of the supply chain, or across the entire supply chain. This risk includes events such as downturns in the global economy, shortages of critical raw materials/resources, political instability, new regulatory requirements, and natural disasters such as hurricanes and tsunamis.
- Extended value-chain risk – Risk stemming from problems with upstream or downstream supply chain partners, ranging from Tier One and secondary suppliers to outsourcers and even end customers.
- Internal operational risk – Risk that can occur anywhere along the chain from product development and manufacturing to distribution. Increased efficiency

has removed much of the "cushion" that traditionally helped companies absorb disruptions in these areas.

- Functional support risk – Risk that can occur in support areas such as legal, finance, human resources and, especially, IT. Shortcomings in these functions can lead to anything from a lack of needed talent to regulatory compliance problems and interruptions to the vital flow of operational data.

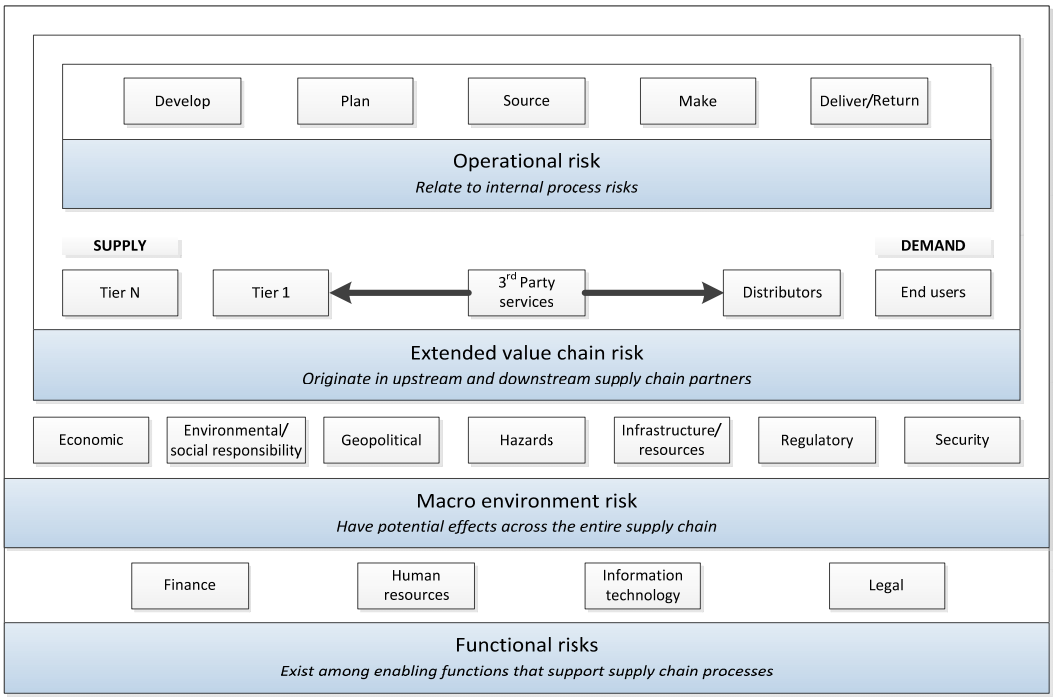

Figure 2-4: Supply chain risks

Source: Deloitte (2013b)

The Deloitte (2013b) research highlights the growing significance of risk for business. As an illustration, the survey reports that a majority (48 %) of respondents noted that the frequency of risk events that had negative outcomes on their enterprises had increased over the last three years. The increase in risk events was most evident in high-tech companies (67 %), followed by industrial product and then diversified manufacturing companies.

In the Deloitte (2013b) survey, risk events were reported to be more frequent and also to have had an increasingly larger impact on enterprises. A majority (53 %) of respondents stated that risky events had become more costly over the preceding three

years, including a significant proportion (13 %) who reported that the risks had become much more costly. Executives from technology-intensive, industrial, and diversified manufacturing industries were most likely to report that chain risks had become more costly. These industries were seeing greater impacts from supply chain issues because of the complex, interwoven, and time-sensitive nature of their supply chains, where a problem in one section of the chain can rapidly have a ripple effect up and down the chain.

2.4.2 Strategic uncertainty as a future challenge for agribusinesses

Risk and uncertainty are also identified as constituting a future strategic challenge for agribusinesses and their underlying value chains. The type and sources of risks and uncertainty faced by agribusinesses have exploded in recent times (Boehlje *et al.*, 2011; Enyinda & Mbah, 2016; Slezak, 2015). These new uncertainties that agribusinesses face are more complex and difficult to analyse and manage because they are increasingly unpredictable, both in terms of frequency and consequence. The need to understand and manage risks and uncertainty in agribusiness value chains is specifically of strategic importance in creating long-term value because risk and uncertainty have both an upside and downside, which requires consideration in the planning and management of chains.

2.4.3 Risk in agriculture and agribusiness value chains

The changing risk landscape in agriculture and agricultural value chains, and the factors driving this changing landscape, require specific attention (Jaffee *et al.*, 2010). This view is confirmed by noting that agriculture is characterised by highly variable returns and is associated with unpredictable circumstances that determine the final output, value and cost of the production process (Cervantes-Godoy *et al.*, 2013). Concisely noted by Chuku and Okoye (2009), “shocks in agriculture are triggered by a system of multi-scalar stressors or risks”. These stressors interact in complex and chaotic ways to increase the vulnerability of agribusinesses and agricultural value chains to catastrophes.

Therefore, "in light of the omnipresence of risks and massive structural changes in global and national agri-food systems, farmers, agribusiness firms, and governments face new challenges in the design of risk management strategies" (Jaffee *et al.*, 2010). As a result, it is becoming increasingly important to understand and appreciate the risks and their impacts on the agri-value chain and to develop strategies and policies to prevail over these perils. The value of characterising risk from an agri-value chain perspective is therefore clear, both for policymakers and for stakeholders, in order to shape their policy and decision-making.

In the context of agribusinesses, the risks posed by the complexity of the modern agricultural value chain system constitute a strategic risk. The effects of globalisation and changing consumer markets compound this complexity. Agribusinesses face rapid and devastating economic losses, should some part of the chain be interrupted. If a major buyer goes down, or some other critical link in a business's chain (over which it has no influence) fails, agribusiness could see their revenue, reputation and returns on investments collapse. In a value chain context, disruptions can also ripple throughout the system, and can have a damaging impact on the chain and its links for indefinite periods of time.

Because of the difficulty in managing worst-case scenarios in value chains, it is pertinent to contemplate the fragility of agribusiness chains and the role that the coordination mechanisms play in managing risk and fragility in chains. The even more compelling argument for value chain players to contemplate fragility is the view that whatever is fragile will eventually be broken, and what is fragile will be effected much more by significant events than by a series of in-between ones (Taleb, 2012).

2.4.4 Food value-chain risks

Beyond the general risks associated with doing business in an increasingly complex environment and the typical risks associated with agricultural and agribusiness chains, lie the risks that make food value chains unique. Food safety risks in value chains are well known, with equally familiar consequences. These outbreaks can affect hordes of consumers and result in significant medical costs and, in the worst cases, fatalities. 'Food scares and scandals' also result in losses of revenue, remedial and recall costs,

damage to corporate identities, and liability and damages claims for businesses in the chains that are involved. The significance of these food chains risks is evidenced in a survey by the (EFSA, 2010) which reveals that 79 % of European consumers are concerned about the safety of their food and the commercial impacts of food safety scandals (Hussain & Dawson, 2013). It is noted that the food value chain is particularly exposed to risk and uncertainty in its functioning (Diabat et al., 2012; Handayati et al., 2015). Despite the obvious impacts of food safety risks, a lesser known but more challenging risk is food fraud and economic adulteration. Effective risk management of food fraud and adulteration requires more than a general approach to chain risks, but instead, an in-depth "scientific knowledge of ingredients, packaging and manufacturing processes that drive food quality and safety" (Deloitte, 2013a; Everstine *et al.*, 2013).

The complexity, in itself, of the modern agricultural value chain system is a strategic risk for agribusinesses. Agribusinesses and their chains face swift and devastating consequences should some part of the chain that they are involved in be disturbed. If a key buyer unexpectedly goes bankrupt, a major product recall is required, or a strategic link in the chain fails, agribusiness' revenue, reputations and returns on investments can perceivably collapse overnight. The strategic risk arising as a result of the interconnectedness of many value chains, especially those that are highly coordinated or integrated, highlights the exposure that a disruption in one link of the chain can cause in other links, up and down the chain (Slezak, 2014).

2.5 GENERAL RISK AND COORDINATION IN A CHAIN

In addition to gains in efficiency, inter-firm synergy and responsiveness, chain participants often report the need to manage risks as a reason for greater coordination within chains (Gray & Boehlje, 2005). The risks include the typical risks, such as input/output price risks, quantity/quality risks, and safety/health risks. Moreover, the increasing interest and importance of food safety, quality and traceability often drive increasing vertical coordination and integration. However, because of the difficulty in managing worst-case scenarios in value chains, it is pertinent to contemplate the fragility of agribusiness chains and the role that the coordination mechanisms play in managing risk and fragility in chains (Gray & Boehlje, 2005).

The success of value chains is largely determined by how well the coordination governance structure manages the sharing of the risks and rewards of the supply chain among its participants (Gray & Boehlje, 2005; Wever *et al.*, 2010; Wever *et al.*, 2012). The important implications of "the different types of risks encountered in alternative supply chain business structures, the incidence of risk on the part of individual supply chain partners, and the sharing of risk and reward among supply chain participants" on the most likely participants in a chain is noted Gray and Boehlje (2005).

Moreover, governance structures in value chains are influenced by the nature and extent of transaction costs, where a change in the transaction costs arising in an exchange may lead to a change in the coordination mechanism of the chain. Key characteristics of transactions in this context are the degree of uncertainty surrounding the transaction, the degree of asset specificity, and the frequency of the transactions (Hobbs, 1996). In all three of these key characteristics, risk is an integral element.

2.5.1 Risk and value chain players

Value chain players can be significant sources of risk and uncertainty, but can also offer important avenues for managing and mitigating risk, and exploiting opportunities that flow from uncertainty (Boehlje *et al.*, 2011; Wever *et al.*, 2012). Given the difficulty of establishing sustainable risk/reward sharing arrangements, it is not uncommon for one firm in the chain to become the chain 'captain'. The chain manager or 'captain' may choose to become the residual claimant on profits from the chain and to assume a major share of the risk. The 'captain' might decide to share a greater fraction of the profits, while shifting more of the risk to the other participants. Failure to find a risk/reward sharing arrangement that provides appropriate incentives, and is perceived as fair, also encourages ownership integration of stages by one firm (Preckel *et al.*, 2004).

The type and extent of interdependency between actors in a value chain is a further dimension of the interaction between risk, its impacts in value chains and value chain actors (Wever *et al.*, 2012). Specifically, the greater interdependency that characterises coordinated value chains renders individual actors in these value chains more vulnerable to new forms of risk emanating from the coordination of the chain (Elms &

Low, 2013). These are so-called 'systemic risks', which see the whole chain breaking down if one part of the system collapses, especially if the system is fragile (Martínez-Jaramillo *et al.*, 2010).

2.5.2 Risk sharing and costs of vertical alignment

Risk attitude and sharing arrangements between value chain stakeholders also have a material impact on coordination mechanisms between stakeholders (Gray & Boehlje, 2005). The premise is that firms assess the risk-sharing transaction costs of monitoring channel partners against the willingness of the marketplace to compensate them for the risk. In cases where the risk-sharing transaction costs exceed the willingness of the market to compensate for these costs, firms may choose to vertically integrate to avoid the transactions costs associated with moral hazard and the adverse selection associated with other coordination mechanisms. In such cases, firms conclude "that the internal transactions costs associated with owning stages of the chain (agency costs, influence costs, increased production risks, employee risks, etc.) are less than the external transactions costs (moral hazard, adverse selection, and risk premia)", which then justifies the strategy to pursue more intensely coordinated governance mechanisms (Gray & Boehlje, 2005).

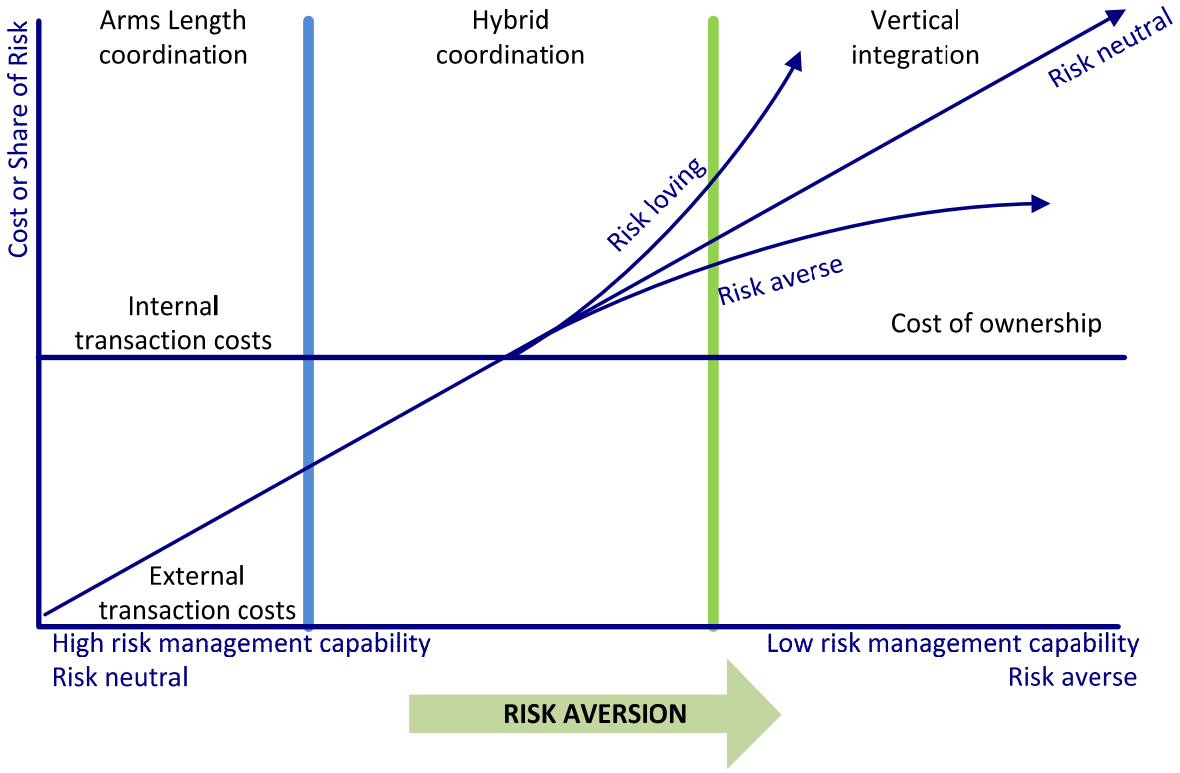

Figure 2-5: Framework for external transaction costs of risk sharing versus the internal transaction costs of vertical ownership.

Source: Adapted from Gray and Boehlje (2005)

A framework (Figure 2-5 above) of external transaction costs of risk sharing in comparison with internal transaction costs of ownership is a useful reference point for illustrating the idea. The vertical axis measures the total cost of the transactions of products, services, information, and compensation between stages of the chain. The horizontal axis represents the risk aversion or ability to manage risk for a specific value-chain actor (Gray & Boehlje, 2005). This framework informs coordination mechanism strategies on the basis of transaction costs, risk attitudes and the ability of specific actors to bear and manage risks in value chains.

External transaction costs tend to decline to a point less than the internal transaction costs of chain ownership, as firms become used to working together and are better equipped to handle the risks in the exchange between segments of the chain (Gray & Boehlje, 2005). Therefore, assuming that the objective of coordination mechanisms is to reduce external transactions costs, firms will favour partners that are less risk averse or better able to bear or manage risk. Conversely, firms that are willing to absorb more

risk may prefer partners that are more risk averse and which are aligned in highly coordinated relationships. In such arrangements, risk and rewards are transferred to the party willing to absorb the risk (Gray & Boehlje, 2005; Preckel *et al.*, 2004). Therefore, while transaction costs are essential to determining an appropriate governance structure for value chains the nature of the risk and uncertainties to which chains are exposed and the risk aversion and sharing characteristics of the chain players are no less important in establishing a suitable chain governance structure (Gray & Boehlje, 2005).

2.5.3 Transaction costs and risk preferences

The influence of transaction costs and risk preferences which effect marketing arrangements has also received some attention (Franken, 2008; Franken *et al.*, 2012; Franken *et al.*, 2014). The works of Franken (2008); Franken *et al.* (2012); Franken *et al.* (2014) extended the vertical coordination and risk question to include consideration of the risk preferences of stakeholders in the chain. Risk preferences and asset specificity, for example, impact on Illinois producers' use of contracts and spot markets (Franken, 2008). It is noted that producers' investments in specific hog genetics and human capital are, in particular, related to selection of long-term marketing contracts over spot markets (Franken, 2008). Producers who perceive greater levels of price risk or who are more risk averse are more likely to use contracts. A comparison of risk behaviour and transaction cost models with a more unified framework and demonstrate that risk preferences and asset specificity, a key transaction attribute, impact on contract and spot market use (Franken, 2008).

2.5.4 Chain-wide consequences of transaction risks

Risk and uncertainty in agri-food supply chains has also proven to have chain-wide consequences. Agribusiness value chains are characterised by strong interdependencies between the different stages (Wever *et al.*, 2012). Interdependency can lead to negative externalities, as when a downstream actor is exposed to transaction risks resulting from activities further upstream in the supply chain. For example, a change in the formula used to calculate the price in a farmer–processor transaction, may reduce incentives for farmers to produce high-quality products. This can increase the risks of low-quality products being exchanged in the processor–retailer transaction. An important

implication of risk in value chains is that agribusinesses should take a more chain-wide approach to managing their relations (Wever *et al.*, 2010; Wever *et al.*, 2012).

2.5.5 Interdependency in chains

The interdependencies that develop as value chains become increasingly coordinated and integrated expose these chains and individual actors in these chains to risk that emanates from the interdependencies (OECD, 2011; OECD, 2013). These risks, which emanate from the chain, are typically the risk that the whole chain will break down if one part of the system collapses (Garvey *et al.*, 2015). In this context, (Wever *et al.*, 2012) highlight the fact that the type and degree of interdependence between value chain actors has a significant bearing on the fragility of the value chain.

Value chains are effectively two or more dyads of economic actors that are linked together in a chain or *filière* ('thread'). These dyads are characterised by varying degrees of interdependence between the actors. Interdependence is evident when the behaviour of the actors of a dyad and the outcomes of their behaviour depend on the behaviour of other actors in the chain (Wever *et al.*, 2012). Interdependence between actors can be differentiated based on the 'type' (Thompson, 1967) of relationship between actors and the 'channel' (Borgatti & Li, 2009) through which relationships between actors is established.

The differentiation based on the 'type' of interdependence can be segregated further into independent, sequential or reciprocal relationships to characterise interdependence between organisations (Wever *et al.*, 2012). Interdependence between actors can also be described on the basis of various interfaces or channels that are common to the actors (Figure 2-6 below). Actors may, for example, be linked through their participation in the same quality management system (Wever *et al.*, 2010) or the brand under which they produce (Raynaud *et al.*, 2005).

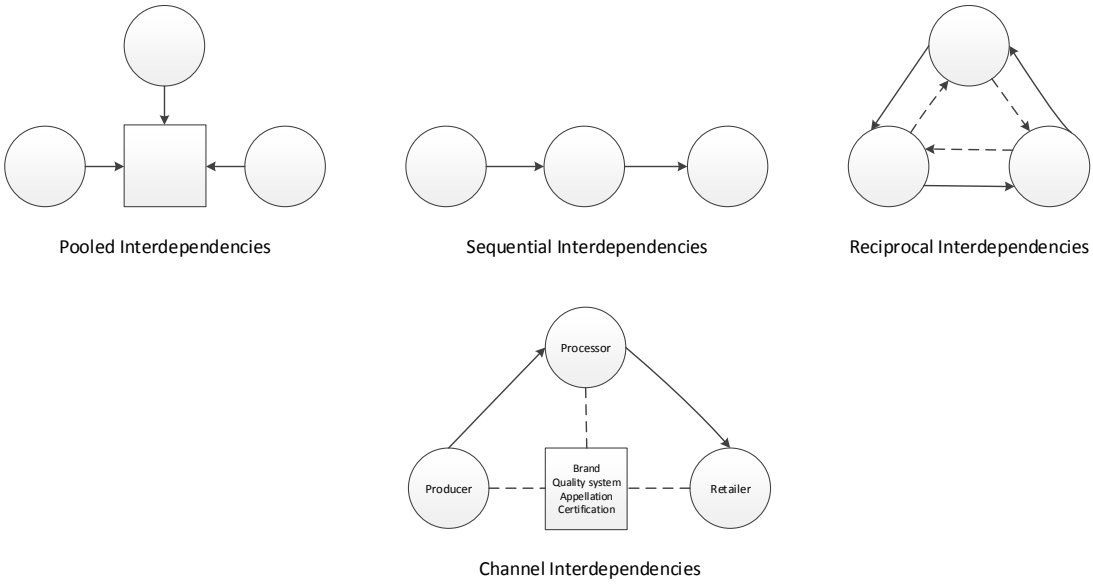

Figure 2-6: Channel of interdependencies between actors

Source: Lazzarini *et al.* (2001); Wever *et al.* (2012)

Multiple interdependence types can co-exist when actors are linked through more than one channel (Wever *et al.*, 2012). Sequential and pooled interdependence may co-exist between value chain actors because of the transactions between them and as a result of these actors' participation in a collective brand, mark or similar connection. The concept of interdependencies is critical in analysing coordination. Essentially, coordination is the management of interdependencies between activities and where there are no interdependencies there is nothing to coordinate (Malone & Crowston, 1990). The degree of interdependence also matters given the influence it has on the system's fragility because of the organization of chain into a series or network of interdependent exchanges (Mentzer *et al.*, 2000; Ziggers & Trienekens, 1999).

2.5.6 Networked chains

Networked chains, also described as netchains or value chain networks, provide a another dimension to the coordination of vertical and horizontal linkages between actors that align into a network of value-adding chain (Lazzarini *et al.*, 2001). Netchains are defined as a "set of networks comprised of horizontal ties between firms within a particular industry or group, such that these networks (or layers) are sequentially arranged based on the vertical ties between firms in different layers" (Lazzarini *et al.*, 2001). As an analytical framework networked chains have been applied in the

examination of coordination mechanisms in agribusiness value chains and networks including, amongst others, agri-food cooperatives (Maria Garcia Perez & Garcia Martinez, 2007), wool farmer cooperatives (D Haese *et al.*, 2007), agricultural contracting (Chaddad *et al.*, 2009) and cattle breeding cooperatives (Höhler & Kühl, 2016).

The premise of networked chains is the simultaneous consideration of the interdependencies of complex inter-organisational relations rather than inferring that interdependent economic activities are either exclusively vertically or horizontally coordinated (Lazzarini *et al.*, 2001). The conscious design of interdependencies in formulating inter-organisational coordination is central to the networked chain phenomenon. However, contemplation of the conditions leading to the interdependencies is as important as the interdependencies themselves because these conditions influence the vulnerability of the chain and actors in the chain to the consequences of risk and uncertainty (Wever *et al.*, 2012).

The layering that is inherent to networked chains is a further property that warrants further consideration in the context of disturbances in complex systems and the fitness of such systems to cope with risk and uncertainty. The notion is drawn from the fragility landscape (Taleb, 2012) where the antifragility of the higher level requires the fragility of the lower level. The foundation of this phenomenon is the principle of subsidiarity which dictates that matters should be contained to the smallest possible unit that can manage them with efficacy (Taleb, 2012). In essence, containment of the consequences of a disturbance in the lower levels prevents contagion at the higher levels. Practically layering provides a mechanism to manage the vulnerability of the overall value chain system albeit at the risk of the underlying chains that constitute the value chain network. In this regard, the desirability of this property of networked chains depends on the locus and goals of the contemplator in the context of these systems.

2.6 SUMMARY

Consideration of systemic risk and uncertainty in complex systems has grown in prominence since the “millennium bug” emphasised the phenomenon (Jüttner, 2005).

The subsequent surge and the increasingly unrestricted occurrence of convexity effects in a range of contexts bears specific testimony to the increasing exposure of economic, social, political and value chains systems to systemic risk. As a consequence, it is important for this thesis, in studying value chain fragility, that the chapter provide a thorough overview of the landscape, relevant nomenclature and the prominent themes related risk and uncertainty in the context of agribusiness value chains and the coordination of these chains.

This chapter has argued that the growing importance of the sustainability theme in value chains heralds a shift in emphasis and the emergence of durability as a new frontier in agribusiness research. The interest in the sustainability theme is fuelled by the consequences of interconnectedness and the underestimation of the system's vulnerability, which is equally topical for international agricultural and food value chains (Beske *et al.*, 2014; Rosin *et al.*, 2013). A further key dimension of the chapter is the foundation of nomenclature that is laid for the rest of the thesis. Undoubtedly, definition and clarification of the terms in the uncertainty landscape is particularly important because of the loose use of terminology which could mean several different or similar things at the same time. The measurability of risk and knowledge of its distribution provides for the distinction between risk and uncertainty, while the relative vulnerability to risk or uncertainty relates to fragility.

Beyond the setting of fragility in the agribusiness landscape and the terminology dimensions, the chapter also reviewed contemporary matters in value chains and particularly in agribusiness and food related chains. Considering value chain risk and uncertainty, the chapter highlights the growing global phenomenon in general (Deloitte, 2013b) and in the food chain specifically (Deloitte, 2013a; Jüttner, 2005). The review of the literature further confirms the relationship between risk and uncertainty and the coordination of value chains. The unavoidable interdependencies that develop in the process of aligning into a sequential chain of activities inadvertently impact on the chain's ability to deal with disturbances due to the players, their interdependency and the coordination of the exchanges between players, also in a context of networked chains. This chapter specifically set the scene to develop the dimensions of value chains fragility and its analysis in the subsequent chapters. As a matter of sequence, Chapter 3

of the thesis builds from the theoretical background of Chapter 2 and delves into the factors contributing to agribusiness value chain fragility.

CHAPTER 3
DETERMINANTS OF VALUE CHAIN FRAGILITY

3.1 INTRODUCTION

Agriculture has, over the past few decades, become integrated and is now characterised by a system of value chains from production through the stages of value addition to the sale of consumable products (King *et al.*, 2010; Kinsey, 2001; Sexton, 2013). The globalised nature of the agricultural system is also well known (Busch & Bain, 2004; Gereffi & Lee, 2009; Sporleder & Boland, 2011). This network of value chains has become increasingly connected and complex with a range of processes and transformations, which often span the four hemispheres. This introduces complexity due to the challenges of global logistics, the increasing exposure and dependence on the health and whims of the global economy, the flux of geo-political forces, environmental effects, consumerism, and global "interconnectedness" (KPMG, 2013; Swinnen, 2015).

As a result of this multi-faceted complexity, agricultural value chains are inherently exposed and vulnerable to adverse events in the economy, the environment, politics, the consumer landscape, and the structures that govern these chains. The exposure and vulnerability of these chains to such events is attributable to the increasing interconnectedness of the agricultural system, and this phenomenon has grabbed the attention of researchers, practitioners, authorities and the general public (Bode *et al.*, 2013; KPMG, 2013; Neves & Scare, 2010; Wagner & Bode, 2006). Yet, the consequences of adverse events on reputations, returns and the sustainability of individual businesses or whole supply chains seem to be vaguely appreciated in practice. There is, however, some clear evidence of the impact of such adverse events on value chains, including a loss of shareholder value (Hendricks & Singhal, 2005); (Hendricks & Singhal, 2008), business unit closures (Engber, 2012), profits turned to losses in weeks (Engber, 2012), civil liabilities (Huspeni, 2014) and knock-on effects (Acheson, 2007; Nganje & Skilton, 2011; Williams-Grut, 2015).

Accelerating consequences of events in chains highlights the vulnerabilities of the particular chains and the extent to which chains are breakable or fragile. A greater awareness of the fragility of value chains would, therefore, reveal the constraints and opportunities in risk management, and inform risk management strategies and appropriate coordination and governance mechanisms.

The purpose of this chapter is to position fragility as a concept in the evolving literature of agribusiness research. The chapter identifies the factors that cause agricultural value chains to be fragile, and develops a framework to evaluate agricultural value chain fragility in different contexts. As a first attempt to develop such a framework, this chapter unpacks the concept of fragility and the various exogenous and endogenous factors that determine the fragility of agricultural and food chains. The chapter probes the notion that value chain fragility is influenced by a set of factors that are both critical to the success, and contribute to the fragility, of value chains.

3.2 OPERATIONALISING FRAGILITY FOR AGRIBUSINESS VALUE CHAINS

Operationalisation fragility, as a concept, in agribusiness value chain research requires that fragility be contextualised in the domain of uncertainty. Placing fragility in perspective in the uncertainty landscape specifically calls for the nuances of risk and fragility to be unpacked and contrasted, and the factors influencing the fragility of agribusiness value chains to be explored.

3.2.1 Risk analysis is not a fragility analysis

The primary goal of risk management is not to accurately estimate the probabilities or impacts of events, but is to reveal and assess uncertainty so that acceptable decisions can be made under conditions of uncertainty (Aven, 2015). However, traditional risk analysis frameworks approach risk management through a common approach which identifies, assesses and mitigates risks (Altay & Green, 2006; Kleindorfer & Saad, 2005). These frameworks for risk analysis implicitly require reliable and accurate measures of risk. A fragility analysis is, in many respects, the antithesis of a risk analysis. Rather than attempting to deal with probabilities and impacts of events, a

fragility analysis approaches risk management by determining the vulnerability to events. Vulnerability in this instance refers to the extent of the tendency to suffer adverse consequences when impacted by perilous events.

3.2.2 Classical risk analysis

The classical approach to risk analysis entails dealing with two specific concepts to arrive at an impression of risk. These concepts are the probability that an event will occur, and the impact when such an event does occur. Probability, within a value chain management context, is a measure of how often a detrimental event that results in a loss occurs. Impact, on the other hand, refers to the significance of that loss to the organisation. Therefore, as discussed in prior research (Hallikas *et al.*, 2002; Luce & Raiffa, 1957; Shapira, 1995; Yates & Stone, 1992), risk is perceived to exist when there is a relatively high likelihood that a detrimental event might occur and that event has a significant associated impact or cost.

The effectiveness of this approach, however, relies heavily on knowing the probability that an event will occur and what the impact will be when the event does occur. This paradigm lies at the heart of traditional risk management. Grasping the probability and the impact of events is, however, not a simple feat and presents some specific challenges (Munro & Zeisberger, 2010). A classification quadrant for risk, considering probabilities and impacts, reveals the complexity in dealing with these concepts in risk analysis (Munro & Zeisberger, 2010; Taleb, 2009b). The crux of the risk classification quadrant is that the impact (or "payoff") and the probability of an event are on a continuum of complexity and difficulty to estimate, respectively (Taleb, 2009b) (Figure 3-1 below). Therefore, while comprehension of the nature of risk and uncertainty is essential to informed and conscious risk management it is equally clear from the quadrant that some types of risk and uncertainty are much more intelligible than others are.

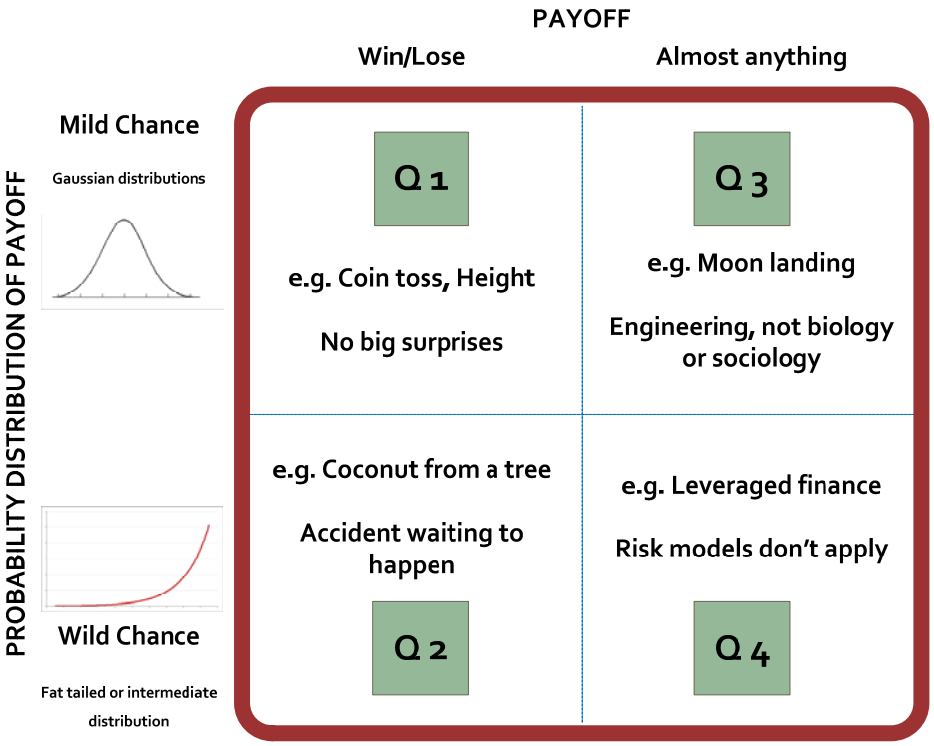

Figure 3-1: Risk classification quadrant

Source: Taleb (2009b); Munro and Zeisberger (2010)

3.2.3 Fragility analysis

The applicability of the traditional risk analysis approach is questioned the more difficult or impossible it becomes to identify and quantify either the impact or the probability of an event, or both (Munro & Zeisberger, 2010). This shortcoming is noted by (Garvey *et al.*, 2015) in the context of value chains where it is noted that existing measurement models have a localised view and inadequately consider the structure of chains (supply network), the effects of propagated risk, and risk's implicit casual structure within the chain.

Cognisant of the inherent complexity of value chains (Giannakis & Louis, 2011; Giannakis & Papadopoulos, 2015; Manuj & Mentzer, 2008; Thun & Hoenig, 2011) and the accompanying uncertainties, it is argued that risk in value chains is increasingly of the fourth quadrant of the risk classification quadrant. In the fourth quadrant landscape, (Taleb, 2009b) proposes that current approaches to prediction, forecasting, and risk management must be turned on their heads. The argument by Taleb (2012) is that "it is far easier to figure out if something is fragile than to predict the occurrence of an event

that may harm it" if the determination of the probabilities and impacts are unmanageable. The reasoning is that "fragility can be measured", while "risk is not measurable" (or as measurable, as is thought).

It is also argued that the analysis of the sensitivity to harm is a more workable approach to risk management, than is attempting to forecast the event that would cause the harm (Taleb, 2009b; Taleb *et al.*, 2012). The detection of non-linearities or convexity is the way to identify fragility. The degree of convexity can be used as a straight measure of the extent of the fragility (Taleb *et al.*, 2012).

3.2.4 Factors contributing to fragility

Not all risks influence all value chains (Manuj & Mentzer, 2008) and company risks are also not necessarily supply chain risks. Chain vulnerability is also a function of the chain's characteristics and any losses that a firm incurs is a result of its chain's vulnerability to a given chain disruption (Wagner & Bode, 2006). Consequently, appropriate factors in assessing fragility will vary from industry to industry, from company to company, and from entity to entity (Stonebraker *et al.*, 2009). Analogous to other operational measures, like productivity and quality, the definition and refinement of these measures must be suited to a specific context (Stonebraker *et al.*, 2009). The development of a framework to assess agri-based value chain fragility, therefore, requires a tailor-made approach to highlight the value chain's unique idiosyncrasies.

An exploration of the factors that contribute to the fragility of value chains is the foundation to developing a framework to assess this fragility. The complexity of the product, the process and the chain (Hashemi *et al.*, 2013) and the risks associated with the coordination of supply and demand and disruptions of the chain (Kleindorfer & Saad, 2005) are the key elements of uncertainty that affect the design and management of agri-based value chains. A review of the literature highlights a range of possible factors that might influence the fragility in value chains, or not. These include internal factors, like management, logistics, operations, marketing and sales, and supporting functions (Porter & Millar, 1985), and external factors like economic, environmental,

social, geopolitical, infrastructure and regulatory uncertainty, and the complexity of the chain, the process and the product from a chain perspective (Table 3-2 below). These dimensions of fragility comprise the basis to develop the rest of the chapter, which assesses subsets of these factors to arrive at a specific, tailor-made framework to examine generalised agribusiness value chain fragility as derived from the combination of the respective chains under consideration in the section.

Table 3-1: Literature related to drivers of uncertainty in value chains

Internal factors		External factors		Chain factors	
Management	Jüttner (2005), Power (2009), Vlajic *et al.* (2012)	Economic risks	Vlajic *et al.* (2012)	Supply Chain Collaboration Complexity	
Inbound logistics	Stonebraker *et al.* (2009)	Environmental risk		Supply Chain Coordination Complexity	Hashemi *et al.* (2013)
Operations	Vlajic *et al.* (2012), Perotto (2012)	Social/Societal risk	Bogataj and Bogataj (2007), Vlajic *et al.* (2012)	Supply Chain Configuration Complexity	
Outbound logistics	Stonebraker *et al.* (2009)	Geo-political risk	Chopra and Sodhi (2004), World Economic Forum (2015)	Information	Vlajic *et al.* (2012)
Marketing & sales	Wagner and Bode (2008), Vlajic *et al.* (2012)	Infrastructure risk	Vlajic *et al.* (2012)		
Firm infrastructure		Regulatory risk			
Human resources	Stonebraker *et al.* (2009)				
Technology	Chopra and Sodhi (2004)				
Procurement	Wagner and Bode (2008), Stonebraker *et al.* (2009)				
Financial risk	Gabriel and Baker (1980)				

Table 3-2: Operationalised value chain fragility factors

Internal	External	Chain
Management	Economic risks	Supply Chain Collaboration Complexity
Risk committee at board level	Market price fluctuation	Alignment with key suppliers' chain strategy
Risk appetite (Averse/Neutral/Seeking)	State of the economy	Alignment with key buyers' chain strategy
Risk analysis activity	Interest rate risk	Relations with key suppliers? (Coordination)
Risk and disaster management plan	Foreign exchange risk	Relations with key buyers? (Coordination)
Risk culture and ethics of business	Environmental risk	To what extent are key suppliers replaceable
Inbound logistics	Natural disasters	To what extent are key buyers replaceable
Breakdowns	Biological factors	Level of trust and openness with key suppliers?
Damage en route	Man-made hazards	Level of trust and openness with key buyers?
Accidents	Unpredictable hazards	Similarity of business culture with key suppliers
Outsourcing	Social/Societal risk	Similarity of business culture with key buyers
Operations	Political unrest	Extent of influence on each other's chain decisions? (Supplier)
Product complexity	Criminal acts	Extent of influence on each other's chain decisions? (Buyer)
Process complexity	Negative public reactions	Supply Chain Coordination Complexity
Order complexity	Industrial action	Level of information sharing with key suppliers
Production capacity	Changing customer attitudes	Level of information sharing with key buyers
Operational disruption	Geo-political risk	Integration level of logistics processes with key suppliers
Poor reliability of operations	Terrorism	Integration level of logistics processes with key buyers
Product/process certifications	Weaponising of finance	Independence of entities in making logistics decisions (Suppliers)
Outbound logistics	Weak political leadership	Independence of entities in making logistics decisions (Buyers)
Breakdowns	Global political instability	Variability between orders and delivery from key suppliers
Damage en route	Local political instability	Variability between orders and delivery from key buyers
Shipping mishaps	Infrastructure risk	What is the extent of long-term orders with your key suppliers?
Outsourcing	Poor transport infrastructure	What is the extent of long-term orders from your key buyers?
Marketing & sales	Insufficient traffic capacity	Degree of communication between multiple tiers and channels? (Suppliers)
Concentration of buyers	Uneven level of technological development	Degree of communication between multiple tiers and channels? (Customers)
Failure of buyer	Third party dependency	Information technology used with key suppliers?
Power of buyers	Regulatory risk	Information technology used with key buyers?
Buyer quality problems	Changes in laws and regulations	Supply Chain Configuration Complexity
Buyer off-take problems	Changes in company dependent rules	Number of value-adding tiers in the value chain?
Significant decrease in prices	Certifications and compliance	Number of logistics channels in the value chain?
Limitation in agreements		Complexity of linkages of key suppliers (with others)
Lean inventory		How complex are the linkages of your key buyers
Product quality hazards		What is the geographical spread of this supply network?
Product safety hazards		How long do you intend to source from these key suppliers?
Firm infrastructure		How long do you intend to sell from these key buyers?
Sophisticated equipment/infrastructure restrictions		What is your type of partnership with these key suppliers?
Relationship specific assets with supplier		What is your type of partnership with these key buyers?

Relationship specific assets with buyer Lack of infrastructure to support information sharing Lack of information visibility Varying ICT standards Human resources Labour Training Professionalism Culture & Ethics Technology Information security Intellectual property Procurement Variability in supply of raw materials Heterogeneous raw materials Concentration of suppliers Power of suppliers Failure of supplier Supplier quality problems Supplier delivery problems Significant increases in prices Limitation in agreements Financial risk Cash flow risk Leverage position		Rigid planning Information Inadequate decision support system Slow data transfer and processing Late detection of disturbances Lack of data about disturbances Inaccuracy of data Insufficient data analysis Intellectual property risk

3.3 AN EMPIRICAL ASSESSMENT OF FACTORS THAT DETERMINE VALUE CHAIN FRAGILITY

Tailor-making a framework to assess agri-based value chain fragility requires the filtering of the large spectrum of possible factors which may cause fragility down to a number of priority factors. The purpose of this prioritisation is to prune away factors which are irrelevant or not influential, and to narrow down the factors to a practical few that are relevant and at least highly influential on value chain fragility. These narrowed down, prioritised, factors suggest the essential or prominent features of an operational framework to analyse value chain fragility in future.

3.3.1 Methodology and Data

The methodology to develop a tailor-made framework to assess agri-based value chain fragility followed a type of normative Delphi (also called a consensus Delphi) approach. The method, focused on the opinions and consensus of experts, was used to prioritise the theoretical factors that may cause agri-based value chain fragility. Sixty-two key experts, with expertise or stakes in South African fruit, lamb and mohair value chains, were asked to evaluate the degree of influence of each of the indicators on the fragility of these or their specific value chains. The degree of influence aimed to capture whether the indicator is relevant and whether the indicator is important to the fragility of agri-based value chains. This approach follows the method used by (Kirezieva *et al.*, 2013) in developing a framework to assess food safety management systems in the fresh produce chain.

The theoretically constructed fragility framework with 139 indicators or factors that could influence value-chain fragility was presented in an electronic questionnaire to respondents (see Annexure 1 for the questionnaire). The 139 indicators were grouped into 3 main categories, internal (69), external (25) and chain (45) factors and 19 sub-categories. Respondents were requested to rate each of the indicators in terms of the indictor's influence on value-chain fragility on a five-point Likert scale (not influential at all, important, slightly influential, somewhat influential, very influential, and extremely influential). Respondents were also offered the option to comment on whether any influential factors were omitted, how relevant and practical the concept of

fragility was, how complex or abstract the concept was, how clear the questions were, and whether they wished to mention any further matters related to the research.

Based on the respondents' answers, the initial list of factors was passed through a methodical filtering process to reduce the number of factors to a few, prioritised, factors that could be employed in a practical framework to asses value chain fragility. The filtering process entailed identifying and retaining only the most influential factors, then reducing these factors by combining correlated factors into principal components, and then retaining only those factors or components which showed statistically acceptable consistency or reliability (Figure 3-2 below).

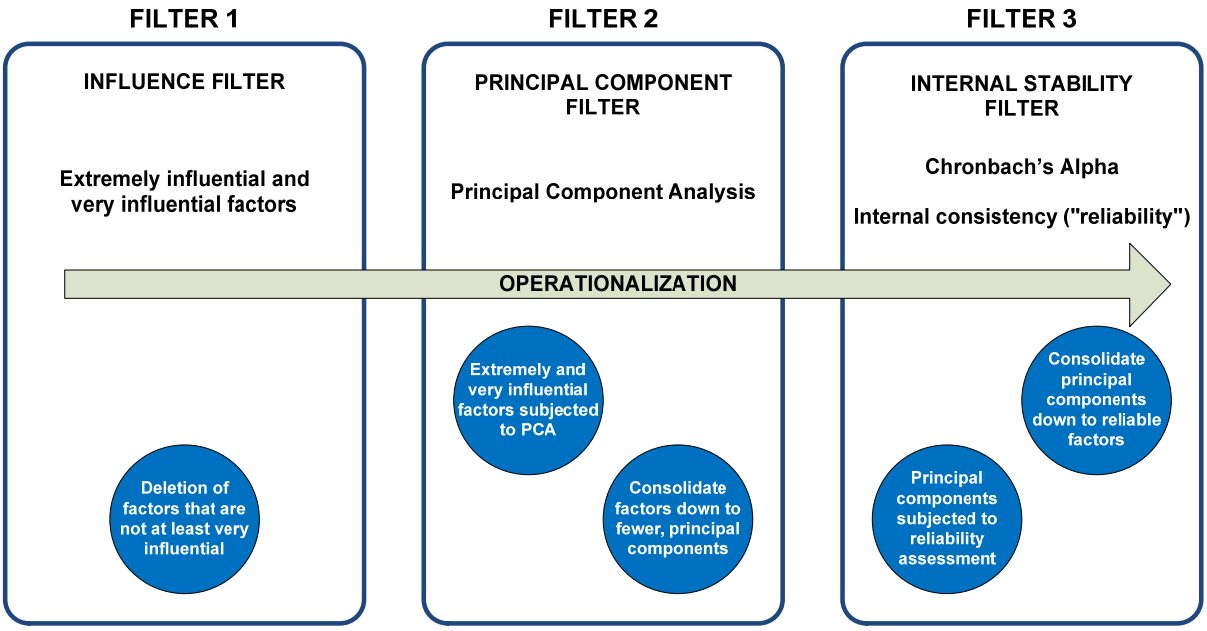

Figure 3-2: Process of operationalising value chain fragility

Practically, the filtering process entailed:

- Counting the frequency of responses per factor to identify those factors with the greatest number of extremely influential and very influential responses.
- Isolating those factors where the sum of extremely influential and very influential factors is in the upper quartile of factors.

- Retaining factors that fall in the upper quartile of influence and deleting all others.
- Conducting a principal component analysis to reduce the dimensions of the framework by identifying correlations between the remaining factors, and combining correlated factors to further reduce the number of factors in the framework.
- Conducting an analysis of the new or remaining factors or principal components to determine the internal consistency and reliability of these principal components.
- Retaining only internally consistent and reliable components or factors in the framework and deleting all other factors to arrive at a logical and robust framework to engage agribusiness value chain fragility.

Fragility, as a concept, was discussed in the introduction of the questionnaire to ensure a clear baseline position of the definition of fragility. Respondents' grasp of fragility was also tested with open-ended questions related to the degree relevance, practicality, abstractness and complexity of fragility in relation to agribusiness value chains.

3.3.2 Overview of respondents

The expert respondents were selected to be resources on the basis that they are either: 1) experienced in the field of, or 2) consultants to, or 3) represent a constituency in, or 4) are stakeholders in, agri-based value chains. The selection of experts was also tailored to ensure representation across the typical agri-based value chain. Experts included stakeholders ranging from input suppliers, through the chain of activities, to the retailing of consumable products and supporting activities to the chain. The experts were also sourced from diverse geographical regions, including South Africa, Belgium, the Netherlands and the UK, to provide a Global Value Chain (GVC) dimension to the framework.

The survey questionnaire was presented to 84 expert respondents in three agricultural value chains (meat, fibre and export fruit) after requesting their participation in the

research. Overall, 62 experts responded to the request with completed questionnaires (response rate: 74 %). Respondents were spread across the typical agricultural value chain, from input providers through to retailers, intermediaries and third parties (Figure 3-3 below) that are involved or acquainted with the particular value chains.

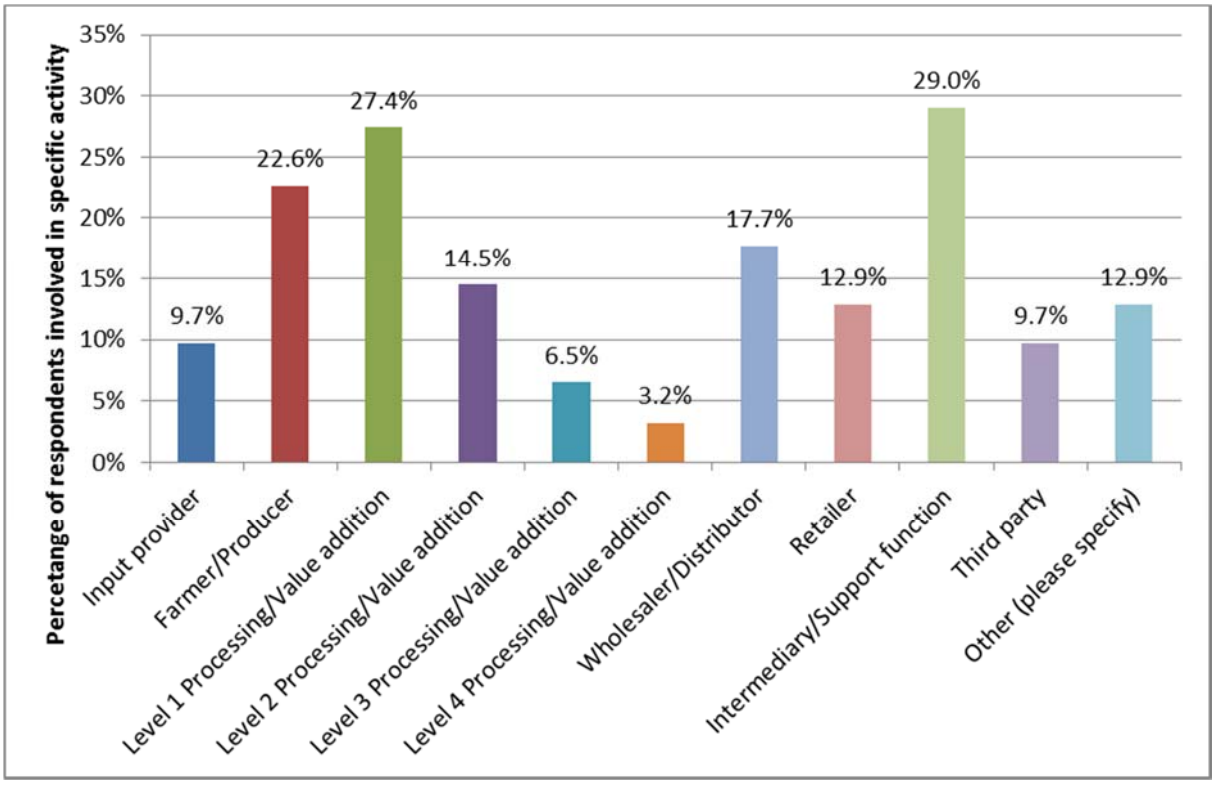

Figure 3-3: Spread of respondents across the agricultural value chain

Geographically, 78 % of respondents were located in South Africa, 11 % in Belgium, 8 % in the United Kingdom and 4% in other regions. In terms of the different commodities, 30 % of respondents were involved in the lamb value chain, 37 % in the fruit value chain, 10 % in the fibre chain, 11 % in the meat and fruit chain (typically retailers) and 13 % in the meat, fruit and fibre chains (typically service providers to the stakeholders in the various chains).

3.3.3 Results

Based on the frequency of the Likert scale score for each of the factors (in relation to the influence variable) 17 % of the factors were considered ‘extremely’, 40 % ‘very’, 23 % ‘somewhat’, 15 % ‘slightly’ and 5 % ‘not’ influential on value chain fragility (Figure 3-4 below).

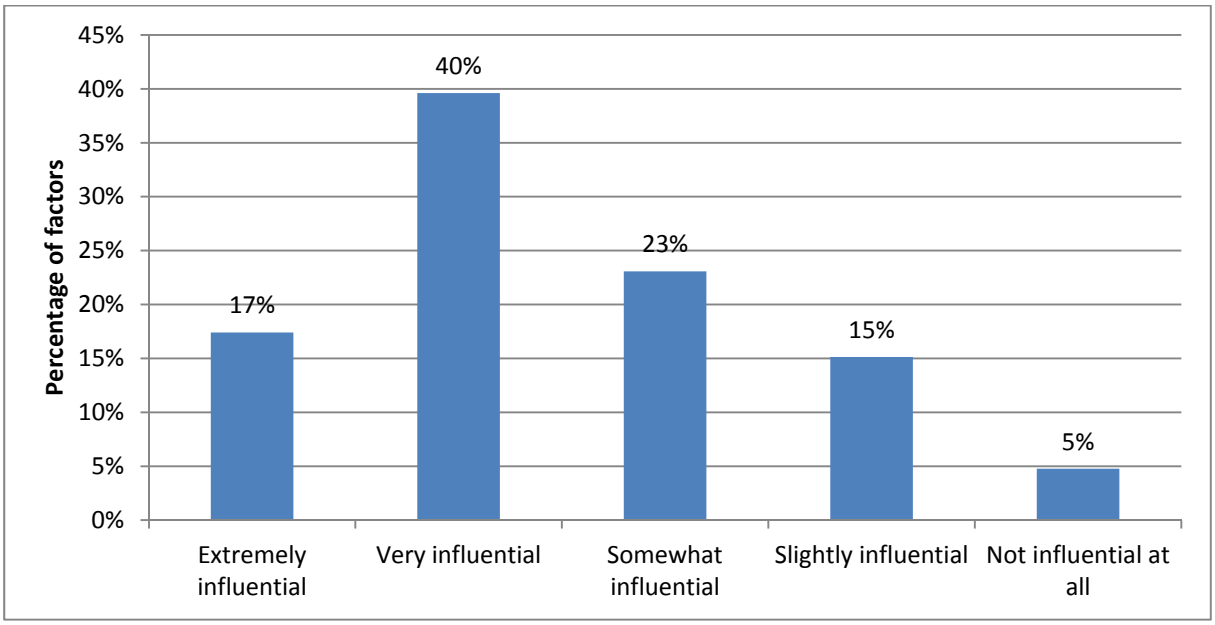

Figure 3-4: Spread of responses related to the influence of factors

Internal, chain, and then external, factors constitute the grouping of extremely influential factors that contribute to value chain fragility (Figure 3-5 below).

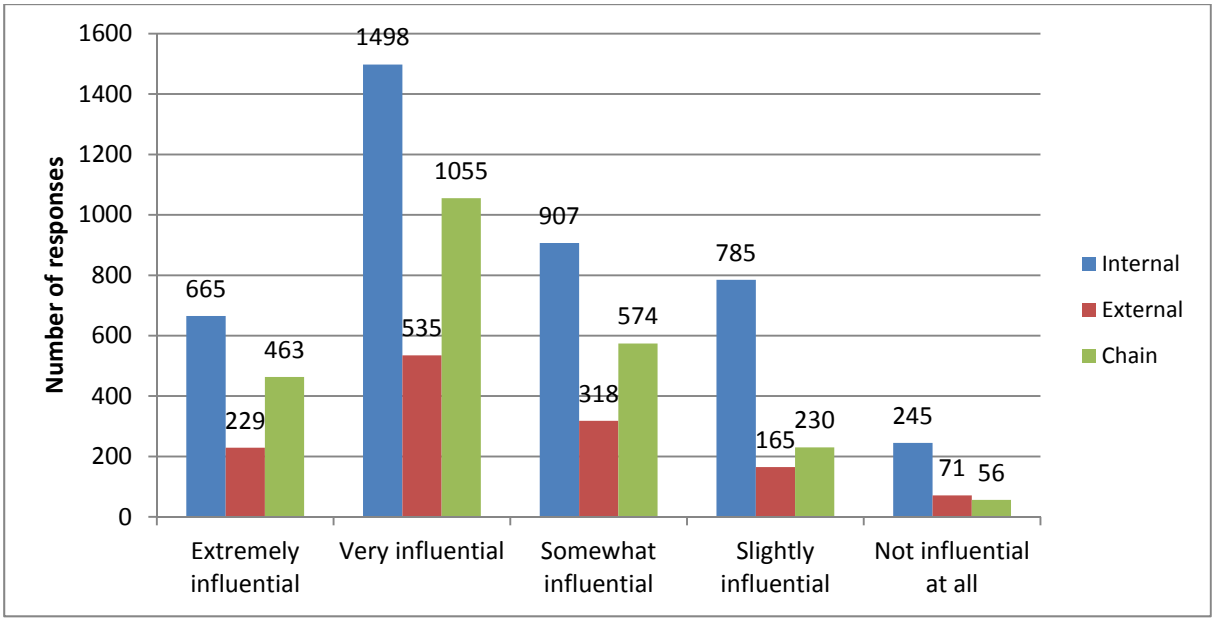

Figure 3-5: Spread of responses related to the influence of factors by source

At this level of the filtering process, product quality and safety standards, and supplier quality problems were the most prominent internal factors; natural disasters were the most prominent external factor; and inaccuracy of data was the most prominent chain factor (Table 3-3 below).

Table 3-3: Prominent factors based on the frequency of an extremely influential score

Type of factor		
Internal	External	Chain
Product quality and safety standards (n=22) Supplier quality problems (n=21)	Natural disasters (n=21)	Inaccuracy of data (n=22)

A deconstructed view of the specific category and type of factor confirms these outcomes. In the case of internal factors, quality and safety standards in the product complexity category, and supplier quality problems in the procurement of raw materials category, are most prominent (Figure 3-6 below). Natural disasters in the environmental category of the external grouping of factors (Figure 3-7 below) and the inaccuracy of data in the information category of the chain grouping of factors (Figure 3-8 below) are the most prominent extremely influential factors.

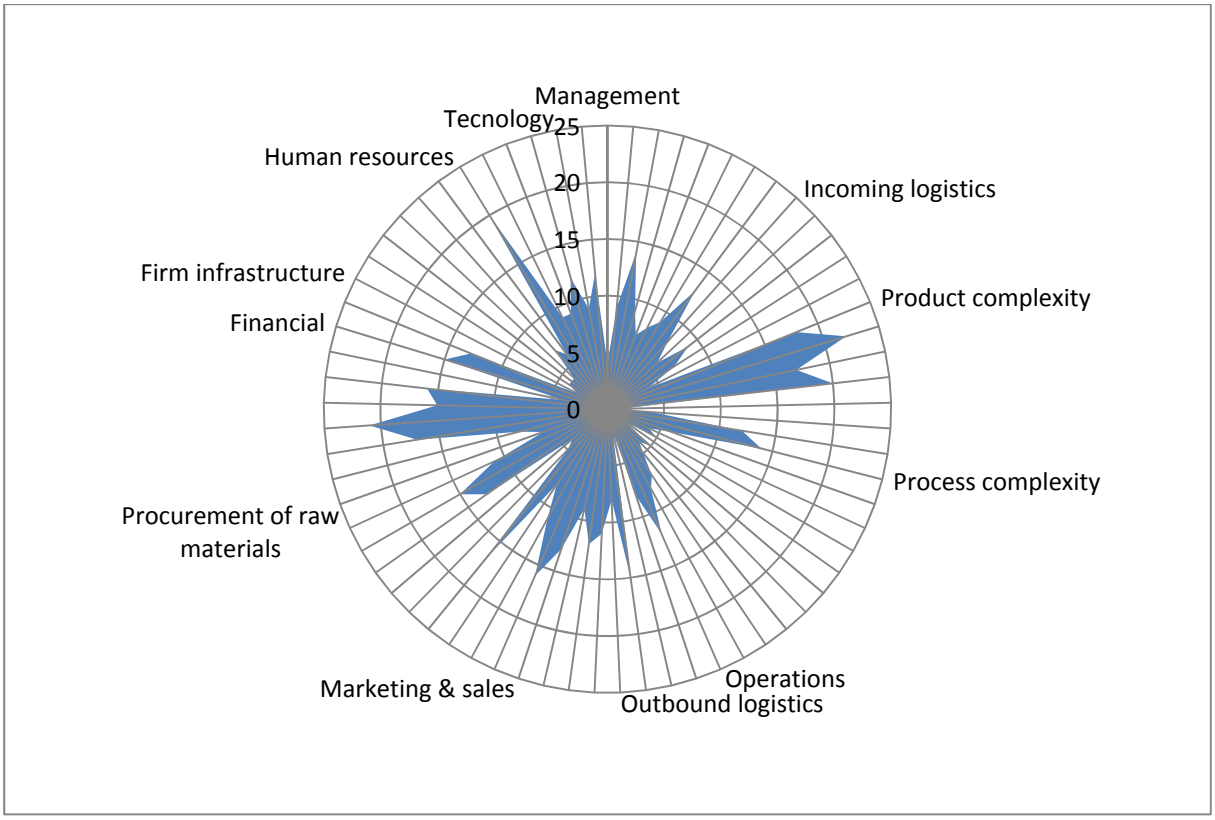

Figure 3-6: Frequency of extremely influential score per category of internal factors

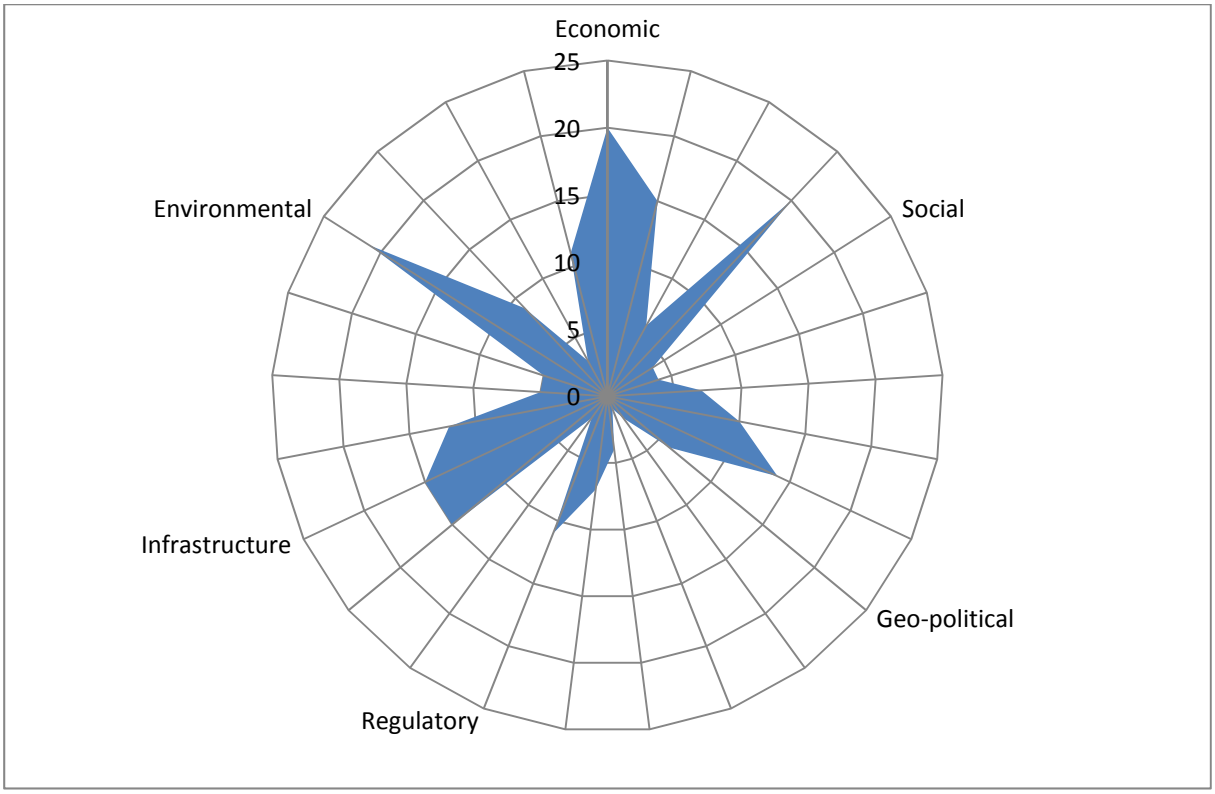

Figure 3-7: Frequency of extremely influential score per category of external factors

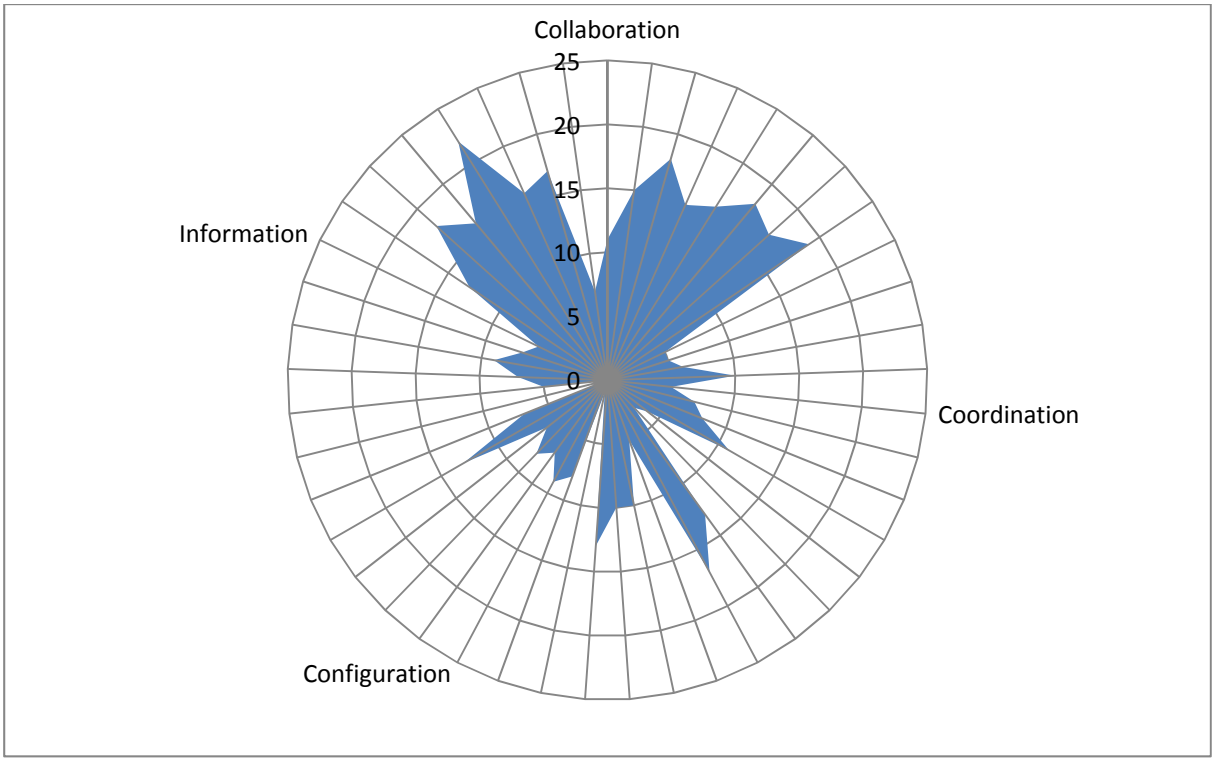

Figure 3-8: Frequency of extremely influential score per category of chain factors

The interquartile range (IQR) is an indicative of the variability of data points in data set. The higher the IQR, the more variable the data set; in contrast, the smaller the IQR, the less variable the data set. The factor '*terrorism*' in the geopolitical category of external factors is the factor which exhibits the greatest IQR (Figure 3-9 below). The varied response to the influence of terrorism on value chain fragility is expected in light of the geographical concentration of terrorism and the consequent influence on value chain fragility.

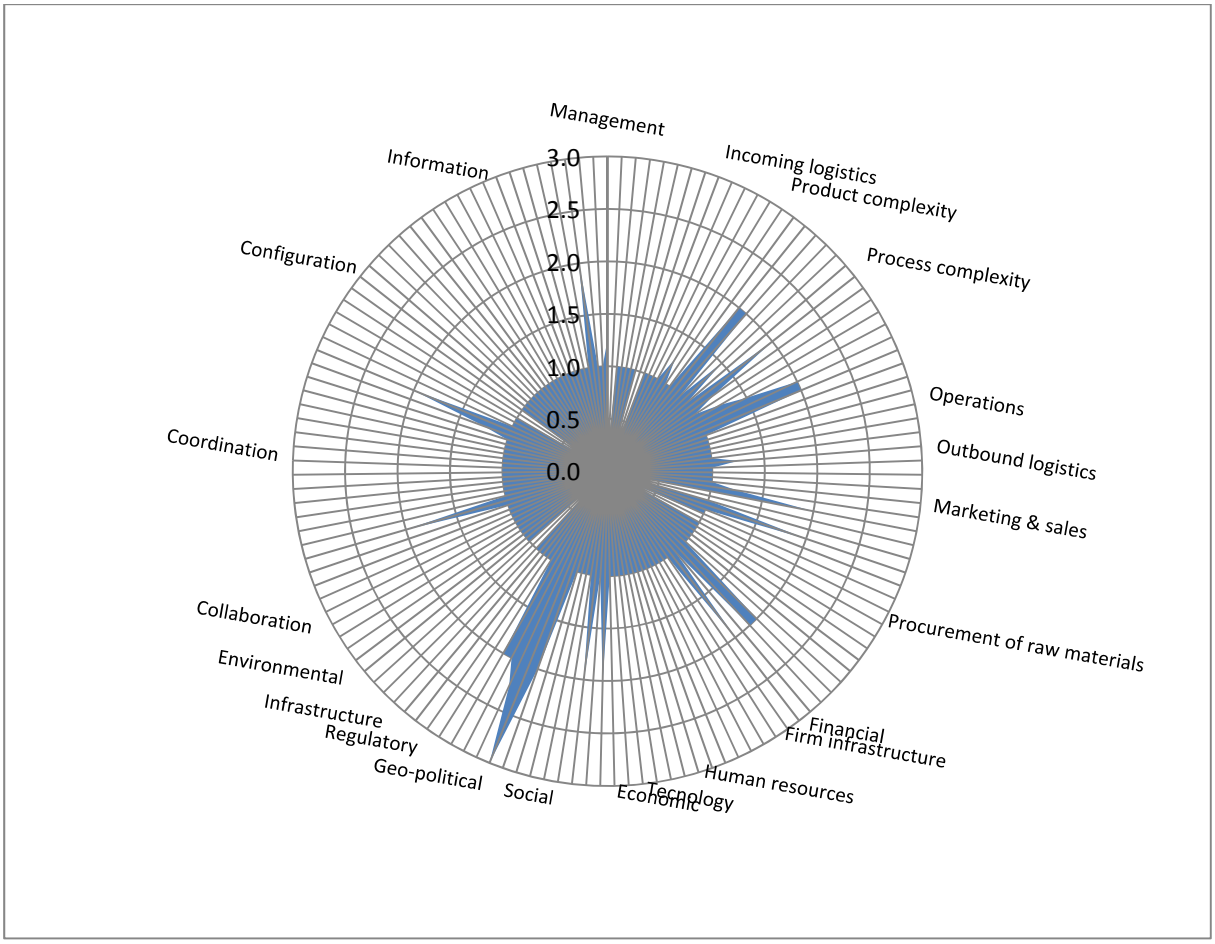

Figure 3-9: Interquartile range of the scores of influence on value chain fragility

Pursuant to the overview of the initial responses by respondents, the filtering process is aimed at reducing the number of factors in a structured way to arrive at an operational framework to assess value chain fragility. The first step in the filtering process is to eliminate factors based on their level of influence on value chain fragility. The frequency of responses per factor was counted to identify those factors where the mode of the specific factors was considered extremely influential or very influential. Those factors where the sum of "extremely influential" and the sum of "very influential" factors were in the upper quartile of all the factors were retained for further analysis and filtering. The other, "insufficiently influential", factors were deleted. As a first step in prioritisation, this process identifies the upper quartile of factors that are extremely influential or very influential and allows for the deletion of those factors that are not from the framework. Following the Filter 1 process, 65 very and extremely influential factors remained in the framework. These factors were spread across the internal (25), external (12) and chain (28) groups (Figure 3-10 below).

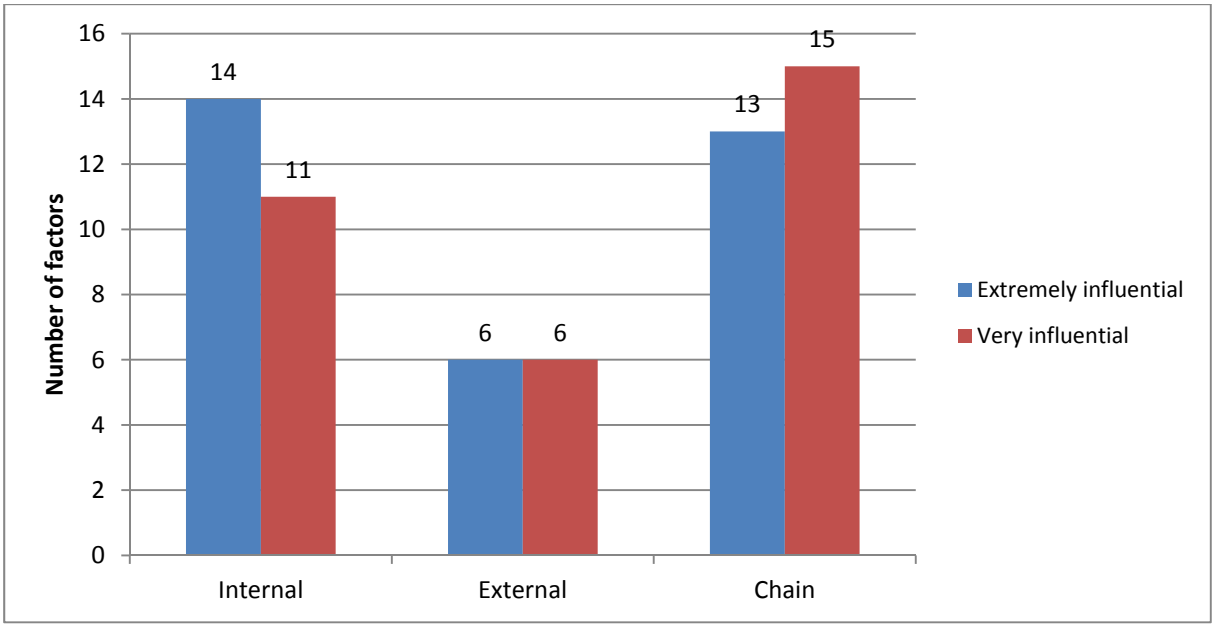

Figure 3-10: Summary of the number of very and extremely influential factors in the upper quartile

These 65 factors which came from the Filter 1 process were subjected to the Filter 2 process. The Filter 2 process was a dimension reduction exercise using a Principal Components Analysis (PCA). PCA is a variable-reduction technique that shares many similarities to exploratory factor analysis. Its aim is to reduce a larger set of variables into a smaller set of 'new' variables, or 'principal components', which account for most of the variance in the original variables. The PCA reduced the dimensions of the framework by identifying correlations between the remaining factors and combining correlated factors to further reduce the number of factors in the framework to 22 factors. Reduction of the factors was performed within the groups of factors. These new factors consisted of 10 internal, 5 external and 7 chain factors. The details and the results of the PCA are attached in Appendix 1 to this thesis.

Subsequent to the new variables from the PCA, the 22 remaining factors then entered the last filtering process in the development of the operationalised value chain fragility framework. The Filter 3 process was an assessment of the internal consistency or reliability of the value chain fragility framework on the basis of Cronbach alpha's reliability coefficient. Assessing the reliability of the instrument is the final hurdle in arriving at an operational framework since it assesses the ability of the instrument to measure consistently and allows for adjustment of the instrument to ensure acceptable

reliability. Employing an iterative process, the framework of 22 remaining factors was assessed and factors that would improve the reliability of the framework through their omission were deleted from the group of factors. Accordingly, a further 6 factors were ejected from the value chain fragility framework to leave only 16 factors that combine in the final, operationalised value chain fragility framework (Table 3-4 below). In the final framework, Cronbach's alpha coefficient was 0.871 across all factors.[2] Considering the operationalised value chain fragility factors, it is evident that the 16 remaining factors combine in a reliable framework to assess value chain fragility (Gliem & Gliem, 2003).

Table 3-4: Operationalised value chain fragility framework

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Supplier relationship and alignment	6.846	79.104	.374	.587	.869
Buyer relationship and alignment	6.807	78.019	.441	.549	.866
Information sharing with buyers independence of buyer logistics and order variability	6.743	79.584	.386	.534	.868
Degree of chain communication	6.839	78.861	.394	.493	.868
Number of chain links, channels and interdependency	6.823	75.869	.600	.581	.859
Sufficient, accurate, timely data, analysis and decision support	6.859	74.315	.670	.615	.856
State of the economy and prices	6.882	75.353	.611	.597	.858
Social stability and public relations	6.837	75.696	.599	.664	.859
Laws, regulations & compliance requirements	6.862	78.135	.445	.631	.866
Quality of infrastructure	6.910	78.164	.462	.520	.865
Operational reliability	6.874	76.919	.518	.599	.863
Product quality & safety	6.837	77.609	.471	.536	.865
Supplier reliability	6.856	78.709	.445	.645	.866
Labour & training	6.847	76.660	.548	.501	.861
Cash flow risk	2.965	74.318	.622	.609	.858
Lack of information visibility	3.195	77.444	.513	.503	.863

The result of the filtering process is a basic, reliable framework that consists of 6 chain, 4 external and 6 internal factors that can be operationally employed to assess the fragility of value chains (Table 3-5 below). The details and the results of the internal stability analysis are also attached in Appendix 1 to this thesis.

2 The interpretation is that the closer Cronbach's alpha coefficient is to 1.0, the greater the internal consistency of the items in the scale is. The general rule of thumb in evaluating Cronbach's Alpha is > .9 – Excellent, _ > .8 – Good, > .7 – Acceptable, > .6 – Questionable, > .5 – Poor, and < .5 – Unacceptable.

Table 3-5: Operationalised value chain fragility factors

Chain factors	Supplier relationship and alignment Buyer relationship and alignment Information sharing with buyers Degree of chain-wide communication Degree of chain complexity Adequate, accurate, timely data, analysis and decision-making
External factors	State of the economy and prices Social stability and public relations Changes in public and private compliance requirements Quality and adequacy of supporting infrastructure
Internal factors	Operational reliability Product quality & safety performance Supplier reliability Quality and training of human resources Cash flow position Information visibility

The result of the methodical filtering process is that an initial 139 theoretical factors were reduced to 16 factors at the end of the process (Figure 3-11 below). The successful reduction of the number of factors allows for the transition from a conceptual notion to the operationalisation of the framework and for its practical use in assessing value chain fragility. Interestingly, it is noted that, as a result of the filtering, the proportion of factors split across the internal, external and chain constructs changes from being dominated by internal factors to where all the factors almost contribute equally to value chain fragility in the final framework (Figure 3-12 below).

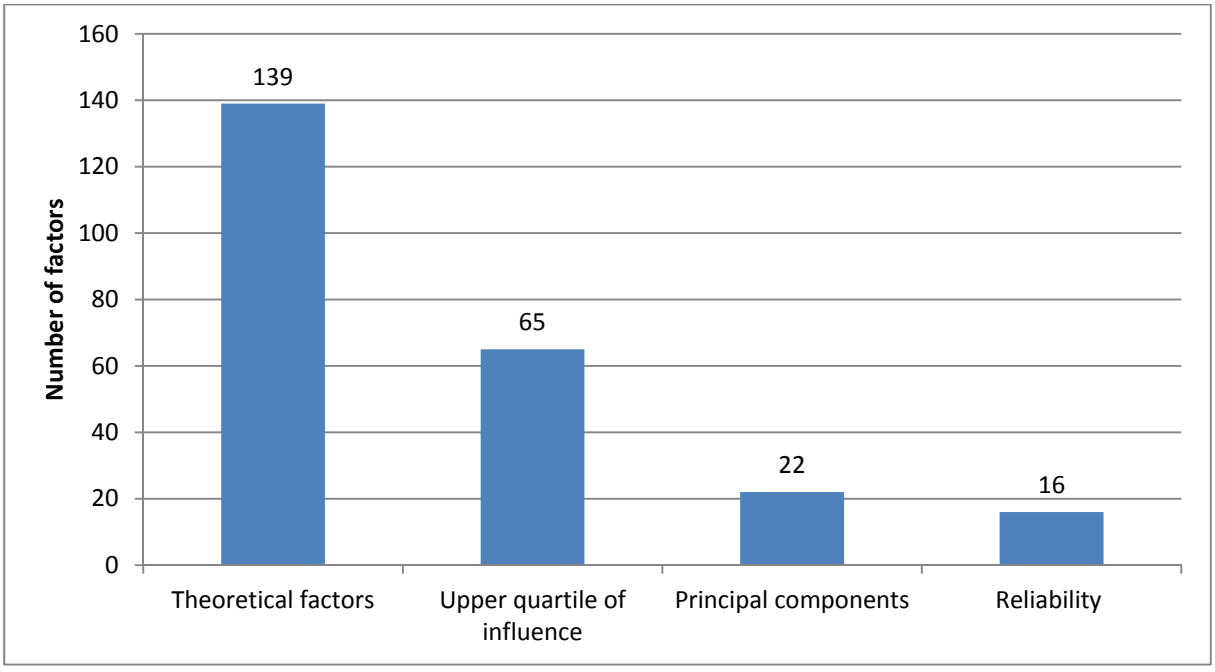

Figure 3-11: Number of factors in the value chain fragility framework through the filtering process

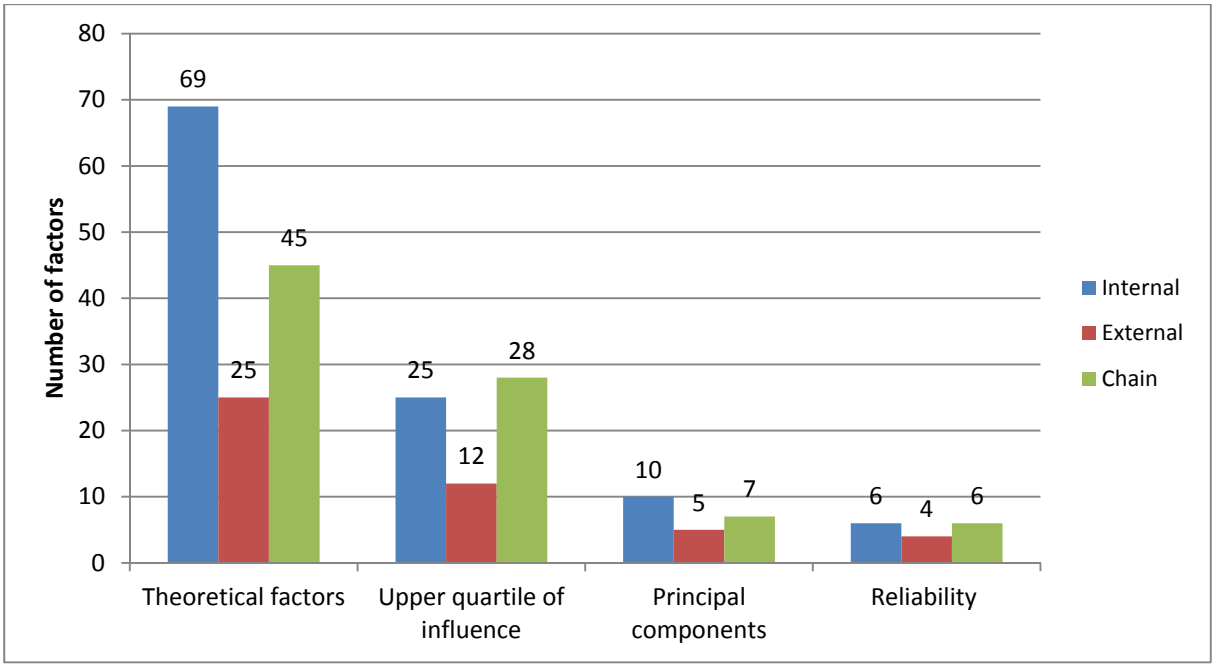

Figure 3-12: Number of factors, per grouping, in the value chain fragility framework

3.4 DISCUSSION

Sixty-two industry experts and stakeholders participated by way of an expert opinion survey to validate a framework to assess value chain fragility in the agribusiness context. These experts and stakeholders are from the South African meat, fibre and export fruit chains. The purpose of the validation was to forge together the conceptual tentacles of fragility from a range of chains and contexts into a generic compact, empirically evaluated and practical framework for assessing value chain fragility. The purpose was not to assess the probability of occurrence of adverse events and payoffs, but rather to define fragility and to identify the factors that influence fragility generically. The process required industry experts and stakeholders to review some specific dimensions of value chains and the influences on chain fragility. Dimension reduction techniques were then used to arrive at a pilot operational framework to assess value chain fragility. The purpose of this pilot framework is to analyse fragility across a group of chains albeit that such an assessment for specific chains in a specific context is equally possible and potentially interesting.

3.4.1 Chain Factors

The development of an operational framework to assess value chain fragility has isolated a number of chain factors that contribute to this phenomenon. These factors include the supplier and buyer relationship and alignment, information sharing with buyers, the degree of chain-wide communication, the degree of chain complexity, and the adequacy, accuracy and relevance of data, its analysis and effect on decision-making.

Two main streams of influence on value chain fragility are evident from these chain factors. The first is the nature of the coordination and alignment between chain stakeholders and the complexity of the chain. It is aptly noted that there is always some kind of relationship and coordination if any production takes place. Coordination and alignment are essentially at the heart of the value chain phenomenon (Hobbs, 1996). Exploring the proper coordination (i.e., coordination with limited scope for error) of value chains is also the foundation of value chain research (Peterson *et al.*, 2001). It is therefore fitting that coordination and alignment, as core dimensions of value chains, emerge as factors that are relatable to the fragility of value chains, too. Popular and scientific literature confirms the contemporary nature of the coordination question in value chains in general (Chan *et al.*, 2009; Du *et al.*, 2016; KPMG, 2013; Masten & Kim, 2015; Ponte *et al.*, 2014) and in agricultural chains (Handayati *et al.*, 2015; KPMG, 2013) specifically. The inference is, therefore, that idiosyncrasies in the coordination and alignment of value chains not only cause coordination errors that impact on the performance of the chain, but also render the chain vulnerable to accelerating impacts.

The second stream of factors to have an influence on value chain fragility comprises the role of information and information sharing in decision-making in the chain. Value chains are defined by two dimensions, a set of activities and a flow of information. The prominence of information in the functioning of value chains is highlighted by the notion that every business is “an information business”. Besides the chain activities, the value chain includes “all the information that flows within a company and its suppliers, its distributors, and its existing or potential customers” (Evans & Wurster, 1997). The range of relationships that businesses enter into and maintain includes the company’s

relationships (supplier, customer and employee), brand identity, and process coordination, all of which are dependent on various forms of information. Coincidentally, information is at the heart of the current business processes, and also for value chains. However, notwithstanding the prominence of information in the value chain, it is, in fact, the way that information is created, interpreted, shared, integrated and used that makes chains fragile. An obvious example of this is the well-known bullwhip phenomenon ('bullwhip effect') that develops as a result of challenges in information sharing in the value chain (Lee *et al.*, 1997; Taylor & Fearne, 2006).

3.4.2 External Factors

The boundary between external and internal factors is not always that distinct and the limits depend on the margin of the system in question (Vlajic *et al.*, 2012; Waters, 2011). In discussing both the external and internal factors, it is therefore sensible to keep the arbitrary and contextual distinction between these types of factors in mind, albeit that a broad distinction is being made.

The analysis suggests that the external factors that can be justifiably incorporated in operational framework to assess value chain fragility include the state of the economy and product prices, social stability, changes in public and private compliance requirements, and the quality and adequacy of supporting infrastructure. The significance of the set factors is judged by reflecting on critical external factors that are known to be influential in the successful operations of value chains. External factors arise from the environment within which the value chain is operating. In literature, external or macro-environmental factors are known to have an impact on any portion of the supply chain, or across the entire supply chain. These include events such as downturns in the global economy, shortages of critical raw materials, political and social instability, changes in regulatory requirements, and natural disasters (Deloitte, 2013b). Legal, political and actions of government, behaviour of competitors, financial and economic actors, environmental impact, and random events are identified for value chains in general (Stonebraker *et al.*, 2009), and financial, market, legal, infrastructure, societal and environmental factors for food chains (Vlajic *et al.*, 2010).

Considering the context, the set of external factors isolated for use in the value chain fragility framework are broadly aligned with the group of prominent external themes that scholars and practitioners give emphasis to in terms of their influence on the functioning of value chains.

3.4.3 Internal Factors

Internal value chain fragility factors include the reliability of operations, product quality and safety, reliability of suppliers, human resources, cash flow position, and the visibility of information. In principle, the internal elements of value chains centre on planning and execution of the "value" processes of development, conception, sourcing, making and delivering in the value chain. Physical logistics, the behaviour of suppliers and buyers, information, communication, product and process, and people are identified as influential internal factors in supply chains (Stonebraker *et al.*, 2009). Those internal factors contained in the value chain fragility framework are also broadly aligned with the set of prominent internal themes that scholars and practitioners focus on in terms of their influence on the functioning of value chains.

3.5 SUMMARY

Conceptually fragility is at the frontier of the agribusiness system's pursuit of sustainability in a world characterised by increasing interconnectedness, interdependencies, and uncertainty. Hence, fragility goes beyond the firm boundary and is addressed at value chain level. Based on expert opinion across the agribusiness value chain, the study isolates a set of factors that influence the fragility of these value chains. The essence of the findings is that those elements that are known to be critical for the success of value chains are also the same elements that drive the fragility of the chains. What makes a chain work well is also what a chain is vulnerable to.

This chapter provides a pilot framework to study fragility in agribusiness value chains, based on expert opinions. The contemporary nature of the study highlights the need for fragility to be explored in more depth and along a range of trajectories to make it useful for academia and practitioners in the agribusiness value chain. These trajectories include developing frameworks to quantify chain fragility and exploring chain, sector

and context-specific variations and comparisons to capture specific nuances of fragility. Most importantly, this chapter fits a puzzle piece into the conceptual framework, as discussed, to allow for the further analysis of fragility in agricultural value chains.

There is no doubt that understanding and managing risk and fragility in the value chain should be important for most organisations and their sustainability (Beske & Seuring, 2014). Value chain risk and fragility are also not expected to subside in the near future, but rather to accelerate as globalisation continues to evolve, consumers needs become more nuanced, and greater demands are placed on the extended value chain (Khan & Burnes, 2007). Current research and guidance seems to be inadequate to meet this challenge. Value chain risk management needs an integration of knowledge from multiple research disciplines, and new analysis tools should aim at proactively managing supply chain disturbances (Musa, 2012; Tang & Musa, 2011). Moreover, knowing what influences fragility in value chains enables the development of tools to measure the extent of fragility, which is useful for decision-making, strategic planning, and the design and management of agricultural-based value chains. Chapter 4 of the thesis builds from Chapter 3 in developing a measure for agribusiness value chains, including a case study.

CHAPTER 4
MEASURING FRAGILITY OF VALUE CHAINS

4.1 INTRODUCTION

The future holds an imminent surge in global uncertainty and complexity and this will come about sooner than expected. Opinion is that many global supply chains were not designed for, and are ill-equipped to deal with, this looming uncertainty and complexity (Malik *et al.*, 2011). At the same time, value chains have become sophisticated and essential to the competitiveness of many businesses, even though their interwoven and global nature also makes them increasingly exposed to the challenges that accompany uncertainty and complexity (Deloitte, 2013b). The network of value chains that constitute the agribusiness system has also become increasingly connected, complex and volatile (KPMG, 2013; Swinnen, 2015) and mirrors global developments in value chains. As a result of these challenges, agricultural value chains are inherently exposed and vulnerable to adverse events in the economy, the environment, politics, the consumer landscape and the structures that govern these chains (Bode *et al.*, 2013; KPMG, 2013; Neves & Scare, 2010; Wagner & Bode, 2006).

There is compelling evidence that illustrates the impact of value chain fragility, including a loss of shareholder value (Hendricks & Singhal, 2005; Hendricks & Singhal, 2008), business unit closures (Engber, 2012), profits turned to losses in weeks (Engber, 2012), civil liabilities (Huspeni, 2014), lack of transparency (Linich, 2014) and knock-on effects (Acheson, 2007; Nganje & Skilton, 2011; Williams-Grut, 2015). Consequently, there is a particular need to measure the fragility of value chains in general (Stonebraker *et al.*, 2009) and agricultural value chains in particular. A measure of value chain fragility would reveal the constraints and opportunities in risk management, and inform risk management strategies and appropriate coordination and governance mechanisms in agribusiness value chains.

The purpose of this chapter is to advance the argument that fragility, as a concept, provide a further and useful dimension to the uncertainty discourse in agribusiness value chains – especially through its measurement. The development of an approach to

quantify agribusiness value fragility will also enable a range of analyses to follow, which would be useful for practitioners and academia. Against this background, this chapter adapts and tailors a framework to measure agribusiness value chain fragility. As a first attempt to develop such a framework, this chapter positions the measurement of fragility in a conceptual landscape, and considers the risk and uncertainty continuum and the link to fragility. The chapter also explores some principles and the actual measuring of fragility in the agribusiness context. The chapter concludes by measuring the fragility of the South African Lamb value chain to showcase the framework and the accompanying concepts and the implications for the study, as well as the practice of agribusiness value chains.

4.2 CONCEPTUAL SETTING

Agribusiness value chains are required to deliver to increasingly complex, nuanced and demanding consumer needs within an environment that is ever more challenging and where uncertainty is inherent in the system (Boehlje *et al.*, 2011; Sexton, 2013). Within the agricultural value chain system, the consequences of adverse events are also increasingly reaching beyond firm boundaries and spilling into value chains (Linich, 2014). Consequently, there is an increasing move towards more coordinated exchanges in value chains in an attempt to manage uncertainty in these chains (Hobbs, 1996; Hobbs & Young, 1999; Sexton, 2013). However, increasingly coordinated exchange in value chains, almost silently, brings about a predicament in pursuing a specific coordination direction. When uncertainties in a chain have predictable probabilities and the payoffs (consequences or outcomes) are simple, increasing coordination brings about high performance value chains. Conversely, when uncertainties in a chain have less predictable or unpredictable probabilities and the payoffs (consequences or outcomes) are complex (due to complex interdependencies, non-linear relationships, etc.), increasing coordination brings about increasingly fragile value chains (Gray & Boehlje, 2005; Taleb, 2009b).

The strategic imperative for enterprises and their value chains is therefore to find the appropriate coordination strategy which balances the performance of value chains with the fragility of these chains. In essence, the conceptual framework sets up the age-old dilemma that uncertainty is inherent in the pursuit of opportunity in the context of

agricultural value chains. As such, the objective is to build a framework to examine the trade-off between chain performance and chain fragility (Vahid Nooraie & Parast, 2016).

The purpose of this chapter is to develop and empirically examine fragility as a concept and to operationalise a method to measure the fragility of agribusiness chains. While the literature is awash with frameworks that measure the performance of agribusiness value chains (Aramyan *et al.*, 2007; Fattahi *et al.*, 2013; Molnar, 2010; Osés *et al.*, 2012), the measurement of fragility of the very same chains is unexplored. The absence of a measure of value chain fragility has also prevented the examination of the trade-off between the juxtaposed objectives of performance and fragility in value chains – the theme which is central to this thesis's conceptual framework. A measure of value chain fragility would inform the design, organisation, governance and management of value chains and ultimately focus attention on the trade-off between high performance and fragile value chains. Contemplation of this trade-off in value chains is interesting, bearing in mind that value chains are investments where the interplay of revenue, costs and uncertainty drive the attractiveness of the investment.

4.3 PRINCIPLES OF MEASURING FRAGILITY

Cognisant of the relevance of uncertainty in value chains, the ability to measure fragility is evidently important in exploring all of the extents, dimensions and interactions of fragility and in plotting strategies to manage fragility and its consequences in agribusiness value chains. This section discusses principles in measuring fragility to lay a foundation to propose a metric for value chain fragility. The detection and measurement of value chain fragility discussed in the sub-sections that follow builds on the various elements that influence chain fragility as identified in Chapter 3.

4.3.1 An alternative approach to measuring risk and uncertainty

'Black Swan events' are "large-scale unpredictable and irregular events of massive consequence" (Taleb, 2012). A Black Swan event (Aven, 2013; Taleb, 2007; Taleb, 2009a) is characterised by complex payoffs and fat-tailed probability distributions typical of leveraged finance, economic systems, epidemics, catastrophes and the

development of the internet (Munro & Zeisberger, 2010). Black Swan events are specifically problematic for risk measurement and management because of the impossibility of predicting their occurrence and calculating their impacts (Taleb, 2012) according to the risk and uncertainty map discussed in Chapter 3. The impossibility of predicting the occurrence and calculating the impacts of Black Swan events relate to a number of epistemological difficulties. These difficulties relate to both the probability and outcome dimensions as Taleb (2012) notes:

- **Probability**
    - The generator of Black Swan events is not known and consequently only outcomes are observed, not probability distributions. The point is that some statistical properties of Black Swan events only emerge after the event;
    - Assuming that past events are good predictors of future events, the rare nature of Black Swan events implies that a sample that is larger and larger in inverse proportion to the occurrence of the event is required to derive the probabilities of future occurrences from the data. The point is that for particularly rare events, there is most certainly insufficient data to determine the probability of a future rare event;
- **Outcome**
    - In complex systems, in the Black Swan terrain, the extent of typical events tends to be indeterminable, or at least much more indeterminable than is recognised. Therefore, by way of example, the occurrence of a war may be predictable, but its effect not; and equally so with economic crises (Adelson, 2013).

Whereas the typical risk management approach relies on knowledge of the probability and probability distribution of events and the typicality of single events, the approach is evidently severely inadequate, even flawed, in the case of Black Swan events in complex systems like value chains (Taleb, 2009b). An alternative approach is to determine if something is vulnerable to a Black Swan event rather than to attempt to predict the occurrence of such an event. The reasoning is that vulnerability, and hence

fragility, can be measured, while risk is not as measurable as is thought, especially in complex systems (Aven, 2015; Taleb *et al.*, 2012). This approach is without a doubt counterintuitive and in opposition to mainstream approaches employed by practitioners and academics to understand and manage the various sources of risk and uncertainty (Ge *et al.*, 2016; Heckmann *et al.*, 2015). Measuring fragility, rather than risk, does, however, solve some very specific shortcomings of the old-style, probability and impact approach, and is the fundamental rationale for the approach in the thesis.

4.3.2 Unit of measurement

Fragility has been positioned as being a measure of the sensitivity to specific risks. In the context of value chains there is, however, not a specific or clear guideline as to which variable or indicator or mix of indicators is recommended in assessing fragility. Value chain fragility could be measured for revenue, costs, margin, gross or net profit, reputation, business continuity, sustainability, volumes, etc.

Examples of the unit of measure include gross profit as a measure to gauge the robustness of value chains (Vlajic *et al.*, 2012). Margin erosion, sudden changes in demand, disruption of physical product flow, product quality failure, regulatory non-compliance and worker-safety failure and, social responsibility are also considered to be indicators of impact (Deloitte, 2013b). A mix of indicators in an indexed fashion has also been employed by considering the impact and probability of an adverse event in relation to a specific variable (Stonebraker *et al.*, 2009). In other cases, market share, reputation, levels of trust, number of casualties or affected people or entities are also indicators of the impacts of adverse events, such as food scandals (Stanciu, 2015).

In developing a framework to assess fragility in value chains, it may therefore be useful to suggest a premise from where fragility is to be considered. Conversely, allowing for some freedom in defining the basis of fragility will possibly permit wider application of such a framework. In this thesis, as a generic point of reference, the concept of business continuity is suggested as the lens through which to view fragility. The ISO 22301 standard of 2012 is a generic business continuity management standard that describes business continuity as a position where a business's operations can continue and products and services are delivered at predefined levels, where brands and value-

creating activities are protected, and where the reputations and interests of key stakeholders are safeguarded whenever disruptive incidents occur (International Organization for Standardization, 2012). This point of reference provides a broad point of departure when fragility is considered in relation to adverse events in value chains and emphasises an evaluation of whether a particular value chain is able to sustain continuity or not.

4.3.3 What to measure

There is also a significant debate regarding whether risk, and consequently, fragility, should be approached quantitatively of qualitatively. A number of schools of thought exist on the topic (Khan & Burnes, 2007). A concise summary of the schools of thought are that risk can range between a "techno-scientific perspective, which sees risk as objective and measurable, to a social constructionist perspective, which sees it as being determined by the social, political and historical viewpoints" of stakeholders (Lupton, 1999). In essence, if risk and fragility are assumed to be objective and measureable, then a framework to measure them must consider variables that are objective. Such variables include actual turnover, margin, profit, costs, and frequency of events (assuming that the frequency of past events can predict the occurrence of future events). Alternatively, if risk or fragility is viewed subjectively, then a framework to measure them must consider variables that are subjective – like the perceived impact or probability of an event or the perceived ability to maintain business continuity.

In terms of making a decision about approaching risk and fragility, (Bernstein, 1996) questions the extent to which the past determines the future and how useful past events are in informing a framework for assessing risk and fragility. Although it is increasingly possible to use numbers to scrutinise what has happened in the past, the future cannot be quantified because it is unknown (Bernstein, 1996). Moreover, it is questionable to what extent there should be a reliance on patterns of the past to forecast the future. Bernstein (1996) questions whether the facts as they are seen, or subjective beliefs in what lies hidden in the future, carry more weight when considering risk and fragility and whether the dividing line between the two approaches can be accurately judged. Khan and Burnes (2007) emphasise the point of the on-going debate between those who see risk and fragility as objective and those who see it as subjective, noting that the

debate is most likely not resolvable. It is, however, important to be aware of the debate and the significant implications for how risk, uncertainty and fragility is seen and managed.

Bounded rationality is a further complication in attempting to produce a framework with which to evaluate fragility. Bounded rationality implies that although people may intend to make rational decisions, their capacity to evaluate accurately all possible decision alternatives is physically limited. This also applies when assessing risk, specifically, where people intend to make rational assessments of risk but their capacity to accurately assess its likelihood and all the possible outcomes and iterations is limited. This is compounded in the context of value chains where spillover effects in the extended chain are even more difficult to assess rationally. Bounded rationality is problematic in situations of complexity or uncertainty where the ability of people to make a fully rational decision is impeded (Hobbs, 1996).

4.3.4 The scope of measurement

The development of a metric to measure fragility presents significant challenges (Stonebraker *et al.*, 2009). Similar metrics or measures of sustainability (Callens & Tyteca, 1999; Figge & Hahn, 2004; Krajnc & Glavič, 2003; Veleva & Ellenbecker, 2000), robustness (Durach *et al.*, 2015) or resilience (Melnyk, 2014; Vecchi & Vallisi, 2015) of value chains are equally difficult to measure. Citing Stonebraker *et al.* (2009) some of "the difficulty results from the simultaneous interactivity of multiple variables measured in different units and by different methods for different periods and in different entities. Further, some measures are highly subjective".

On this basis, the following criteria are suggested as desirable characteristics for supply chain fragility measures (Stonebraker *et al.*, 2009):

- "Ability to compare the current state and progress of different agribusiness value chains against a benchmark, standard, target, or goal (Atkinson, 2000; Callens & Tyteca, 1999; Krajnc & Glavič, 2003; Labuschagne *et al.*, 2005);

- Use of cardinal scales of performance as an indicator of improvement over time against a target or benchmark (Spangenberg *et al.*, 2002);

- Ability to provide absolute measures, relative measures, and indexed measures for various applications (Figge & Hahn, 2004);

- Ability to facilitate reactive as well as proactive, and sequential as well as simultaneous, responses (Sawhney, 2006);

- Ability to support a comparative analysis to identify Pareto-like most critical efforts."

4.4 A METRIC OF FRAGILITY

Variables are not fragile when a linear payoff is observed in relation to a linear disturbance. When the impact of an adverse event remains proportional to the size of the shock, the specific variable is not considered to be fragile. However, when a concave payoff is observed in reaction to a disturbance and the payoff becomes disproportionately larger as the adverse event becomes larger, the variable is considered to be fragile (Figure 4-1 below). With particularly large types of events, the difference in harm between a linear and negatively convex payoff can escalate exponentially (Taleb, 2012).

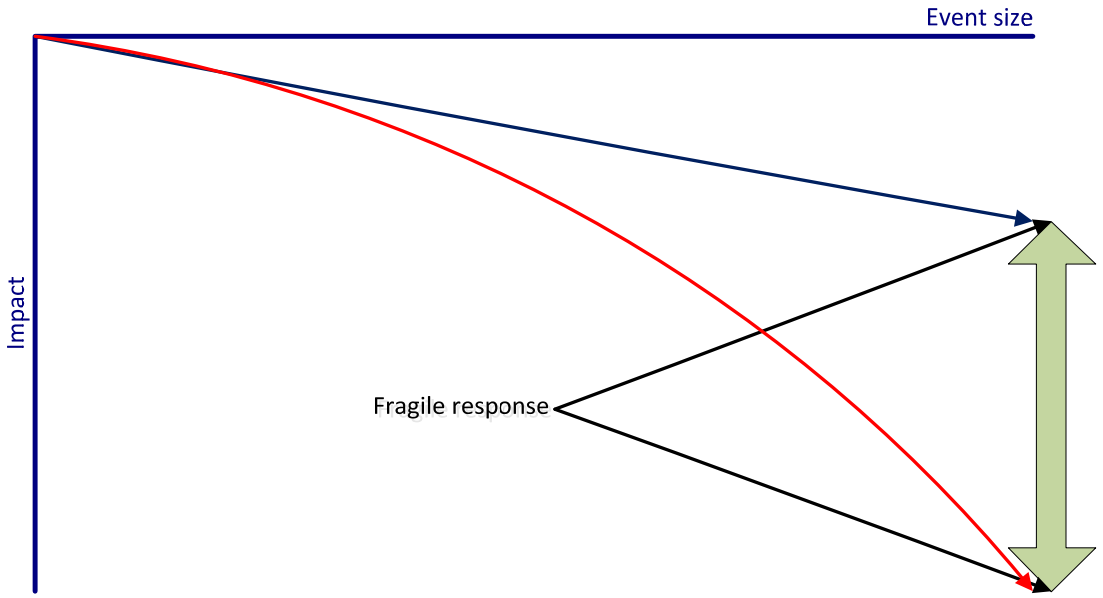

Figure 4-1: The harm of non-linear impacts

Source: Taleb (2012)

Such negative convexity effects are fairly recurrent in economic and financial settings and systems. These negative convexity effects typically develop as result of size and as a result of positive or reinforcing feedback effects resulting from complexity and interconnectedness (Taleb *et al.*, 2012). The relevance of negative convexity effects to agribusiness value chains is evident, given the complexity, interconnectedness and oftentimes the size of these chains, and the very notable accelerating effects that are frequently observed in instances of food scandals, product recalls, public fallouts, etc.

This section explores the detection of fragility, the development of a composite index of fragility, and the operationalisation of an all-encompassing fragility value to gauge value chain fragility.

4.4.1 Detecting fragility

Identifying fragility in variables has been approached in a number of ways. Using the "threat level" and "impact" of specific disturbances, Stonebraker *et al.* (2009) developed the "The Goldhar–Stonebraker Supply Chain Fragility Index Matrix". This approach, however, misses the point argued thus far and stays on the course of a typical

risk analysis by attempting to understand disturbances rather than the results of the disturbances. A simple point estimate from a conventional risk assessment does not give a sense of the potential for convexity effects and is effectively an estimate of a single or average shock (Taleb *et al.*, 2012) that does not capture the necessary nuances.

An alternative approach, using a heuristic or shortcut, attempts to assess the fragility of a system and not the particular event that will expose that fragility (Taleb *et al.*, 2012). The principle of applying a heuristic to detect fragility was suggested by Taleb *et al.* (2012) in the context of stress testing in the banking sector and involves:

> "averaging the model results over a range of shocks. When convexity effects are present, the average of the model results will not be equal to the model results of the average shock. The heuristic is a scalar that measures the extent of that deviation, and is calculated as F, where: f(α) is the profit or loss for a certain level α in the state variable concerned, or a general vector if we are concerned with higher dimensional cases (Equation 4-1 below).

Equation 4-1:

$$\boldsymbol{F} = \frac{f(\alpha+\Delta)+f(\alpha-\Delta)}{2} - f(\alpha)$$

where $F = \ Average\ shock - \ Average\ over\ a\ range\ of\ shocks$

> In this equation Δ is a change in α, a certain multiple of the mean deviation of the variable. The severity of the convexity expressed by F should be interpreted in relation to the total capital (for a bank stress test, or GDP for a sovereign debt stress debt), and can be scaled by it, allowing for comparability of results, and hence an ordinal ranking of fragilities, among similar types of institutions. When F=0 (or a small share of the total capital) the outcome is robust, in the sense that the payoff function is linear and the potential gain from a smaller (by the amount) x is equal to the potential loss from an equivalently sized larger x. When F <0, and significantly so with respect to capital, the outcome is fragile, in the sense that the additional losses with a small unfavourable shock (i.e., compared to a given tail outcome) will be much larger than the additional gains with a small favourable shock."

Therefore, volatility is bad in such a situation; i.e. we can say that an institution for which F is negative is "fragile" to higher volatility and particularly fragile to the specific event (Figure 4-2 below).

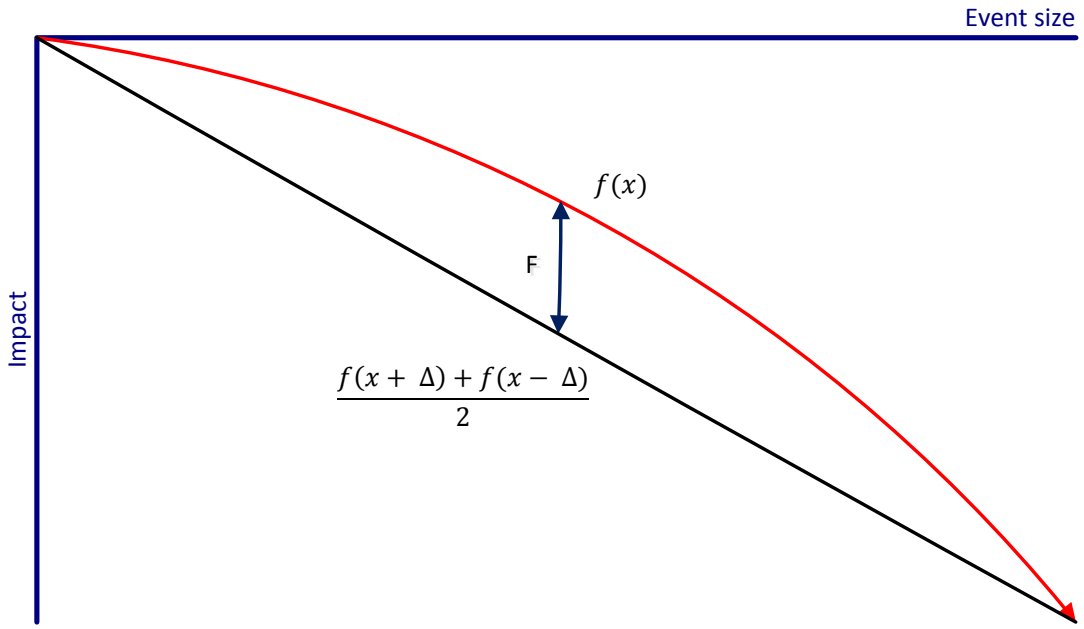

Figure 4-2: Detecting fragility

Source: Taleb (2012)

An equivalent approach is applied to the framework to measure value chain fragility. This approach is a variation of the basic heuristic proposed by Taleb *et al.* (2012) and Taleb and Douady (2013) to suit the illustrative and exploratory purposes of the exercise in this thesis. Practically, in the case of this specific analysis, this heuristic measures the difference in overall impact between an average shock and the average of a range of shocks per factor.

4.4.2 A composite index for chain players and a whole chain

The fragility tool, adapted as described above, provides a measure of the fragility of specific variables. It does, however, not yet provide for a single measure that encompasses all of the fragility variables identified for agribusiness value chains. The route to a complete value chain tool is to develop a composite index per chain player

and then a final score denoting "value chain fragility", comprised of all the composite indices of each value chain player in the chain being analysed. Examples of typical composite indices in supply chains include a composite sustainable supply chain performance index for the automobile industry (Gopal & Thakkar, 2014), benchmarking of green logistics performance with a composite index (Lau, 2011), and a collaboration index to a measure for supply chain collaboration (Simatupang & Sridharan, 2005).

Consequently, to arrive at single measure that combines the different dimensions of fragility into a single measure, a polygon is developed with the final sub-index values encompassing the overall fragility of the value chain in question according the approach by Gopal and Thakkar (2014). Employing this approach the fragility measure per chain stakeholder is determined on the basis of the area of the polygon. The point where the axes meet corresponds to a value of 0. The value corresponding to the edges of the polygon is 0.4461. The larger the area of the polygon is, the greater the fragility of the individual stakeholder under analysis is. The area of the polygon is calculated by dividing the total area of the polygon into triangles. Then, using the formula (0.5*a*b*sin(360/17)), the area of each separate triangle is calculated and summed to arrive at a total value for fragility.

The same procedure is then used to combine the individual fragility scores per chain player into a composite index that represents a measure of fragility for the whole chain. A graph is drawn with the each of the values of the links to analyse the overall fragility of the value chain in question. The value chain fragility measure is determined on the basis of the area of the polygon. The point where the axes meet corresponds to a value of 0. Similar to the approach earlier, the larger the area of the polygon is, the greater the fragility of the value chain under analysis is. The area of the polygon is also calculated by dividing the total area of the polygon into triangles. Then, using the formula (0.5 base*perpendicular height) area of each triangle is calculated and summed to arrive at the overall fragility score for the chain in question. Therefore, in summary, the process to arrive at a composite index of value chain fragility is achieved in three main steps as described below:

Step 1 – determine the fragility to each of the fragility factors for each player

Step 2 – combine each of the fragility outcomes per fragility factor into a composite index (represented by an area) of fragility for each chain player

Step 3 – combine each of the fragility outcomes per chain player into a composite index (represented by an area) of fragility for each chain.

In each of these instances, the composite index provides for a combined measure of a number of elements to form a product that is representative of the overall picture of fragility in a chain. While this approach is certainly not without shortcomings, the composite index does provide for a standardised approach and a useful statistical measure to gauge the overall fragility in a chain, having considered the elements that contribute to fragility.

4.5 MEASURING VALUE CHAIN FRAGILITY – A CASE STUDY

The tool to measure value chain fragility was operationalised in the South African lamb value chain to demonstrate its use in measuring fragility and to relate this measurement to the governance mechanism in the chains. The attraction of the lamb value chain for the specific analysis was, firstly, the perishability of the product and the accompanying fragility expected to be inherent to the chain and, secondly, the range of chain configurations prevalent in the sector which enabled a comparison between chain configurations.

The tool specifically provides the means to interrogate the conceptual framework of this thesis by connecting fragility to the coordination of the value chain and highlighting the trade-off between coordination intensity and fragility. Consequently, for the purposes of this illustration, the fragility was measured and modelled for two coordination configurations of a basic version of the South African lamb chain. The measures of fragility, in this instance, is particular to the specific chains and not generalisable to other chains because of the context specific characteristics of the case study.

4.5.1 Overview of the South African lamb value chain

The generic South African lamb value chain encompasses six main activities, from input provision to consumption. Key activities are input supply, production (may also include finishing in a feedlot), collation, value addition, retailing and consumption (Figure 4-3 below). A range of variations between the collating and retailing activities is possible, including a trading (wholesale), value addition (packing, processing) and a direct option.

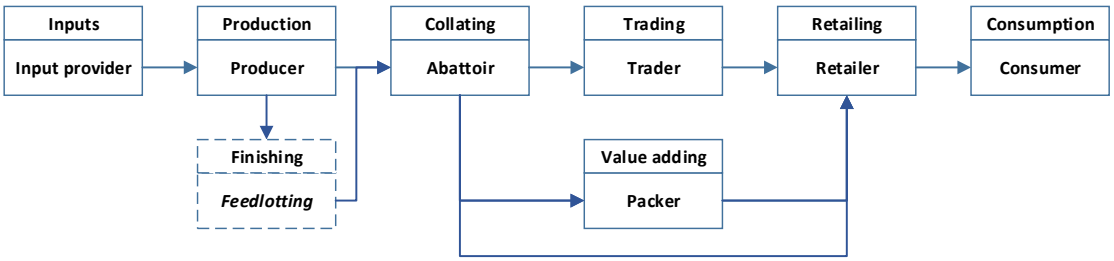

Figure 4-3: Basic South African lamb chain

Recent and extensive evaluation of the South African lamb value chain (Spies, 2011; Van der Merwe, 2013; Wilson, 2015) provides encompassing details of its extent, stakeholders, activities, coordination and governance, differentiation strategies, trends, etc. Consequently, and in the interest of conciseness, this thesis does not offer another broad narrative of the generic chain, apart from the basic details in relation to fragility and the coordination of the chain.

4.5.2 Overview of the Respondents and the specific chains

4.5.2.1 Respondents

The survey questionnaire was presented to 200 respondents in selected South African lamb chain configurations, after requesting their participation in the research. Overall, 77 responded to the request with completed questionnaires (response rate 38.5 %). In some instances, respondents marked more than one activity if there was a measure of vertical integration involved and consequently the overall responses per activity total to more than the number of respondents. In terms of the adequacy of the sample, the 77 responses provide for at least a 90 % confidence level and a 10 % confidence interval, considering a population of 8 000 sheep farmers, 247 registered sheep abattoirs, 18

meat packers and 2 975 registered meat outlets (n=11 240). Respondents were actors actively involved in the particular chains and they were spread across the typical lamb value chain, from producers through to retailers (Figure 4-4 below).

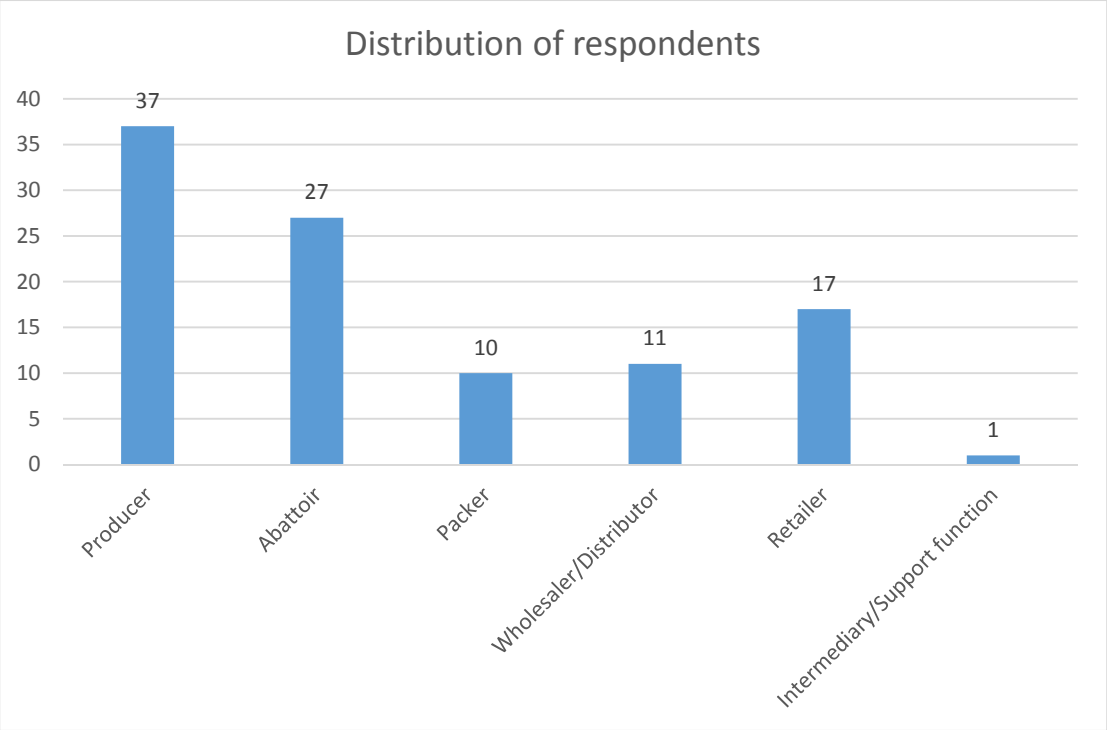

Figure 4-4: Distribution of respondents across the lamb value chain

A stratified and random sampling approach was employed to identify and source respondents for data collection. The different activities in the chain were the strata and within these strata, respondents were randomly selected sources.

4.5.2.2 Chain configurations

Two specific chain configurations were chosen to showcase the influence of the coordination interdependence regimen on the fragility of the chain. The specific chain actors included in the analysis were producers, abattoirs, packers and retailers (Figure 4-5 below).

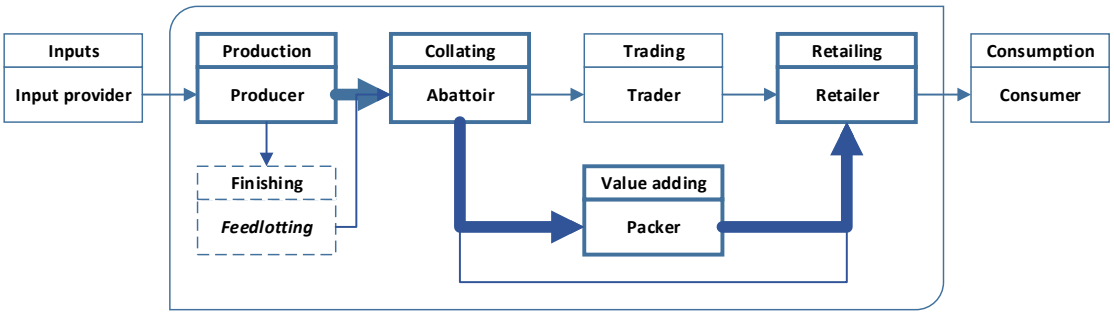

Figure 4-5: Configuration of South African lamb value chain for analysis

The specific configurations are:

- The first configuration is the commodity chain, characterised by low levels of interdependency and limited coordination intensity.
- The second chain configuration is the differentiated chain, characterised by high levels of interdependency and some degree of coordination intensity.

In the interest of concealing the identities of the specific chain stakeholders, the chain configurations were randomised and grouped based on the type and extent of interdependence and coordination intensity in the respective chains elicited from respondents. The type of interdependence was based on the classification of interdependencies discussed in Chapter 2 and the extent of interdependence on a five-point scale of interdependence ranging from independent to extremely interdependent. On this basis, chains were reconstructed to undertake the analysis.

4.5.3 Methodology and Data

The methodology to measure value chain fragility entailed presenting each of the 17 value chain fragility factors, as determined in Chapter 3, to all respondents. In the survey, respondent's reactions were elicited in response to a progressively worsening adverse event, in relation to the specific factor. Buyer reliability, as an additional factor, was added to the framework on the recommendation of some respondents. The extent of adverse events was worsened in 10 % increments from 10 % to 90 % and respondents were required to indicate the corresponding impact of the adverse event on business continuity in 10 equally sized incremental categories, ranging from 0 %–10 % to 90 %–100 % (see Annexure 2 for the questionnaire). This method is analogous to stress

testing in economic systems, including value chains (Amini *et al.*, 2012; Falasca *et al.*, 2008; Schmitt & Singh, 2009) which is, in essence, an analysis conducted under a range of adverse scenarios to determine whether the entity under scrutiny is able to withstand the impact of adverse events.

An overall measure of value chain fragility is achieved by determining sequential composite indices. A composite index of the fragility of each of the 17 factors characterises the overall fragility of the specific activities in the chain. Moreover, a further composite index of all of the fragility scores of each of the activities in the chain characterises the overall fragility of the specific chain in question.

Data was collected by way of a structured survey that was either emailed to respondents or completed in person. In a range of cases, the physical completion of the questionnaire was preferred above an electronic assessment of the questionnaire. Data processing was undertaken in Microsoft Excel and the @Risk add-in.

A further dimension of the analysis was to simulate value chain fragility using @Risk, a Monte Carlo simulation tool. The parameters from the survey of the South African lamb value chain, a triangular distribution, and 5000 iterations the fragility of the two different lamb value chain configurations (greater and lesser coordination intensity) were used to simulate a range of possible outcomes for the fragility of the respective chains. The specific purpose was to compare value chain fragility in the context of the different coordination regimes in the South African Lamb value chain.

The methodology culminates with a two-sample Student t Test which was used to test whether the average fragility of the two different lamb value chains, with different dependency regimes, are significantly different from each other. The null hypothesis for the exercise is that there is no statistically significant difference in the average chain fragility of the two different South African lamb chain configurations. By way of deduction, the alternative hypothesis is then that there is a statistically significant difference in the average chain fragility of the two different South African lamb chain configurations.

4.5.4 Results

4.5.4.1 Fragility of activities

The primary aim of this chapter is to showcase the framework to measure agribusiness value chain fragility and to explore the usefulness of the framework through a case study – in this case – selected chains in the broader South African lamb value chain. The results of the analysis provide an array of interesting and noteworthy outcomes of the mean (Figure 4-6 below) and maximum (Figure 4-7 below) fragility. Considering the results, it is evident that the framework is able to detect non-linear effects in response to progressively deteriorating parameters. These non-linear effects correspond to the fragility of the specific factor, which is ultimately an indication of the vulnerability of the factor in question to adverse events, specifically, to rare, high impact events (Table 4-1 below). Here negative scores indicate fragility (negative convexity effect) and positive scores anti-fragility (positive convexity effect).

Table 4-1: Major fragility factors and scores per chain player

Producers	Quality and safety performance (-10.46)
	Operational reliability (-8.43)
	Cash flow position (-8.41)
	Buyer reliability (-8.37)
Abattoirs	Quality and safety performance (-14.03)
	Cash flow position (-12.96)
	Quality and training of human resources (-9.10)
	Quality, adequacy of infrastructure (-8.30)
Packers	Cash flow position (-15.52)
	Regulations (-13.29)
	Supplier reliability (-13.20)
	Operational reliability (-12.64)
Retailers	Quality and safety performance (-15.81)
	Cash flow position (-12.40)
	Management information visibility (-10.20)
	Supplier relationship and alignment (-10.20)

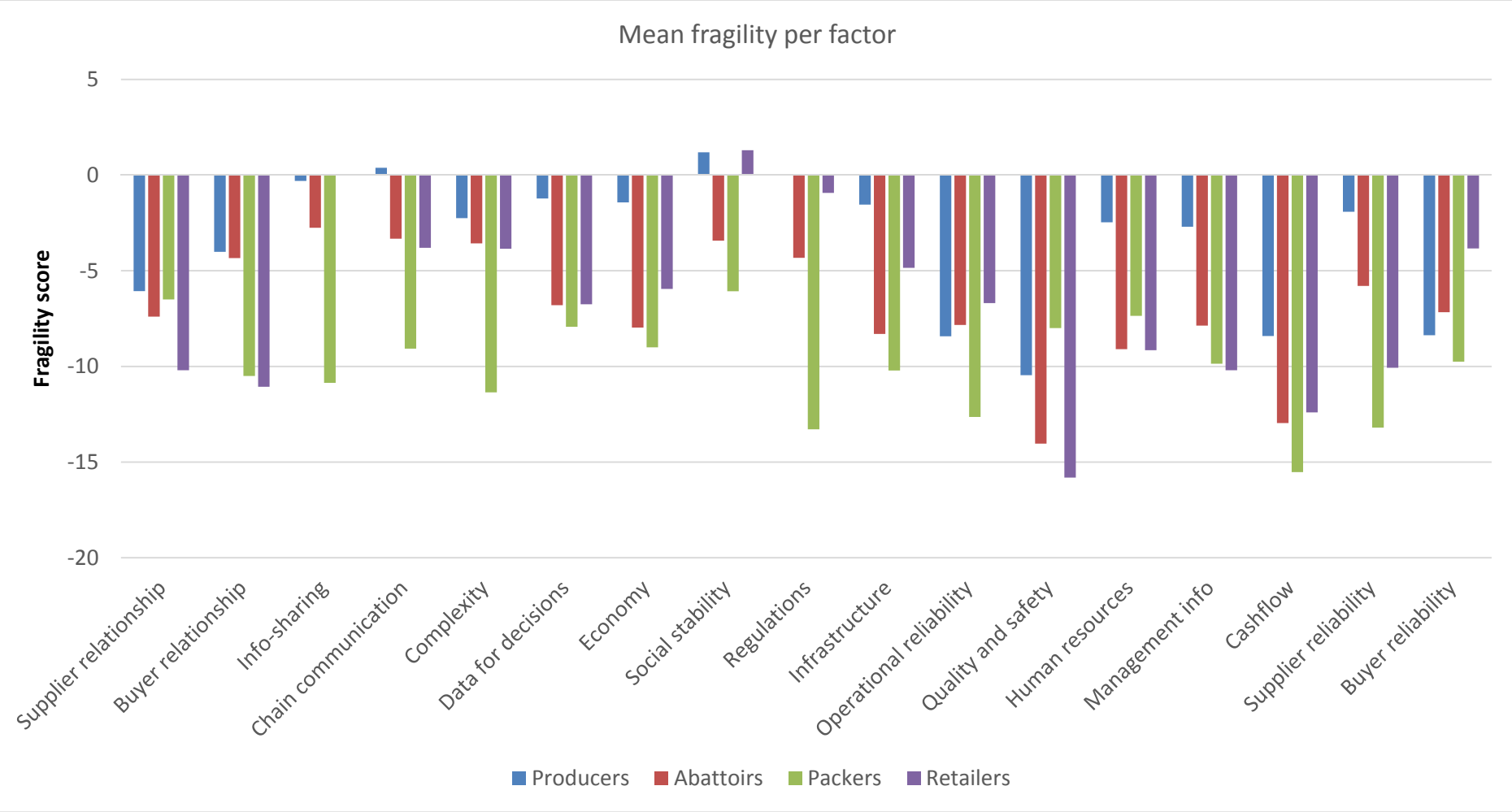

Figure 4-6: Mean fragility, per factor, in the typical South African lamb value chain

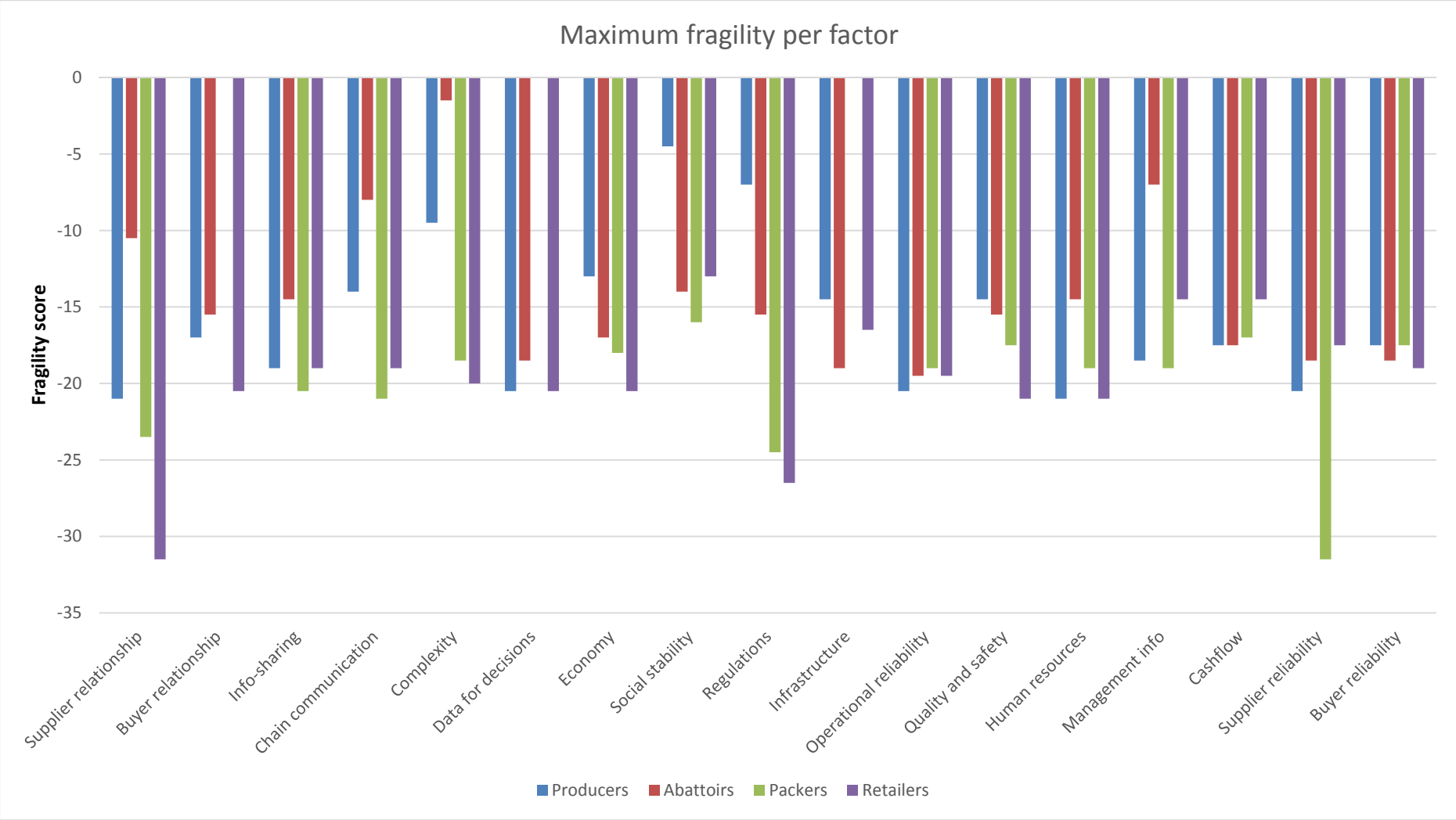

Figure 4-7: Maximum fragility, per factor, in the typical South African lamb value chain

Interestingly, there is some divergence and some convergence in the major fragility factors across the South African lamb value chain. It is specifically noteworthy that, for example, the quality and safety performance and the cash flow position of the specific actors rank very highly in terms of fragility across the chain and for most actors. Conversely, the nuances at the different levels in the chain are also evident with specific factors, unique to each activity, emerging as significant dimensions of fragility. Producers are uniquely fragile to buyer and operational reliability, abattoirs to the quality and training of human resources, and the quality and adequacy of infrastructure, packers to regulations and supplier reliability, and retailers to the management information and supplier relationship and alignment.

Considering the fragility of the respective actors in the South African lamb chain, is it equally noteworthy that while the actors differ in terms of the fragility to specific factors, the overall fragility score per actor is fairly similar (Figure 4-8 below). In the context of the South African lamb chain, this observation has a range of interesting implications. The first observation relates to the perennial discussion of which actor is more exposed to uncertainty. In this specific case, it is noteworthy that packers and retailers are exposed to relatively higher levels of fragility, as opposed to producers and abattoirs.

Figure 4-8: Fragility, per actor, in the typical South African lamb value chain

While there are nuances to the sources of fragility in the South African lamb chain, the order of overall magnitude of fragility is somewhat similar for most actors (Figure 4–9 below). Therefore, the second observation relates to the differences in the fragility factors per actor and the equal size of the overall fragility per actor. The implication is that large impact, rare events for one actor could foreseeably have a similar impact on another actor, and that such an event would not remotely be on the radar of the second actor. By way of example, given the other players' sequential interdependency with packers in the specific lamb value chain, a change in regulations and compliance requirements at the packer level could, conceivably, have dire spill-over effects for retailers, abattoirs and producers due the golden thread of exposure to quality and safety performance and cash flow uncertainty.

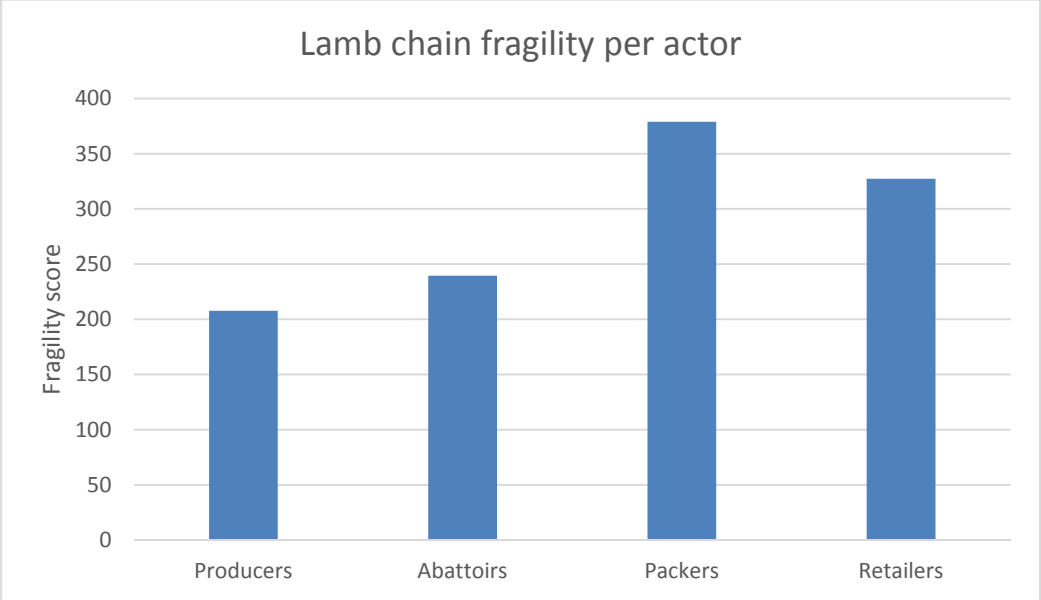

Figure 4-9: Overall fragility, per actor, in the typical South African lamb value chain

The differences in the fragility between actors in the chain also poses interesting questions. Why the fragility of packers is particularly higher than the fragility of other actors and why the fragility of producers is so low are two examples. This dissertation did not examine these observations in more detail because it would have required further analysis and consultation with the actors outside the scope of the dissertation. In the absence of a specific analysis it is ventured that the techo-economic characteristics of the actors and the activities and the nature of the interdependencies in the exchanges in the chain culminate in these nuances in fragility between actors.

4.5.4.2 Value chain fragility

The ultimate outcome of the fragility analysis is to arrive at metric for value chain fragility. As contemplated, the framework developed in this thesis provides a vector for fragility that stretches from the factor to the chain level. In the context of the specific value chain, the vector for the South African lamb value chain amounts to a nondescript value of 166 215, which corresponds to the area of the polygon (Figure 4-10 below), assembled from the fragility scores of the component parts of the particular chain.

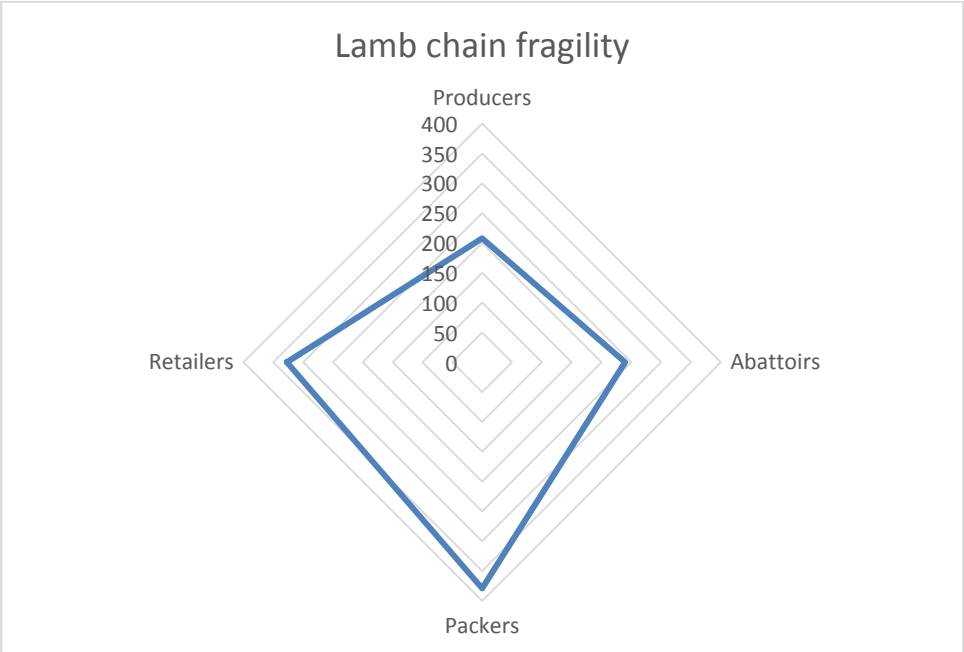

Figure 4-10: Fragility of the typical South African lamb value chain

While this single outcome of the framework with regard to value chain fragility does not generate an interesting value per se, it does showcase the process to arrive at a measure for fragility. Analogous to the approach used in stress testing and risk analysis, the fragility measure only really comes to fruition through comparative analyses of the same entity over time, or of different entities, players or factors at the same time. The next sections of this chapter explore the application of the measure of value chain fragility.

4.5.4.3 Comparing the fragility of chains

Comparing the fragility of different agribusiness value chains brings the development in this thesis of the framework to asses and measure such fragility to its natural conclusion. The analysis and comparison of two different value chain coordination regimes in the South African lamb chain reveals that the chain (Chain 2) characterised by greater levels of interdependency and coordination control is significantly more fragile, overall, than the general the South African lamb chain (Chain 1). Using the Student t-test to test for significant differences between the means of the fragility of the two chains, the t-stat of 30.48 is larger than the critical value of 2.58 at the 1 % significance level for 5000 iterations of the Monte Carlo simulation. The null hypothesis, of no significant difference in the mean fragility of the two chains, is therefore rejected. In the specific instance, the difference between the chains is linked to a range of differences at the factor and actor (Figure 4-11 below) levels which culminates in a 17 % greater overall chain fragility (Figure 4-12 below) of the chain, characterised by greater interdependency and coordination control. Interestingly, the higher fragility develops from greater fragility at the abattoir and packer level in the specific case.

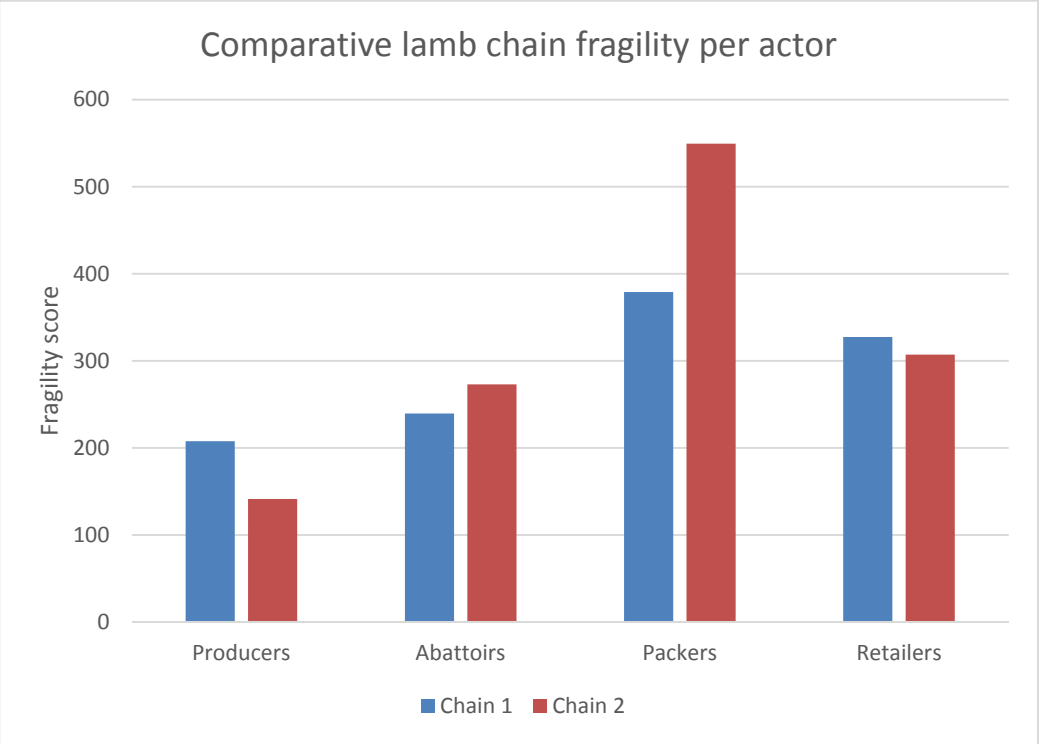

Figure 4-11: Comparison of fragility, per actor, for two typical South African lamb value chains

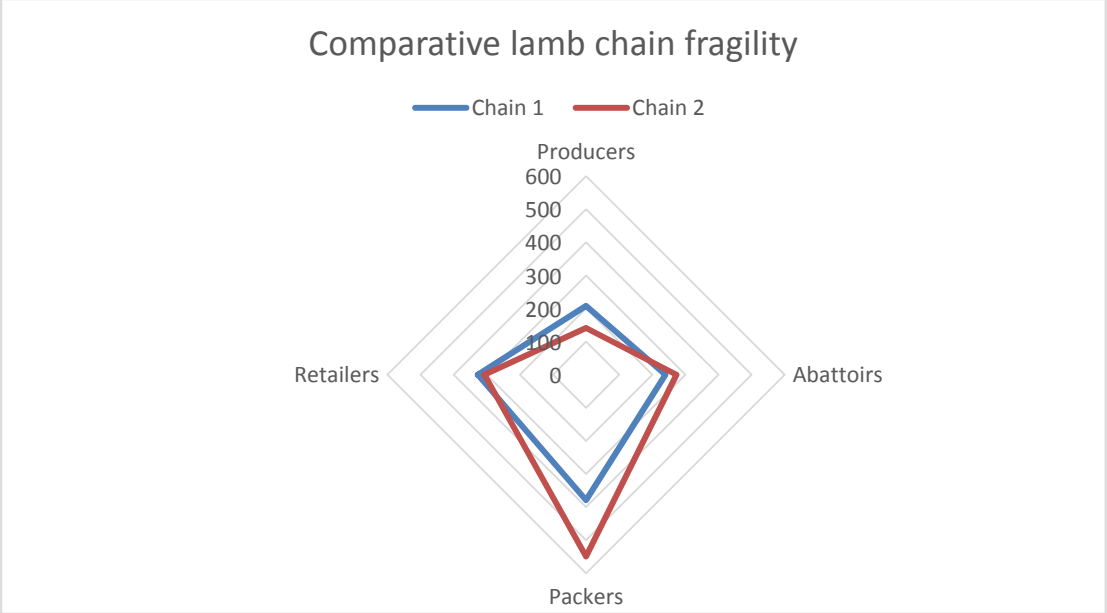

Figure 4-12: Overall chain fragility of two typical South African lamb value chains

4.6 DISCUSSION

The purpose of the analytical component of this chapter was to explore an approach to measure value chain fragility and to use this systematic approach to analyse the design and management of agribusiness value chains. The foray to measure fragility in agribusiness value chains materialised in the context of the South African lamb value chain, and stakeholders in this chain were required to consider specific dimensions of a range of value chain fragility factors in their specific context. The process entailed applying the fragility heuristic to individual factors, then combining these individual factors into composite indices to portray measures of fragility for individual stakeholders and eventually for chains.

4.6.1 Detection

The development of an operational framework to measure value chain fragility enables the detection of the presence and the extent of fragility at a range of levels in value chains, including for specific variables, stakeholders and chains. Considering the results of the South African lamb value chain case study, it is evident that the framework to measure value chain fragility is capable of detecting non-linear responses following progressive deterioration in the range of fragility factors.

Equivalent to the broad approach of a traditional risk analysis, the fragility analysis evidently accentuates fragility at the variable, stakeholder and chain level, which enables the pinpointing of specific causes of fragility at whichever level is of interest. Moreover, the measurement of fragility at these different levels of the chain enables comparisons between variables, stakeholders and chains. Such comparisons are useful for identifying and tracking the extent of fragility, on the one hand, and to craft strategies aimed at addressing fragility for specific factors, stakeholders and governance of chains, on the other.

A commentary is also made of the plausible need to explore the initial fragility factors in more depth, particularly the distinction between catalysts and causes of fragility. This distinction is a further layer in the fragility puzzle and Taleb (2012) specifically notes that catalysts are often confused for causes of fragility, focusing the attention on the catalyst rather than the cause. Considering extent and the nature of the range of fragility factors in the successive stages of the South African lamb chain, the relatively large but stable fragility of, for example, quality and safety performance, operational reliability, cash flow position, and human resources, raises the suspicion that these factors may well be catalysts rather than causes of fragility in the particular chains.

4.6.2 Measurement

The results of the analysis also point to the ability of the value chain fragility framework to attach a quantified value to the fragility of the component parts and the overall fragility in a chain. Whereas detecting fragility is an important first step, the quantification of fragility is an equally important and logical second step to the whole fragility approach to uncertainty and the exposure to it.

Self-evidently, the framework provides a similar type of outcome to a traditional risk analysis, albeit from a different point of departure, by classifying specific priority factors, actors, etc., based on the extent of their fragility. The ability to measure fragility therefore enables the prioritisation of factors for purposes of strategic decision-making at a range of levels in the chain. The key outcome, as in the case with traditional risk analysis, is for chain players and the chain as a whole to be cognisant of the hazard of

potentially devastating uncertainties and to reinvent and manage entities within the chain and the chain itself, mindful of the exposure to these uncertainties.

In the case of the South African lamb value chain, the overarching priority factors are evidently the quality and safety performance and the cash flow position in the chain, given these factors' high ranking fragility scores throughout. Thereafter, activity-specific nuances influence the priority factors for the respective activities in the chain, as determined by the unique attributes of the different activities. These very specific outcomes of the analysis point to the importance for the whole South African lamb chain to limit exposure to adverse events related quality and safety performance and cash flow position so as to manage the fragility of the overall chain. Specific stakeholders are equally tasked with managing exposure to activity-specific fragilities that could cascade into the rest of the chain due to sequential interdependencies in a typical chain.

4.6.3 Fragility and coordination

The pinnacle of the fragility analysis framework is the ability that the measurement of fragility provides for undertaking comparative analyses, with fragility as a centrepiece to the analysis. The results of the analysis conducted in the South African lamb value chain case study points to the link between growing coordination intensity (Peterson *et al.*, 2001) and growing fragility of the particular chain. This finding concurs with literature which notes, amongst other things, that increasingly lean strategies, brought about by increasing coordination, reduce costs and waste from supply chains, and also reduce a supply chain's resilience (Brede & de Vries, 2009; Maslaric *et al.*, 2013) and by abstraction, increase their fragility. This assertion is also aligned to Taleb (2012)'s thesis that the effects of high impact, improbable events "are inevitably increasing, as a result of complexity, interdependence between parts, globalization, and that beastly thing called 'efficiency' that makes people sail too close to the wind". The heart of the argument is that increasing fragility is due to the increasing vertical coordination intensity, and not that the coordination intensity is due to this fragility. The direction of the causal effect is argued by Gray and Boehlje (2005) who note the risk of vertical alignment in a chain context.

The measurement of value chain fragility in the South African lamb value chain case study accentuates the chemistry between fragility and the coordination of value chains, as posited in the conceptual framework of this thesis. The explosive increase in fragility, with an increase in coordination intensity, specifically highlights an underlying convexity effect in the particular lamb chains (Anderson, 1972). Given the results of the analysis, it is argued that increasing coordination intensity should not be desirable if at the expense of explosively increasing fragility. This point is confirmed by Taleb *et al.* (2012) who argue that "the central issue of the world today, (is) that of the misunderstanding of non-linear responses by those involved in creating 'efficiencies' and 'optimization' of systems … where many economic results are completely cancelled by convexity effects". The peril of convexity effects is accentuated by the property that the sum of the parts becomes increasingly different from the parts (Anderson, 1972).

Given that the coordination and alignment of interdependencies in a value chain are at the centre of the value creation process (Hobbs, 1996), it follows that a chain's coordination mechanism is pivotal to ensuring fit and proper coordination of the chain, with minimum potential for error (Peterson *et al.*, 2001; Wysocki *et al.*, 2003). Here, the error implies accelerating harm from convexity effects, because anything that is fragile is disproportionately harmed by an increase in uncertainty (Taleb, 2012) and will inevitably be broken by time. This specific finding is particularly captivating, considering the potential influence on the coordination and governance literature.

4.6.4 Shortcomings

The fragility heuristic to gauge value chain fragility discussed in this chapter is a shortcut to identifying and quantifying value chain fragility. Seeing that the measure is a shortcut, there is therefore significant scope to interrogate and refine the measure and the way in which it is calculated, constructed and interpreted in the context of value chains. The measure also does not model the pass-through effect where a shock is introduced at one end of the chain and then modelled through the chain, with a clear distinction between cause and effect and the nature of the interdependency between links. In theory, the relationship between overall chain fragility is a function of,

amongst other things, the fragility of the individual links and their differentiating features, and the nature of the links between chain players. This relationship between chain fragility and its components certainly warrants further exploration, but, without the tools to arrive at a measure of fragility, as developed in this chapter, such analyses have not been possible, to date.

A further challenge of the approach to measure fragility is that fragility, as a phenomenon, seems awkwardly counter-intuitive to average actors in the chains. It is therefore foreseeable that, from a practical perspective, measuring fragility will be cumbersome for as long as the concept remains unfamiliar and undeveloped in the risk and uncertainty discourse. There is, then, significant scope to popularise fragility as a phenomenon and to increasingly apply, in practice, the concept and tools related to detecting, measuring and, managing fragility as a complementary or alternative approach to the traditional risk and uncertainty discourse.

4.7 SUMMARY

The ability to measure fragility is essential to the domestication of fragility as a phenomenon in the uncertainty landscape. As repeatedly emphasised, it is vastly easier to determine how fragile (or anti-fragile) a complex system, like an agribusiness value chain, is rather than trying to predict the probability and impact that any of a range of events could have on the system (Aven, 2015; Taleb, 2012). The framework and approach detailed in this chapter specifically enables the detection of non-linearity and the quantification of the extent of the non-linearity at the factor, actor, and chain level in response to progressively deteriorating value chain fragility factors. This approach is akin to stress-testing (Amini *et al.*, 2012), albeit if for multiple factors and actors aligned in a chain of interdependencies. Ultimately, the framework to measure agribusiness value chain fragility provides an entirely alternative, and perhaps more appropriate and elegant, approach to the traditional value chain "risk assessment" (Jaffee *et al.*, 2008). The ability to measure value chain fragility is particularly valuable in a context where risk and uncertainty are more pervasive, consequential and unpredictable (Aven, 2015; Taleb, 2012), and the responsibility to defend chain durability is more pressing.

Considering the fragility results of the South African lamb chain case study, a number of specific conclusions are noteworthy. The first is that a number of very specific factors, like quality and safety performance, and cash flow position, have consistently high fragility scores, from the production level through to retailing. The second is that while a golden thread does, indeed, pass through the chain, a range of fragilities is also uniquely localised to a specific player or activity, which highlights the techno-economic (Dorward *et al.*, 2009) uniqueness of individual activities.

The comparison of chains with different interdependencies in the South African lamb chain affirms the hypothesis that increasing coordination intensity in chains, driven by traditional new institutional economic principles, may also be associated with increasing fragility of these chains. Considering the central conceptual framework of this thesis, the contention that there is an inescapable trade-off between chain efficiency and fragility is emphasized by the results of the analysis. The most significant implication of the results of the value chain measurement case study is that the traditional transaction costs economising model that promulgates the coordination of successive exchanges in value chains may, in fact, be contributing to chain fragility in the relentless and blinded quest to economise on the costs of exchange. The result of the analysis is, however, aligned to some literature that questions the risk of increasing vertical coordination (Gray & Boehlje, 2005) where the "development of more tightly aligned chains creates new and less quantifiable risks" in the chain. Equally, a similar argument is made that notions, such as speed and growth of systems, as associated with increasing coordination, are meaningless when presented without accounting for fragility. The point is that under path dependence, growth in the efficiency or coordination of systems, like value chains, cannot be divorced from the hazard of a calamity as a result of these strategies. More pertinently, as Taleb (2012) notes, "if something is fragile, its risk of breaking makes anything you do to improve it or make it 'efficient' inconsequential unless you first reduce that risk of breaking". Publilius Syrus aptly noted that "Nothing can be done both hastily and prudently". Chapter 5 builds from the theoretical constructs related to value chain coordination and from the results of the analysis of Chapter 4 to propose an augmented approach to coordinating agribusiness value chains, while being cognisant of fragility and chain performance pressures.

CHAPTER 5
VALUE CHAIN FRAGILITY AND COORDINATION STRATEGIES

5.1 INTRODUCTION

The network of activities that characterise the global agricultural value chain has evolved into an integrated system of chains from production through the stages of value addition to the final consumption of products. The integrated nature of the system implies a more onerous coordination of the system to be able to capture the benefits and management of the new uncertainties that accompany an integrated system. The success of the system inevitably depends on how successful the coordination of the system is. The essential principle of this notion is emphasised by Peterson *et al.* (2001) who note the complementary nature of a value chain. It is specifically noted by Peterson *et al.* (2001) that "complementarity exists when the combining of individual activities across a transaction interface yields an output larger than the sum of outputs generated by individual activities. The phenomenon is also described non-separability and Alchian and Demsetz (1972) use the example of two men lifting heavy cargo onto a truck. If the cargo is of sufficient weight that both men are needed to do the lifting, then the output of the two working together is far superior to the output of the sum of the two men working alone".

The purpose of this chapter is to explore the new dimensions that value chain fragility, as described, analysed and concluded in Chapters 3 and 4, adds to the theoretical constructs of agribusiness value chain coordination. The chapter also explores the implication of the proposed theoretical alterations on value chain design and coordination in the pursuit of resilient or event anti-fragile value chains. The chapter argues the case, like Wever *et al.* (2012), for the need to explore risk, uncertainty and the coordination of value chains beyond the classical framework that pursues the reduction of transaction costs in exchanges, at all costs. As a result, the chapter explores the interaction between human capacity and frailties in decision-making and the interplay with fragility to inform a new paradigm for the coordination question.

5.2 THEORETICAL FOUNDATIONS OF THE COORDINATION QUESTION

Some form of coordination is inevitable in all production processes (Hobbs, 1996) and the examination of coordination in a value chain context is integral to the study of value chains (Dorward & Omamo, 2009). At the heart of the coordination are incentives to form coordinated business relationships and understanding why these relationships arise is the basis of New Institutional Economics (Hobbs, 1996). The father of New Institutional Economics (Coase, 1937) argued that "in order to understand what a firm does, one must first understand why a firm exists and, therefore, what forces govern the organization of economic activity" – a concept that is extended to value chains and the justification of their existence.

5.2.1 The Transaction Cost Economics Approach

Transaction Cost Economics (TCE), the foundational model that explains the governance of contractual relations, is based on the nature and extent of transaction costs (Riordan & Williamson, 1985; Williamson, 1985). The theory is that the governance of exchange transactions adapts to changes in transaction costs arising from the exchange of a product to ensure efficiency in the exchange. The specific notion by Riordan and Williamson (1985) is that "TCE regards the transaction as the basic unit of analysis and holds that the organization of economic activity is largely to be understood in transaction cost economizing terms. Such economies are realized by aligning governance structures (of which firms and markets are the leading types) with the attributes of transactions in a discriminating way". The classical model posits that the nature and extent of transaction costs are driven by the frequency of transactions, behavioural uncertainty and the investment in specific assets (and the associated transaction costs) (Williamson, 1985).

This practically reduces to an interaction between the objective function, the nature and extent of transaction costs, and the coordination of an exchange (Figure 5-1 below). Assuming a fixed objective function, as will be discussed, the interaction is then reduced to a balancing act between transaction costs and the corresponding coordination mechanism to achieve the objective function (Hobbs, 1996; Peterson *et*

al., 2001). Each of these elements (objective function, transaction costs and coordination) in the transaction triangle are discussed in the sections that follow to position the principles of fragility in relation to the strategies that are required to address the particular fragility.

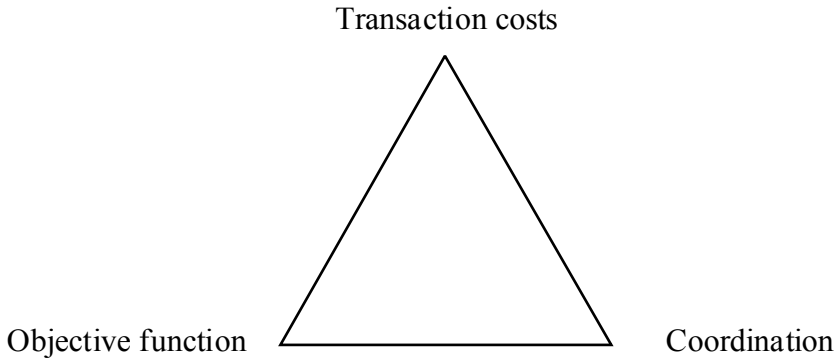

Figure 5-1: The transaction triangle

In the interest of "getting the governance structures right" (Cook & Chaddad, 2000), a stream of literature in the agribusiness value chain coordination domain has been developed using the TCE approach. Examples include Sporleder (1992), Zylbersztajn and Goldberg (1996), Hobbs (1996), Gow and Swinnen (1998), Cook and Chaddad (2000), Wysocki *et al.* (2003), Pingali *et al.* (2005), Ménard and Valceschini (2005), Banterle and Stranieri (2008), Wever *et al.* (2010), Trienekens (2011), Hess *et al.* (2013) and Bensemann and Shadbolt (2015).

5.2.2 Transaction Costs

A simplified model (Figure 5-2 below) reduces the investment in specific assets to an element of behavioural uncertainty because the transaction costs associated with asset specificity are argued to be a function of behavioural uncertainty. The frequency and uncertainty attributes of a transaction therefore determine the nature and extent of the transaction costs associated with the transaction, which in turn drives the coordination mechanism which aims to economise on the transaction costs.

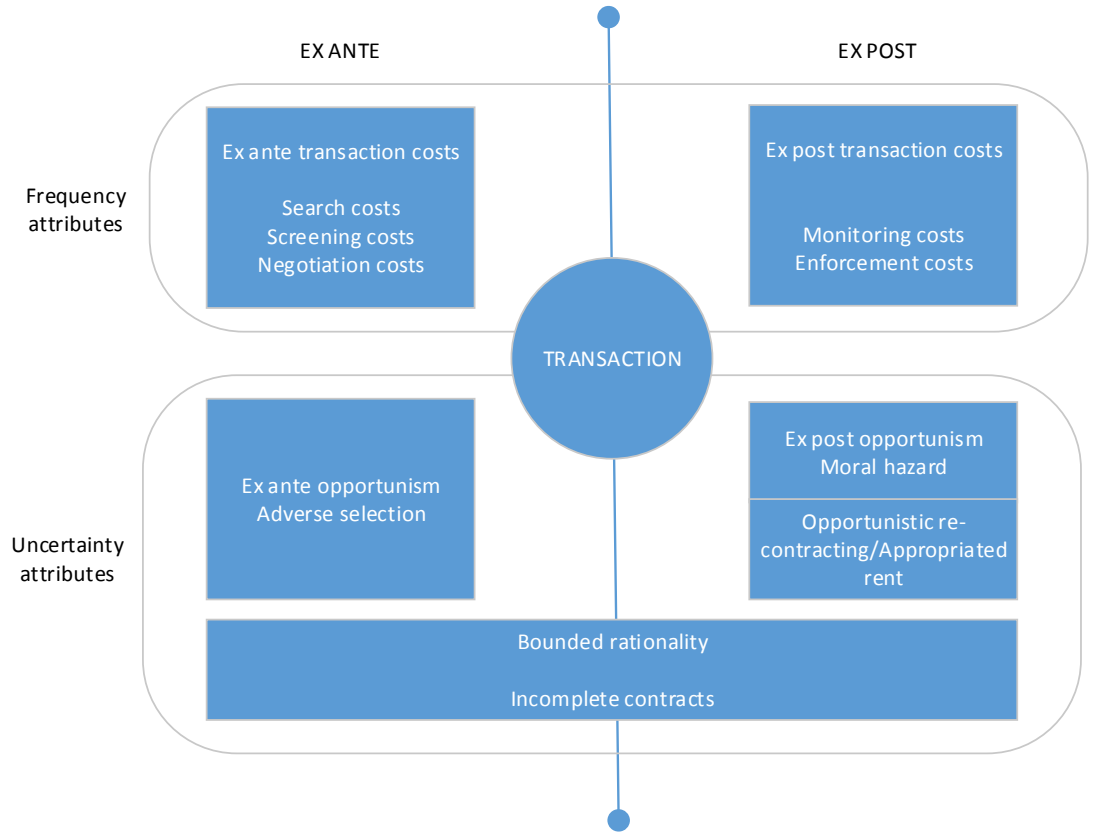

Figure 5-2: Basic transaction cost model

Source: Adapted from Williamson (1985) and Peterson *et al.* (2001)

Considering the basic transaction cost model, transaction costs are generated in two possible ways. The first source is linked to the frequency of the transactions, which are the extent of the actual transaction cost or the volume of the transaction to which transaction costs are tied, or both. Self-evidently, the greater the extent of a specific transaction cost is the higher the transaction costs will become and, likewise, the more the transactions to which transaction costs are tied are conducted between parties, the higher the transaction costs will become, *ceteris paribus*. The second source is linked to the costs associated with safeguarding the transactions against the hazards of opportunism (behavioural uncertainty), given bounded rationality and incomplete contracts. Similarly, the total transaction costs are determined by the extent and the frequency of the costs required to guard against behavioural uncertainty in transactions.

Some authors (Peterson *et al.*, 2001; Rindfleisch & Heide, 1997; Wever *et al.*, 2012) have extended the basic model to identify not only direct transaction costs but also

opportunity costs within the transaction cost economic framework. This extension of the basic transaction cost model affirms that the costs of transacting are not limited to the direct transaction costs, but also include the opportunity costs of the transaction. This extended range of transaction costs is succinctly described by (Peterson *et al.*, 2001), who note these direct and direct costs as the cost of coordination errors.

5.2.3 The Objective Function

The objective of the TCE approach is for actors to economise on the sum of production and transaction costs (Williamson, 1975). This objective is reaffirmed by Williamson (2000) who notes that "to the degree production-cost economies of external procurement are small and/or the transaction costs associated with external procurement are great, alternative supply arrangements deserve serious consideration. Further work in this regard reiterates the objective as being economic efficiency with economic efficiency meaning that parties to a transaction should strive to minimize the costs of the transaction" (Williamson, 2000), to the extent that value (presumably profit) is maximised for both parties. The narrative in this approach is that profit is maximised by economising ("spend less; reduce one's expenses") on production and transaction costs. In the TCE approach, isolating the transaction costs, with revenue and production costs remaining unchanged, implies that profit is maximised when transaction costs are minimised (Equation 5-1). This approach is evident in the analysis of a range of agriculture- and food-based value chains (Dries *et al.*, 2004; Jia & Bijman, 2014; Ketchen & Hult, 2007; Martinez, 2002; Rindfleisch & Heide, 1997; Wever *et al.*, 2012).

Equation 5-1: $$Max \sum_{t=0}^{\infty} \pi_t = Max\ (Revenue_t - (PC_t + TC_t))$$

In the equation Π denotes profit, PC production costs and TC transaction costs over the period t. This approach assumes that stakeholders' objective is maximised profitability, which is achieved through whichever governance structure maximises the "net value of production and transaction costs". Theories on economising behaviour of rational actors also justify this approach on the basis that there is a preference for options that offer the

greatest benefit for the least cost – which roughly equates to a profit maximisation motive.

5.2.4 Coordination

In the value chain context there is, inevitably, some or other harmonisation of the sequential activities required to produce and market a product or service (Hobbs, 1996). The costs of this harmonisation, being the transaction costs of the exchange, are important because they drive the organisation of economic activities ranging from once-off transactions to extended value chains. The mechanism through which the harmonisation of these sequential activities occurs is also known as the "vertical coordination mechanism", "governance structure" or "coordination structure" and it is central to the study of value chains (Hobbs, 1996). The objective function in harmonising exchanges, like the sequential activities in a value chain, is to economise on the costs of the exchanges in the chain. Economising is achieved through the choice of a coordination structure that uniquely ensures that "costly coordination errors" do not occur, and are averted through a range of controls and operational costs (Peterson *et al.*, 2001).

In establishing New Institutional Economics and the role of transaction costs Coase (1937) introduced the market (external) and the firm (internal) as two coordination structures through which transaction costs can be economised. Further work (Williamson, 1979) expanded the coordination options to the market (external), the hierarchy (internal) and the hybrid (a blend of the market and the hierarchy). Later work posited the view that coordination structures are effectively aligned in a coordination continuum (Peterson *et al.*, 2001) with no less than five mainstream coordination structures, ranging from the market to a firm, with a blend of nuanced variations (Ménard, 2004) between these two extremes of the coordination spectrum. Ultimately, the range of coordination options has evolved into a veritable continuum of coordination ranging from low levels of control intensity through the market to intense levels of control intensity through vertical integration (Peterson *et al.*, 2001). How suitable the coordination of the chain is inevitably influences how successful a value chain is at achieving its purpose (Boehlje *et al.*, 1998; Champion & Fearne, 2001). The

coordination of value chains is evaluated on the basis of whether the current coordination mechanism of a specific value chain is costly to sustainable value creation, or not. Following this reasoning, (Peterson *et al.*, 2001) note that "a coordination strategy may be too costly for one of two reasons. First, it allows costly coordination errors to occur. For example, it regularly exposes the firm to the opportunism of trading partners or it results in chronic over or under production in relation to demand. Second, the coordination mechanism creates more operating cost than the cost reduction in coordination errors it is designed to control."

Considering the three elements (transaction costs, the objective function and the coordination mechanism) in the Transaction Costs Economics framework, the design and management of the coordination mechanism is the magic potion for achieving the objective function, given the transaction costs inherent in an exchange. In terms of the founding principles of TCE, (Williamson, 1979) affirms this position and points out that governance structures, or coordination mechanisms, are part of the optimisation problem in exchanges. Evidently, the coordination mechanism remains the key managerial tool in organising sequential transactions, as it is required in value chains, effectively and efficiently. The pertinence of the coordination question in agribusiness value chain is noted in the context of the increasing variety of vertical coordination strategies available to agri-food firms and in how firms decide which strategy to use in which vertical transactions (Peterson *et al.*, 2001).

5.3 INCREASING VERTICAL COORDINATION IN A COMPLEX AND UNCERTAIN LANDSCAPE

Globally, value chains are increasingly characterised by coordinated or integrated exchange (Deloitte, 2013b). This trend towards increasing coordination or integration is advanced by "a number of internal and external forces that are converging to raise the risk wager for global supply chains. Some are macro trends such as globalization and global connectivity, which are making supply chains more complex and amplifying the impact of any problems that may arise. Others stem from the never-ending push to improve efficiency and reduce operating costs. Although trends such as lean manufacturing, just-in-time inventory, reduced product lifecycles, outsourcing, and

supplier consolidation have yielded compelling business benefits, they have also introduced new kinds of supply chain risk and reduced the margin for error" (Deloitte, 2013b).

This trend towards increasing coordination is also observable in agricultural- and food-based value chains (Jie *et al.*, 2015; Lee *et al.*, 2012). Due to the increasingly complex and uncertain environment within which value chains are required to operate, and the value that these chain have to deliver to investors and consumers, there has been a propensity for the governance of value chains to be increasingly coordinated or integrated (Abbots & Coles, 2013; Jaud *et al.*, 2013). This trend is driven by the need to economise on "coordination errors" (Peterson *et al.*, 2001) and the search for efficacy and efficiency (Talluri *et al.*, 1999) in a landscape where companies and chains compete (Jia & Bijman, 2014).

Considering the primary factors of uncertainty, asset specificity and frequency that drive the vertical coordination strategy in the TCE model, it is evident that these factors are advancing the narrative of increasingly coordinated value chains in a landscape that is progressively uncertain and complex, all at once. Allowing for each of these factors individually, the argument is affirmed. Firstly, conventional wisdom, based on the foundations of transaction costs economics, is that the escalating transaction costs associated with growing uncertainty in an exchange can be economised upon through greater control or coordination of the exchange (Hobbs & Young, 1999; Maples *et al.*, 2016; Stuckey & White, 1993; Swinnen, 2007; Swinnen & Maertens, 2007). Practically, Hobbs (1996), highlights the point that low-level uncertainty is conducive to coordination through spot market transactions. When aspects of the transaction (such as quality characteristics) are highly uncertain, a more formal type of vertical coordination – where one party has more control over the outcome of the transaction – is required. These options may include a strategic alliance, a contract, or some form of vertical integration (Hobbs, 1996). Evidence of the thesis concerning chemistry between uncertainty and the increased coordination is evident in pork value chains (Kliebenstein & Lawrence, 1995), and poultry and egg value chains (Martinez, 2002).

Secondly, goods which are non-specific in nature, or produced with non-specific assets, have many alternative uses and their exchange tends to be coordinated through market exchange. However, as asset specificity increases, the coordination of vertical exchanges tends towards increasing vertical integration, depending on the nature and extent of the asset specificity (Hobbs, 1996). Confirmation of the link between increasing asset specificity and increasingly coordinated vertical coordination is evident from food quality and safety measures (Gereffi & Lee, 2009), origin-based products (Barjolle & Sylvander, 2002; Skilton & Wu, 2013; Vlachos, 2014) and differentiated products (Trienekens & Wognum, 2013).

Thirdly, increasing vertical integration to manage the extent or "frequency" of the "costs and risks" of behavioural uncertainty and asset specificity (Abbots & Coles, 2013; Vetter & Karantininis, 2002) and the frequency of monitoring and enforcement costs (Fearne, 1998; Hennessy *et al.*, 2003) is equally evident. In further support of this argument, the founding treatise of TCE presented by Williamson (1979) suggests that economising on transaction costs essentially reduces to economising on bounded rationality, while simultaneously safeguarding the transactions in question against the hazards of opportunism. Increasing vertical coordination essentially allows for economisation on the transaction costs through internalisation in the hierarchy (Williamson, 1979).

5.4 FRAGILITY IN VALUE CHAINS

Principally, in the quest for leaner and more agile value chains, businesses have pursued strategies that reduce operations down to core activities, cut costs and reduce waste in every chain processes to achieve efficient chains that produce just what and how much is needed, when it is needed, and where it is needed (Maslaric *et al.*, 2013). It is noted that "as chains have become more interconnected and global, they have also become more vulnerable, with more potential points of failure and less margin of error for absorbing delays and disruptions" (Deloitte, 2013b).

After sustained emphasis on leanness and responsiveness, chains are now experiencing their vulnerability to chain disturbances as a result of the leanness and responsiveness

(Vlajic *et al.*, 2012). The development of more intensely coordinated and aligned chains is "creating new and less easily quantifiable risks" for the participants in the supply chain (Gray & Boehlje, 2005). These risks are akin to the risks in the fourth quadrant of the risk landscape proposed by Taleb (2009b) that have complex pay-offs and fat-tailed or intermediate distributions. As a result of the complexity and interconnectedness of chains, uncertainty becomes notoriously difficult to manage and the vulnerability of these chains to a range of disturbances multiplies in relation to the degrees of complexity or interdependency, or both. This vulnerability is essentially fragility, implying the possibility of accelerating impact as a result of the complexity and interconnectedness brought about by the interdependencies that characterise the increased coordination of exchanges. The relevance of the phenomenon is confirmed by Diabat *et al.* (2012) who note that "the vulnerability of a chain increases with increasing uncertainty, and increases even further if companies, by outsourcing, have become dependent on other organizations". The point is acknowledged by Christopher and Lee (2004) who note that "the greater uncertainties in supply and demand, increasing globalization of the market, shorter and shorter product and technology life cycles, and the increased use of manufacturing, distribution and logistics partners resulting in complex international supply network relationships have led to increased exposure to risks in the chain".

Therefore, notwithstanding conventional wisdom and the tools that are available to guide the management of the governance of value chains, there is generous evidence that coordination difficulties still plague value chains (Wagner & Bode, 2006). This is evident from the vulnerability of chains (Carvalho *et al.*, 2014; Williams-Grut, 2015), the underperformance of chains (Piramuthu *et al.*, 2013; Souza-Monteiro & Hooker, 2013) and the losses in shareholder value (Hendricks and Singhal, 2005). The emergence of these coordination errors and their impacts point to the vulnerability of value chains, in spite of the tools that are available to manage the coordination of chains. In this context, chain vulnerability is defined as exposure to a harmful or serious disturbance or stressor, arising from risks within and external to the chain (Christopher *et al.*, 2002). Fragility extends the concept of vulnerability and is defined as an accelerating vulnerability to a harmful stressor (Taleb *et al.*, 2012). The vulnerability or the fragility of value chains (Christopher *et al.*, 2002; Liu *et al.*, 2015; Peck, 2005;

Wagner & Bode, 2006) and the contrasting antonyms, resilience (Leat & Revoredo-Giha, 2013; Melnyk, 2014; Scholten *et al.*, 2014; Vecchi & Vallisi, 2015; Waters, 2011) and robustness (An & Ouyang, 2016; Durach *et al.*, 2015; Vlajic *et al.*, 2010; Vlajic *et al.*, 2012) have, therefore, become increasingly topical themes in value chain research. Therefore, given the substantial and growing vulnerability of value chains to disruptions, measuring and managing supply chain vulnerability or fragility has become indispensable in achieving supply chain goals (Wagner & Neshat, 2012).

5.5 A TRADE-OFF BETWEEN LEANNESS AND FRAGILITY

The lean value chain ideology has steered value chains and their management to new extremes. A "zero stock" strategy, as an example of intense cost reductions and integrated chain management, is consistently associated with elevated vulnerability to delays and disruptions in the chain. The practical implication is that a lean strategy reduces costs and waste in the chain, but also multiplies the chain's fragility (Maslaric *et al.*, 2013). The strategic imperative for enterprises and their value chains is therefore to find the appropriate coordination strategy which balances the performance (output and cost effectiveness) of value chains with the fragility of these chains. Conceptually, it is therefore clear that there is a trade-off (Figure 5-3 below) between chain performance and chain fragility (Vahid Nooraie & Parast, 2016).

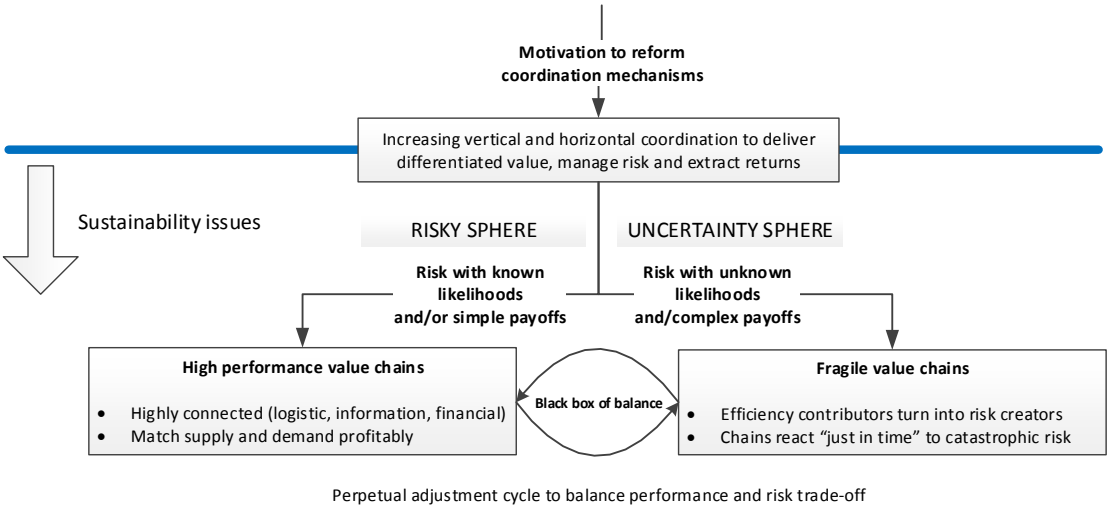

Figure 5-3: Conceptual framework of vertical coordination and fragility

The trade-off between efficiency and resilience is specifically noted in literature (Brede & de Vries, 2009) where the point that "very efficient networks are not resilient while very resilient networks lack in efficiency" is highlighted. The argument is that both "efficiency and resilience are important requirements for network design" (Brede & de Vries, 2009). The importance of this trade-off is therefore equally important to the coordination of value chains – implying that there is a balance between efficiency and fragility and that a happy medium between these must be found, rather than maximising the one or the other at the expense of the one or the other.

Considering this trade-off between efficiency and vulnerability, there is a compelling need to rethink the TCE approach as it has generally been applied in agribusiness research and to guide the coordination question in value chains to provide for a new approach. A new approach would allow for the capturing of the influence of fragility and efficiency in the design and management of value chains. This position is highlighted by Maslaric *et al.* (2013) who note the need to appreciate the trade-off between efficiency and vulnerability, and the need balance lean and resilient approaches. Insofar as the argument for the trade-off is palatable, Taleb (2012) argues that anything that is even remotely fragile will eventually be broken. The trade-off alone may therefore be insufficient and consideration of the path dependent route of surviving before thriving deserves further interrogation.

5.6 HUMAN FACTORS AND DEALING WITH LEAN VERSUS FRAGILE SETTINGS

It is suggested that humans' economising behaviour lies at the heart of fragility (Taleb, 2012). Economising behaviour is seen in choosing a course of action that pursues the passage of perceived maximum benefit, and individuals choose purposefully to get the most from their limited resources. It is, in fact, through the economising behaviour of individuals that the "catallactic" order emerges (Hayek, 1945). The argument is that this order is achieved, not intentionally, but though the purposeful behaviour of many interacting individuals in a system, each pursuing his own particular goals (Hayek, 1945) with an economising mind-set. Agency and prospect theory provide some insights of the human factors that drive typical human economising behaviour. The

ensuing sections briefly explore each of these theories to provide context to the causes of fragility and as a precursor to exploring the development of anti-fragile chains.

5.6.1 Agency problems

The well-known principal–agent problem can emerge when a person or entity (the "agent") is able to make decisions on behalf of, or that impact on, another person or entity – the "principal" (Eisenhardt, 1989). A specific predicament develops when the agent is incentivised to act only in his own best interests and contrary to the interests of the principal. The principal–agent problem is also evident in the value chain management domain because managers could develop divergent and often juxtaposed goals in relation to shareholders whose chains such managers manage (Tosi & Gomez-Mejia, 1989).

The extent and nature of executives' compensation is explored by Frydman and Jenter (2010). Managers' goals are determined by salaries that are payed in fixed cash amounts, made evenly across a period of time. Sometimes these salaries are supplemented with annual bonuses, as additional payments, as reward for exceeding predetermined targets. Managers may also be rewarded though stock options and restricted stock. Typically, manager's short-term incentives are driven by bonuses for achieving performance objectives. Long-term incentives may be added to manager's remuneration mix to encourage the long-term investments that increase value for shareholders. Stock options are a favoured instrument to focus managers' attention on longer-term goals. Stock options encourage managers to increase the value of the stock price, to invest in "risky" positive Net Present Value projects, and they allow for deferred realisation of the value that they accrue for themselves. Conversely, incentivising managers through stock options means that managers' rewards can be unpredictable in a volatile market and it might encourage disproportionate risk-taking to increase value. Options encourage investment in higher-risk/reward projects which incentivises executives to invest in research and development, capital expenditure and acquisitions. In turn shareholder returns are more extreme (positive and negative).

In the context of value chain fragility, the principal–agent dilemma suggests that managers that are not appropriately incentivised are inclined to self-interest seeking behaviour. The issue is highlighted by Dobbin and Jung (2010) who note that:

> "agency theorists' diagnosed the economic malaise of the 1970s as the result of executive obsession with corporate stability over profitability. Management swallowed many of the pills agency theorists prescribed to increase entrepreneurialism and risk-taking; stock options, de-diversification, debt financing, and outsider board members. Management did not swallow the pills prescribed to moderate risk: executive equity holding and independent boards. Thus, in practice, the remedy heightened corporate risk-taking without imposing constraints. Both recessions of the new millennium can be traced directly to these changes in strategy. Stock options were structured to reward executives for short-term share price gains without punishing them for losses – so executives placed bets on business strategies with strong upside and downside possibilities".

This argument is amplified by Taleb and Martin (2012) who reason that "the financial crisis of 2008 happened because of an explosive combination of agency problems, moral hazard, and 'the illusion' that scientific techniques would manage risks and predict rare events in spite of the stark empirical and theoretical realities that suggested otherwise".

5.6.2 Moral hazard

Moral hazard is a further agency problem that encourages increasing fragility, and it also does so in value chains. In this sense, moral hazard implies that there is a lack of incentives for managers in value chains to guard against increasing the fragility of businesses or value chains because they are shielded from the potential consequences of fragility. The privatisation profits and socialisation of losses points to the dilemma of moral hazard. As a consequence of moral hazard, businesses and individuals successfully benefit from profits but avoid losses by having those losses paid for by their principals or society, rather than having to face the consequences of the particular losses themselves. The consequence is that businesses and managers are incentivised

to pursue strategies that either drive up revenues, drive down costs, or both, without concern for the systemic risk that such strategies may introduce into the system (Gray & Boehlje, 2005; Taleb & Martin, 2012). A pertinent case of privatising gains and socialising losses is evident in the extensive bailouts after the 2008 financial crisis where governments bailed out numerous banks, insurers, etc. after they had sustained huge losses in their business dealings through unjustified risk-taking and a lack of due diligence (Colander *et al.*, 2009).

Streamlining of suppliers and buyers, zero inventory, just-in-time processes, made-to-order, contracting, vertical integration, and global value chains are some strategies and tools applied in the management of value chains (Christopher, 1998; Lambert & Cooper, 2000). Managers are rewarded for employing these tools and strategies that either drive up revenues, cut down costs, or contain uncertainty. At the same time, managers are not held responsible for the systemic risk that these strategies and tool introduce into the chain, and for how these measures contribute to increasing the fragility of chains.

This primary cause of this phenomenon is the absence of "skin in the game", described as an asymmetry between actors where the agent typically harms the principle for their own benefit. This point is argued by (Taleb, 2012) that "such systems should tend to implode. And they do. As they say, you can't fool too many people for too long a period of time. But the problem of implosion is that it does not matter to the managers – because of the agency problem, their allegiance is to their own personal financial position. They will not be harmed by subsequent failures; they will keep their salaries, bonuses, options as there is currently no such thing as negative manager compensation".

Ultimately, the current shareholder–manager value system promotes the seeking of profit without regard for the fragility of the system and the eventual consequences for shareholders and principals. Moreover, neither regulators nor shareholders have, yet, proposed alternative approaches to reverse these perverse incentives to ensure the long-term sustainability of value chains (Dobbin & Jung, 2010). The consequence is that value chains are set up to becoming increasingly fragile.

5.6.3 Horizon problems

The horizon problem is another agency problem worth considering in the exploration of fragility. The horizon problem revolves around the short-sighted behaviour in the management of businesses (Dechow & Sloan, 1991) and value chains. Given the structure of executive compensation, the span of executive's employment and shareholders' needs, extensive incentives exist for managers to pursue strategies that improve short-term earnings performance at the expense of the long-term risk profile of the business or chain. This is primarily because managers have a different time horizon to that of shareholders.

It is argued that managers of businesses in a typical manager–shareholder setting tend to focus on short-term rather than long-term performance. It is posited that managers tend to prefer projects that generate quick returns rather than those with slower, but ultimately higher, returns. Executive greed (Haynes *et al.*, 2014) is also known to drive myopic behaviour. Such short-sighted behaviour and short-terms goals can create a host of problems for businesses, shareholders and value chains. These problems include reduced investment returns, the destruction of shareholder value, business and value chain collapses, and the undermining of responsible corporate governance (Atrill, 2015).

Parts of the horizon problem are illustrated by Taleb (2012), with the tale of a turkey that "is fed for 30 months by a butcher, and every day confirms to the turkey and the turkey's economics department and the turkey's risk management department and the turkey's analytical department that the butcher loves turkeys, and every day brings more confidence to the statement. But in month 31 there is be a surprise for the turkey...". One lesson from the tale is that managers, focusing on short-term rather than long-terms goals, can be lulled into mistaking the absence of evidence (of harm) for short-term goals, for evidence of the absence (of risk of harm) in the long term (Figure 5-4 below).

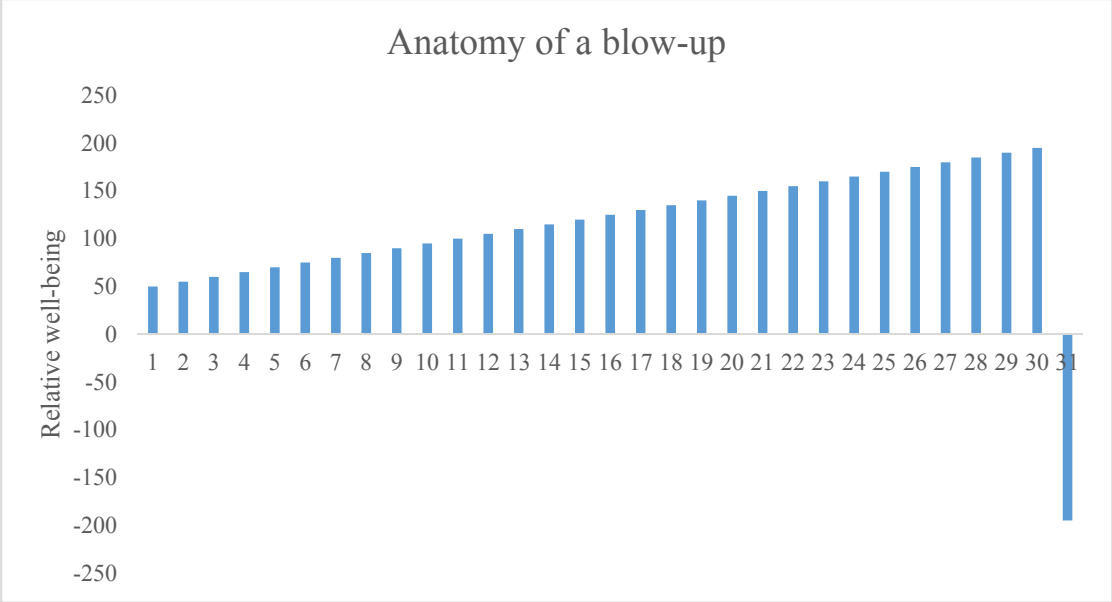

Figure 5-4: The anatomy of a blow-up

Source: Taleb (2012)

In the context of value chains, the economic narrative for this example is that reducing transaction costs in vertical exchanges in the short-term is expected to incrementally increase profitability (relative well-being) in the short-term too. Typical short-term management strategies may include reducing the number of suppliers or buyers and the frequency of transactions; undertaking less extensive and exhaustive searches; and screening and negotiating costs before, and undertaking less extensive and exhaustive monitoring and enforcement after, engaging in vertical exchanges. "Proof" of the desirability of this approach to strive for short-term goals rests in the incremental increase in the profitability of the chain without any apparent detrimental effects.

The short-term benefits of these strategies can, however, be accompanied by an almost silent shift of the underlying risk profile in the continuous quest for achieving typical short-term goals (Figure 5-5 below). It deserves repeating that managers may suffer the misjudgement that reaping the rewards of achieving short-terms goals without any harm is evidence that striving for short-term goals is without long-term risk of harm. Exponential increases in exposure to the effects of adverse selection and moral hazard over time, however, render the chain increasingly fragile and prone to a potentially devastating, but unexpected, blow-up because of the short-term, rather than long-term, focus applied to the management of the goals.

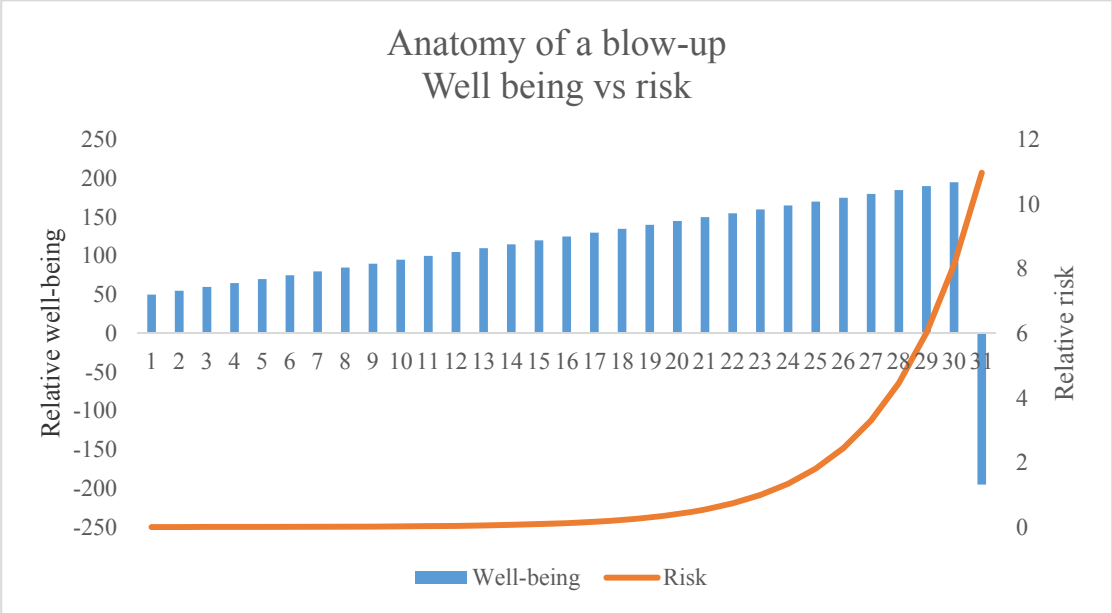

Figure 5-5: Well-being versus risk

Source: Taleb (2012)

Therefore, the asymmetry between managerial and shareholder horizons in the management of value chains may in the long run increase the fragility of businesses and value chains as a result of myopic managerial behaviour (Atrill, 2015).

5.6.4 Bounded rationality, heuristics and cognitive biases

The rational choice model, fundamental to the economics discipline, dictates that the "rational actor" makes choices by assessing the probability of each possible outcome, gauging the utility to be derived from each option, and combining these two metrics to arrive at a decision. Rationally, the choice that offers the optimal combination of probability and utility should be preferred by a rational actor (Gilovich *et al.*, 2002). While the theory of rational choice assumes that actors make these calculations and make them well, the concern is, however, that calculating probability and multi-attribute utility is rather daunting and certainly not without limitations. Advocates of the rational choice theory do not insist that rational actors never make mistakes in their calculations; rather, they specifically insist that these mistakes are random and not systematic. The model assumes that the rational actor will not deviate from the basic constructs of probability when calculating, for example, the occurrence of a drought or

the chances of a disruption in a value chain. The question, however, is whether the average person is mindful enough of the mechanics of strict, theoretical rationality and the generators of uncertainty to justify the absolute reliance on the maxims of the rational choice model (Gilovich *et al.*, 2002).

Exploration of the robustness of the rational choice model led the field of psychology to uncover basic but efficient procedures, called heuristics, which humans intuitively rely on to make decisions 'on the fly'. The premise is that humans "make inferences about the world under limited time and knowledge" (Gigerenzer & Goldstein, 1996) by using heuristics. These heuristics are mental, often automatic, shortcuts that typically focus on limited dimensions of a complex problem to enable decision making with minimal intentional calculation and high levels of accuracy (under most circumstances). The rational choice model typically holds, when the heuristics driving the choice are accurate. However, these heuristics can also lead to deviations from logic, probability or rational choice theory because of the shortcuts in the process and the neglect of evidently influential dimensions of a complex problem. These errors in judgment are called "cognitive biases" and mean that the rational choice model does not hold under the specific circumstances because of systematic errors induced by an inaccurate heuristic. In the end, these cognitive biases form the basis of bounded rationality, as a phenomenon, which asserts that people reason and choose rationally, but only within the constraints imposed by their limited search and computational capability (Kahneman, 2002; Kahneman, 2003).

The perverse effects of bounded rationality in dealing with complexity and uncertainty are highlighted in a number of relevant contexts, including the financial crisis and bounded rationality of the banks (Rötheli, 2010), global value chain management (Connelly *et al.*, 2013), agri-food sector risk (Bachev, 2013), reputational risk and bounded rationality (Walker *et al.*, 2014), flooding and flood risk perception (Birkholz *et al.*, 2014) and chain coordination risk (Croson *et al.*, 2014). Evidently, bounded rationality highlights the prospects of getting some assessments of probabilities and utilities, leading to irrational decision-making, which is consistently wrong.

Therefore, by extension, human propensity to deal with uncertainty irrationally contributes to the "fragilization" of value chains and therefore warrants consideration in the design and management of such chains. In complex contexts, like agribusiness value chains, bounded rationality, due to the reliance on heuristics, contributes to systematic misperception of probabilities or utilities, or both, resulting in irrational decision-making that cause more vulnerability, rather than less vulnerability.

5.6.5 Prospect theory

A further behavioural dimension to fragility, not linked to paradoxical positioning of principals and agents, is described by prospect theory (Tversky & Kahneman, 1973). Prospect theory describes decision-making under risk (Fiegenbaum & Thomas, 1988; Kahneman & Tversky, 1979; Tversky & Kahneman, 1992). The underlying principle of prospect theory is that humans, psychologically, value equally sized gains and losses differently. The phenomenon is described by Taleb (2004) who notes that "in some strategies and life situations, it is said, one gambles dollars to win a succession of pennies. In others one risks a succession of pennies to win dollars. While one would think that the second category would be more appealing to investors and economic agents, we have an overwhelming evidence of the popularity of the first". This, in essence, explains the phenomenon that leads to increasing interdependency and fragility in the design and management of value chains. The thesis is that there is a psychological preference to incrementally improve profits by systematically reducing transaction costs, albeit that such a strategy leads to heightened fragility of the system and the prospect of a drastic loss in profits somewhere in the future. This option is seemingly psychologically preferred over the option to strategically retain some recurring transaction costs, to specifically avoid increasing the fragility of the system and the prospect of a drastic loss in profits (Figure 5-6 below).

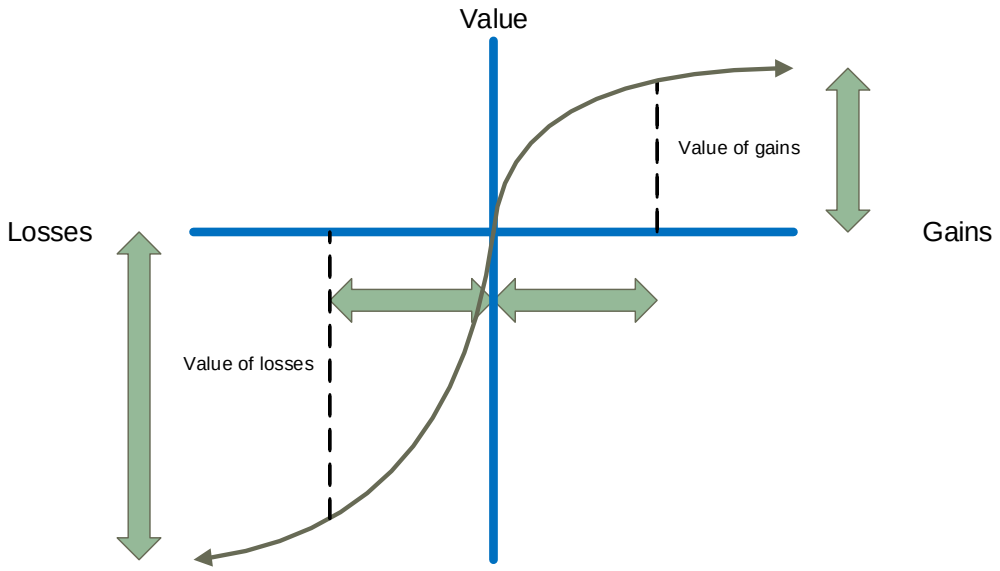

Figure 5-6: Prospect theory and the shape of the value function

Source: Tversky and Kahneman (1973)

Prospect theory proposes that human nature has a preference for outcomes rigged for a single, large loss in exchange for many, small gains over many small losses in exchange for a single, large gain. By deduction, the argument is then that there is an inclination to strive for leanness rather than resilience or anti-fragility in the management and coordination of value chains. The conclusion is that human predisposition drives the generation of fragile systems, or as Taleb (2012) points out, "engaging in policies and actions, all artificial, in which the benefits are small and visible, and the side effects potentially severe and invisible."

5.7 A NEW PARADIGM TO FRAME THE COORDINATION QUESTION

The reality of fragility and its consequences in value chains is undeniable and the risk of unsustainability, in the long run, of these chains seems inescapable. It is equally clear that coordinating value chains is exceedingly challenging, with a range of factors, often opposing, that influence the coordination of the vertical exchanges in value chains. Notwithstanding the best efforts to economise on transaction costs, some residual uncertainty remains in vertical exchanges. Moreover, the uncertainty that remains is seemingly of the fourth quadrant type (Munro & Zeisberger, 2010; Taleb, 2009b) where the distribution is fat tailed and the pay-offs difficult to define. The reasoning is that

this type of uncertainty is not tangible (neither in terms of probability nor payoff) and therefore neglected in the coordination of vertical exchanges.

The traditional TCE paradigm (Williamson, 1975) and the way it is applied only focuses on reducing the costs of behavioural uncertainty, not systemic uncertainty, and therefore neglects residual and systemic uncertainty from the coordination question. This shortcoming is highlighted by Shin (2003) who points out that the traditional TCE model specifically focuses on the uncertainty in the market, and does not question possible uncertainty that may exist in the hierarchy. The point is further emphasised by Rindfleisch and Heide (1997) who comment on uncertainty and the relative merits of tight versus loose coupling in exchanges. The inference that Rindfleisch and Heide (1997) make is that "there are limits to the amount of uncertainty that can be managed through formal organisational arrangements. Extreme levels of uncertainty could lead to information processing problems of such a magnitude that the loose coupling afforded by market governance becomes preferable".

Consequently, the way TCE is used in guiding vertical coordination begs for rethinking, since the original framework is either unclear, underdeveloped or improperly interpreted or applied. Fundamentally, it is clear that there is a trade-off between efficiency and residual and systemic uncertainty in organising vertical exchange (Figure 5-7 below). This calls for including uncertainty in the objective function used to drive economising decisions in vertical coordination. Maximising Net Present Value, rather than profitability, provides the additional dimension to include uncertainty in the economising equation (Equation 5-2 below). This approach would include accounting for uncertainty and would capture increasing value as a result of reducing transaction costs, up to an optimal point, and then decreasing value with further reductions in transaction costs due to the eroding effects of increasing uncertainty.

Equation 5-2: $$Max\ NPV = Max \sum_{n=0}^{N} \frac{Revenue - Costs}{(1+r)^n}$$

In this equation NPV is the Net Present Value from the exchange, r the interest rate and the number periods denoted the duration of the exchange.

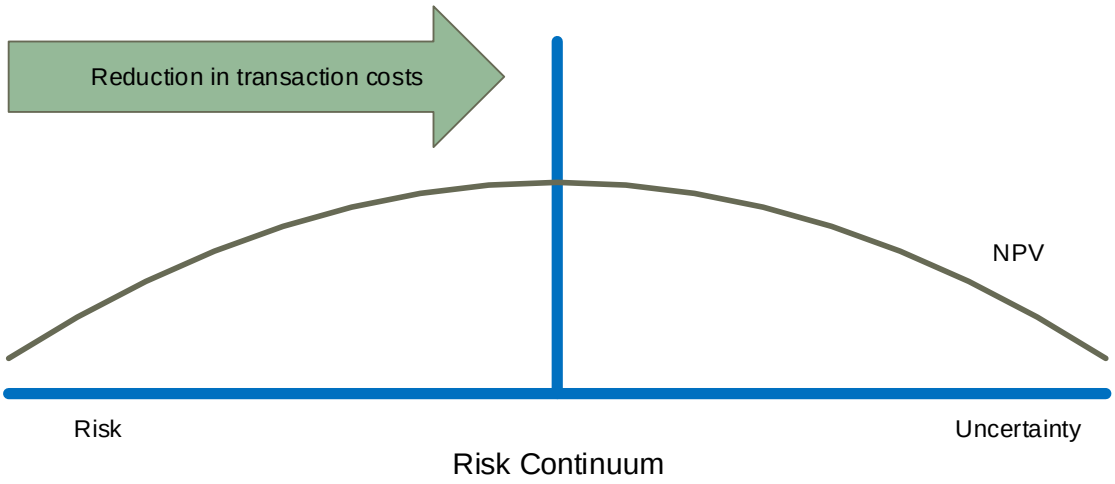

Figure 5-7: Value profile in the risk continuum with reducing transaction costs

Considering the approaches according to the different objective functions, the deviation in value between these two approaches grows as uncertainty grows (Figure 5-8 below). This deviation in value is indicative of the potentially different outcomes that are possible when considering the optimisation of vertical exchanges, with and without uncertainty.

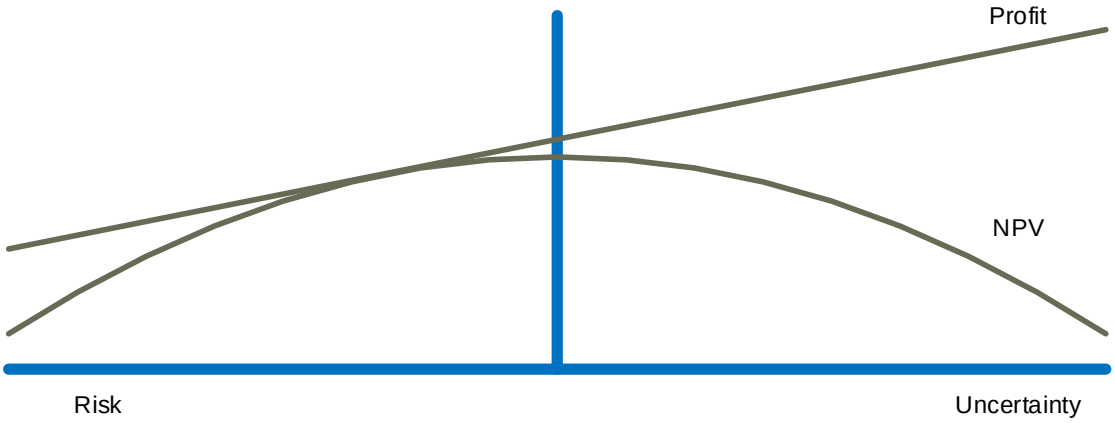

Figure 5-8: Profit and value profile in the risk continuum with reducing transaction costs

Given the evidence of fragility in value chains, it is argued that the application of the TCE model in navigating vertical coordination strategies should not negate uncertainty, particularly residual and systemic uncertainty, in optimising vertical exchange

arrangements. Maximisation of the value from vertical exchange should be sought by managing the trade-off between profitability (through economising of transaction costs) and uncertainty (as a result of economising on transaction costs). The bottom line of the argument is that there is an unavoidable tension between the pursuit of profits and the accompanying uncertainty, and that this trade-off should be optimised to foster sustainability rather than the one or the other of these goals separately. This tension between opposing goals in economising decisions in vertical exchanges is noted (Brede & de Vries, 2009; Carvalho *et al.*, 2012; Duarte *et al.*, 2011; Maslaric *et al.*, 2013; Williamson, 1979), but it is seemingly absent or poorly integrated into the mainstream analytical frameworks (Hobbs, 1996; Peterson *et al.*, 2001) that guide the analysis of vertical coordination strategies for agribusiness value chains. Therefore, integrating uncertainty as a key element in assessing the economising question for vertical exchanges allows for the capturing of the nuances that cause fragile value chains, and in guiding decision-making aimed at ensuring sustainable or anti-fragile value chains. Practically, the approach should tolerate some transaction costs in exchange for lowering uncertainty, and at the same time, accept some uncertainty in exchange for lowering transaction costs, and therefore increasing profitability, to strike an optimised balance between these juxtaposed aims in vertical exchange.

5.8 DESIGNING RESILIENT OR ANTI-FRAGILE VALUE CHAINS

The irreversibility of harm associated with vulnerable systems drives the impulse to seek arrangements in such systems that offer resilience or robustness to the specific harm. As a consequence, the drive for resilience or robustness in value chains is definite (An & Ouyang, 2016; Brenner, 2015; Durach *et al.*, 2015). Robustness or resilience has, in fact, been flaunted as the panacea to vulnerability or fragility in the discourse of value chain coordination (Vlajic *et al.*, 2010; Vlajic *et al.*, 2012). However, there is a distinct nuance between anti-fragile and robustness or resilience. The nuance is described by (Taleb, 2012) as “anti-fragility goes beyond resilience or robustness. The resilient or robust resists shocks and stays the same; the anti-fragile gets better.”

Moreover, given the pervasive and adverse consequences as a result of fragile value chains, there are compelling incentives, not least of which is the pursuit of tenability,

to construct and coordinate chains in ways that are not fragile. An exploration of resilient, robust or anti-fragile concepts in the context of agribusiness value chains provides some insight as to how the management and coordination of chains could be approached to balance fragility and performance.

5.8.1 Resilience or robustness

Resilience and robustness, as principles, are seemingly the default defence against the ravages of uncertainty. In this regard, resilience and robustness refer to a chain's ability to cope with unexpected disturbances or uncertainty, with the goal of preventing undesirable failures of the chain. Resilience or robustness comes from the ability to recover to a desired performance level within an acceptable timeframe and at an acceptable cost, or the ability to reduce the impact as a result of a disturbance.

An extensive framework to design robust food value chains was developed by Vlajic *et al.* (2012). The premise of this particular framework builds from the literature related to risk responses, risk protection strategies, mitigation strategies and mitigation tactics, which are all aimed at either preventing disturbances or reducing the impact of the disturbances. Typical measures to prevent disturbances include making adjustments to the chain structure, using product management, using technical measures for performance management, reducing or avoiding exposure to vulnerability, controlling variability, using revenue management strategies, decreasing lead times, short-term forecasting, using technology to enable data processing for decision-making, enabling information transparency in the chain, collecting data about disturbances, increasing collaboration in the chain, increasing collaboration and coordination between departments, creating an adaptive chain, and improving human resource management (Vlajic *et al.*, 2012). Distinctive measures to reduce the impact of the disturbances also include making adjustments to the chain structure, developing buffers in capacity and inventory, increasing flexibility of the chain, using product management, hedging, developing back-up options, increasing flexibility of planning and control, managing lead times, using information technology to detect disturbances quicker and to improve decision-making, increasing information transparency in the chain, using feedback

loops, increasing preparedness, increasing collaboration the chain, creating an adaptive chain, and using risk-sharing arrangements (Vlajic *et al.*, 2012).

5.8.2 Anti-fragile chains

While chain resilience or robustness is a worthy pursuit in a landscape where uncertainty is increasingly prevalent and pervasive (Maslaric *et al.*, 2013; Vlajic *et al.*, 2012), it is argued that resilient or robust approaches do not offer the ultimate relief to uncertainty, but may, in fact, "intensify the vulnerability of chains to harm from disruption" (Taleb, 2009b; Taleb *et al.*, 2012). Resilience or robustness, as Taleb (2012) argues, will not be good enough because everything with even the most microscopic fragility will be ruined by time – the most ruthless stressor of all.

Mindful of the critiques of robust or resilient approaches, some further thoughts on principles for designing and managing value chains, with anti-fragility in mind, include decentralisation, layering and building redundancy and overcompensation at the governance level. Equally, sticking to simple rules and institutions to govern exchanges, not suppressing or eliminating randomness and volatility, and making sure that stakeholders are accountable players in their particular value chains, are managerial principles for enabling anti-fragility in value chains.

These principles align with the results and challenges in value chain coordination noted in relation to fragility in Chapters 3 and 4 and preceding sections of this chapter regarding the human factor in dealing with uncertainty. While not extensively explored and analysed, these principles offer some food for thought and beg for further interrogation.

5.8.2.1 Governance

5.8.2.1.1 Decentralisation

Decentralisation as a strategy in the governance of complex systems, like value chains, is argued to be essential for enabling anti-fragility. The argument is based on the social organisation principle of subsidiarity which holds that matters ought to be handled by

the smallest, lowest or least centralised competent authority. The general stability (or anti-fragility) of Switzerland, as a country, is ascribed to the principle of subsidiarity, with governance at the cantonal level as opposed to a central government level (Taleb, 2012).

Anti-fragility, through decentralisation, grows from three primary principles. The first is the notion that adverse impacts will be contained in decentralised units, preventing contagion of the entire system. The second notion is that centralised systems are inherently fragile because the institutional architecture, and the set of rules that govern the systems, tend to be vaguer, more abstract, and overly theoretical to be generally applicable, albeit removed from the local context. The third notion is that size fragilizes, that is, adverse events are exacerbated by size, and consequently the size of systems should be limited through decentralisation (Taleb, 2005; Taleb, 2012; Taleb & Martin, 2012).

5.8.2.1.2 Layered systems

Development of layering in the governance of complex systems to enable anti-fragility is largely an extension of decentralisation as a strategy, with the same purpose. A central argument of anti-fragility, as a phenomenon, is that a system's anti-fragility is derived from the fragility of its component parts. The argument is that the antifragility of a system often comes from the fragility of its components. The principle is noted by Taleb (2012) as "things break on a small scale all the time, in order to avoid large-scale generalized catastrophes". Inadvertently, as with decentralisation, layering enables the containment of adverse impacts, and decision-making at the local level as discussed in Chapter 2.

The netchain framework proposed by Lazzarini *et al.* (2001) integrates the principles of network and chain philosophies and suggests an approach that offers an opportunity to extract the benefits of decentralisation and layering in the coordination of exchanges in value chains. In this regard, the netchain framework incorporates the ideas of decentralisation and layering in the pursuit of anti-fragility in value chains.

5.8.2.1.3 Built-in redundancy and overcompensation

Based on the principle of optionality redundancy, overcompensation and spare capacity in systems contribute to the anti-fragility of the system (Taleb, 2012). The logic is that spare capacity and idle resources, such as cash in the bank, extra holding, processing, distribution capacity, stock, and backup suppliers, are beneficial in enduring and even benefiting from adverse events or general turmoil which tend to ruin over-optimised systems. The most anti-fragile systems, like nature, are characterised by the over-insurance provided by redundancy, overcompensation and spare capacity.

In the optimising frame of mind redundancy, overcompensation and spare capacity constitute system inefficiency, wasted resources and excessive transaction costs that would be typically driven from a system through economising interventions. The rationale would be the incremental benefits from increases in efficiency and reduction in costs, albeit that the efficiency contributors become fragility creators.

The plural forms of organisation (Ménard, 2013), where firms or industries employ more than one type of coordination mechanism to govern similar transactions, raise the question whether redundancy, overcapacity and spare capacity are not already enabled through an emerging plural coordination approach in the pursuit of some anti-fragility. Possible regimes may include vertical integration for a set proportion of exchange, while the remaining proportion of exchange may be sought through the spot market (Ménard, 2013; Peterson *et al.*, 2001).

5.8.2.2 Management

5.8.2.2.1 Stick to simple rules

The phenomena of bounded rationality, opportunism, information asymmetry and incomplete contracts complicate the best efforts at controlling uncertainty (Dequech, 2001), especially in complex systems, like value chains (Taleb, 2008; Taleb, 2012). Therefore, from a management perspective, Taleb (2012) argues that the temptation to respond to complexity with complex rules must be resisted. While counterintuitive, the rationale is that complex intuitions or sets of rules governing systems fragilize such

systems and have a troubling tendency to produce cascades of unintended consequences and convexity effects (Taleb, 2005; Taleb & Martin, 2012). In a value chain context, the implication relates to the complexity of chains and the governance and intensity of coordination control exerted in coordinating the sequential stages of value chains (Peterson *et al.*, 2001; Vlajic *et al.*, 2012). The 'thesis' in this regard is that, in the interest of anti-fragility, complex systems should not be governed by overcomplicated institutions or rules – the simpler and less intensive the rules are, the better it is for anti-fragility.

5.8.2.2.2 Resist the urge to suppress randomness

A central thesis of Taleb (2012)'s notion of anti-fragility is that "if anti-fragility is the property of all those natural (and complex) systems that have survived, depriving these systems of volatility, randomness, and stressors will harm them". Flowing from the phenomenon of iatrogenesis (unintended consequences as a result of intervention) in complex systems the argument is that interventions to eliminate volatility, uncertainty or unpredictable disruptions to a system are bound to only intensify the vulnerability of such systems to harm from disruption. Therefore, while randomness and stressors are undoubtedly undesirable and impact on the purpose of systems, the paradox remains that efforts to eliminate randomness and stressors will fragilize systems. In the pursuit of anti-fragility in value chains, the argument is then that randomness and stressors should not be supressed or eliminated at all cost (Taleb, 2012). Practically, the approach to value chains coordination should therefore, at the very least, tolerate some transaction costs in exchange for lowering fragility, and at the same time, accept some fragility in exchange for lowering transaction costs as a pragmatic compromise between these juxtaposed aims in vertical exchange. While pragmatic, Taleb (2012)'s warning that anything that is remotely fragile will be ruined, suppresses the optimism about balanced trade-offs between fragility and chain performance.

5.8.2.2.3 Ensure everyone has skin in the game

Anti-fragility in complex systems is also enabled by ensuring that all stakeholders in such systems have very tractable exposure to both rewards and penalties for their actions in the context of the chains. The argument by (Rötheli, 2010), Taleb (2012), and

Taleb and Martin (2012) is that stakeholders in complex systems like value chains "must face the consequences of their actions and endure failure as well as enjoy success to ensure that each stakeholder is motivated, dedicated and does not take gratuitous risks". This notion seems obvious, given that capitalism is very much about rewards and penalties, and not just about rewards or just penalties – but the principle is not all that widely applied as it should be. Having "skin in the game" provides some recourse to manage fragilising challenges like agency, opportunistic behaviour, adverse selection, and moral hazard. The case in point is seen in instances where a select few stakeholders (usually with power and resources) privatise gains and socialise losses. Bailouts of banks, business rescues of strategic suppliers or buyers, and bonuses for good company results but with no consequences for bad company results, all encourage fragilising behaviour because of the removal of feedback between actions and consequences.

In the interest of contributing to anti-fragility, it is therefore essential that mechanisms are put in place to directly link the behaviour of managers and actors to outcomes and consequences in value chains: skin in the game, as Taleb (2012) terms the principle. Addressing the matter hinges principally on the details of remuneration and performance contracts, risk sharing arrangements between stakeholders in the value chain, and power dynamics in the chain and amongst stakeholders.

5.8.3 Addressing fragility in the South African lamb chain

The analysis in Chapter 4 that illustrates the detection and measurement of fragility in the South African lamb chain shows the inevitable fragility inherent to the alignment of actor and activities in a chain. Considering the omnipresence and the irrevocable consequences of fragility Taleb (2012) argues that addressing fragility should be a preoccupation in the design and management of systems like value chains. A high-level application of possible measures to address chain fragility in the context of the South African lamb value chain concretises these theoretical recommendations and merges theory and practice naturally. A matrix of anti-fragile strategies linked to the particular elements in fragility for each of the different players in the chain ventures an approach to addressing chain fragility in the South African lamb chain (Table 5-1 below).

Table 5-1: Matrix of possible strategies to address fragilty in the South African lamb chain

		Anti-fragile strategies					
		Structure			Management		
		Decentralise	Layer systems	Ensure spare capacity	Keep rules simple	Accept some randomness	Skin in the game
Producers	Quality and safety performance	X	X		X	X	X
	Operational reliability	X	X	X			X
	Cash flow position			X			X
	Buyer reliability	X	X			X	X
Abattoirs	Quality and safety performance	X	X		X	X	X
	Cash flow position			X			X
	Quality, training of human resources	X	X				X
	Quality, adequacy of infrastructure	X	X	X			
Packers	Cash flow position			X			X
	Regulations				X		
	Supplier reliability	X	X			X	X
	Operational reliability	X	X	X			X
Retailers	Quality and safety performance	X	X		X	X	X
	Cash flow position			X			X
	Management information visibility		X				X
	Supplier relationship and alignment	X	X	X	X	X	X

The premise of these strategies is ultimately aligned to the steps towards anti-fragility noted by Taleb (2012) as "first decreasing downside, rather than increasing upside". However, while this matrix provides a foundation to address the dilemma, the high-level approach warrants more refinement, supported by analysis and engagement with stakeholders, to develop a specific anti-fragile strategy for the chain.

5.9 SUMMARY

Rhetorically, the coordination of agribusiness value chains unfolds like the plot of a Greek tragedy. The familiar path, the tragic cycle, is characterised by hubris, *aite* and then nemesis. A tragedy starts with the protagonist committing hubris, developing foolish pride and dangerous over-confidence, which is seen as arrogance before the gods. Hubris is followed by *aite*, where the protagonist is blind to frequent warnings and signs that if he remains unhumbled, he would be struck down. Most of these warnings, though, are false hope since the character's nemesis is already predetermined. Overconfidence in the coordination of agribusiness value chains inevitably results in their ruin.

Agribusiness and value chain literature has been blind to fragility, as a phenomenon, despite clear, practical indications of the existence of such non-linear effects. Therefore, the purpose of this chapter was to explore the new dimensions that fragility adds to the

theoretical constructs of agribusiness value chain coordination and to position these new dimensions in the mainstream landscape. The chapter argues for the need to consider risk, uncertainty and the coordination of value chains beyond the very classical framework that pursues the reduction of transaction costs in exchanges, at all costs. In this regard, a trade-off between the performance and fragility is highlighted, with the proviso that there is a path dependence insofar as surviving first, before thriving.

The chapter also explores the interaction between human capacity and frailties in decision-making and the interplay with fragility to inform a new paradigm for the coordination question. It is suggested that humans' economising behaviour lies at the heart of fragility (Taleb, 2012). It is, in fact, through the economising behaviour of individuals that the "catallactic" order emerges (Hayek, 1945). The argument is that this order is achieved, not intentionally, but though the purposeful behaviour of many interacting individuals in a system, each pursuing his own particular goals (Hayek, 1945) – with an economising mind-set. As such, agency and prospect theory provide some insights of the human factors that drive typical economising behaviour that is a precursor to the development of fragile chains.

The chapter concludes by considering a range of recommendations in the pursuit of chain robustness and resilience, and specifically on measures to reduce vulnerability in agribusiness chains. These factors include decentralisation, layering, redundancy and over compensation, sticking to simple rules, resisting attempts to prevent or curb randomness or volatility from systems that depend on them, and finally ensuring that stakeholders have skin in the game (Taleb, 2012). These recommendations are finally fashioned into a matrix of strategies for the South African lamb chain to conclude the chapter with an application of the measures to a specific case.

CHAPTER 6
CONCLUSION

6.1 INTRODUCTION

This thesis presented a conceptual exploration, analysis and application of fragility as a phenomenon and its usefulness in agribusiness value chain design and management. The broad context of the thesis is that the future is increasingly complex and uncertain, and is fraught with accelerating interdependencies and spillover effects not seen before. Complexity and uncertainty also permeate the business landscape where organisations and their value chains operate, with these phenomena multiplying and reinforcing each other exponentially. As a consequence of this landscape, contemporary agricultural value chains are being organised in ways that are lean and efficient in an effort to secure returns on investments and to manage risk. The manifestation of this response is agricultural value chains that are progressively integrated with greater levels of control and interdependency across the value chain system. However, increasing interdependency through more tightly aligned coordination also introduces new and less concrete uncertainties which render these chains vulnerable or fragile. This fragility is most evident from the lumpy and non-linear consequences of uncertainty and complexity that are revealed in "blow-ups" of value chains, like food scandals, product recalls, instantaneous bankruptcies, reputation and brand devastation. There is compelling evidence that illustrates both the existence and the impact of value chain fragility and how it unfolds within agribusiness value chains.

The goal of the thesis was to discover fragility in the context of agribusiness value chains and to contribute theoretical and managerial wisdom, as well as future research questions in relation to fragility, to the broad agribusiness value chain management discourse. The goal of the thesis was specifically achieved through three core chapters. The first chapter dealt with identifying the factors that cause agribusiness value chain fragility. The second chapter dealt with a method to measure fragility and the application of this method to the case of the lamb value chain in South Africa. The third chapter dealt with the theoretical considerations of value chain fragility, the

implications for the coordination discourse of these chains, and strategies to address fragility.

6.2 DISCUSSION OF THE RESEARCH PROPOSITIONS

This thesis introduces value chain fragility as a phenomenon to the mainstream agribusiness discourse. The premise was to enable greater awareness of chain vulnerability and to argue for a measured approach in the coordination of these chains to balance performance and fragility. The thesis specifically explored (1) fragility in the context of the risk and uncertainty landscape; (2) the unique factors that contribute to the fragility of agribusiness value chains; (3) the development of a framework to measure value chain fragility; (4) a fragility analysis of the South African lamb value chain; (5) a reframing of the theoretical framework that guides value chain coordination; and (6) measures to strike a balance between value chain performance and fragility.

The thesis addresses the aim of the research and the consequent research questions through four concise research propositions, contained in the three core chapters of the thesis. Each of these chapters addresses a specific research proposition, through either empirical, theoretical or a combination of these approaches. The theoretical constructs employed throughout the thesis are founded in the Transaction Cost Economics branch of New Institutional Economics discipline and the empirical assessment was conducted in a range of value chains, notably the South African lamb chain.

6.2.1 Factors influencing agribusiness value chain fragility

The first proposition of the thesis posits that the fragility of agribusiness value chains is influenced by a range of elements which vary in their relevance. The proposition is interrogated in Chapter 3 of the thesis, which develops a framework to explore the factors that influence value chain fragility. Based on expert opinion across the agribusiness value chain, the study isolates a set of factors that influence the fragility of these value chains. The essence of the findings is that those elements that are known to be critical for the success of value chains are also the same elements that drive the fragility of the chains. What makes a chain work well is also what a chain is vulnerable

to. The identification of the factors that influence value chain fragility also provides a platform to quantify value chain fragility, with the aim of identifying priority factors for decision-making and comparative analysis in value chains.

6.2.2 Measuring agribusiness value chain fragility

The second proposition of the thesis is that fragility can be measured and the results employed in a fashion similar to traditional risk analysis. The primary goal of risk management is, after all, to reveal, assess and prioritise hazards so that acceptable decisions can be made under conditions of uncertainty (Aven, 2015; Jüttner, 2005; Manuj & Mentzer, 2008). In the context of this thesis, Chapter 4 develops a framework to detect and measure fragility in an agribusiness value chain setting to reveal, assess and prioritise fragility factors analogous to the type of outcomes from a traditional risk analysis. Ancillary to the measurement of fragility, the proposition also distils principles and the actual measuring of fragility in the agribusiness context. The analysis to interrogate the proposition was carried out in the South African lamb chain where the fragility of a number of chain configurations in the specific chain were measured, discussed and interpreted, as for a classic risk analysis.

6.2.3 Fragility and coordination of exchanges

The third proposition of the thesis is that increasingly coordinated, vertically integrated and overly optimised-strategies increase fragility in complex systems like agribusiness value chains (Brede & de Vries, 2009; Taleb, 2012). This proposition is the foundational premise and apex of the conceptual framework of this thesis and it questions the mechanical application of the dictum to ruthlessly economise on transaction costs in vertical exchanges, without due consideration of the fragility that such economising introduces into the chain. This proposition was interrogated in Chapter 4 and partly in Chapter 5 through the measurement and comparison of value chain fragility of different South African lamb value chain configurations. The analysis of chains with different interdependencies in the South African lamb chain affirms the hypothesis that increasing coordination intensity in chains, driven by traditional new institutional economic principles, may also be associated with increasing fragility of these chains. Considering the central conceptual framework of this thesis, the

contention that there is an inescapable trade-off between chain efficiency and fragility is highlighted by the results of the analysis. The most significant implication of the results of the value chain measurement case study is that the traditional transaction costs economising model that promulgates the coordination of successive exchanges in value chains may, in fact, be contributing to chain fragility in the relentless quest to economise on the costs of exchange.

6.2.4 Economising rationales and chain fragility

The fourth research proposition of the thesis was that the generally employed approach of organising the coordination of vertical exchanges by single-mindedly economising on the costs of the exchange is ignorant of the unintended, fragilising consequences of the approach. While this old-style narrative is rationally palatable because of the cost economising benefits, it also conceals a multiplication of new, less tangible risks as a result of the economising approach. This proposition was explored in Chapter 5 of the thesis which considers some optimisation constructs in vertical exchanges. The argument offered in Chapter 5 is that a more mindful approach to governing exchanges would be to weigh the benefits of economising on the costs of exchange against the consequential systemic risks through the influence of the coordination mechanism. The dilemma is highlighted by Taleb (2012) who notes that "one can't separate financial returns from risks of terminal losses, and 'efficiency' from threat of harm because of the irreparable nature of harm in complex systems". An analysis of the human factor in decision-making under uncertainty also affirms the link between economising behaviour and the inevitable development of fragile systems.

6.3 IMPLICATIONS OF THE RESEARCH

The study and management of the risk and uncertainty continuum has a long history. However, although risk analysis and management is well developed in some disciplines (such as finance, engineering, and project management) it is only relatively recently that their influence and management has emerged as an important issue in value chains. Drawing from the theoretical landscape chapter of this thesis, there is general consensus that the consequences of risk and uncertainty are increasingly relevant in the context of value chains, and that their analysis and management should no longer be limited to the

firm level alone. However, current insights seem inadequate to meet the challenges of accelerating uncertainty and complexity as globalisation continues to evolve. Consequently, new analytical tools, like the analysis of value chain fragility as developed in this thesis, are necessary to explore this emerging territory and for drafting policies and strategies to address these challenges. In this regard, this thesis contributes extensively to new theoretical, managerial and future research domains in the agribusiness value chain dogma.

6.3.1 Implications for literature

This thesis provides a spectrum of implications for the agribusiness, value chain and risk, and uncertainty literature. Conceptually, the thesis extends the agribusiness research pathway by adding a sustainability dimension to the research frontier that charts the durability of value chains as being the coalface of the discipline. In this regard, there is a tension between sustainability and fragility, and the overall the thesis explores this divergence in value chain strategies. Practically, the thesis adds to literature by threshing out the notion of fragility in a value chain context, specifically in the setting of agribusiness value chains where fragility is theoretically most vivid, with known occurrences of food safety and quality scandals, etc. The various chapters of the thesis also provide some separation of the concepts of risk, uncertainty, fragility, robustness and resilience, which is a useful addition to the literature, given the widespread, improper and confusing use of the terminology. Theoretically, the thesis contributes to literature by developing three frameworks in different chapters to approach, measure and interpret the implications of fragility in agribusiness value chains. Moreover, the thesis critiques the misuse of the traditional TCE framework that guides the coordination of value chains by focusing on the often clumsy strategies used to deal with uncertainty in coordination. In this regard, the thesis proposes an adjusted TCE approach to the coordination question that economises on transaction costs, subject to residual uncertainty, rather than one that economises on transaction costs, notwithstanding residual uncertainty. The novelty of the theoretical contribution of the thesis is therefore a system that considers risk and uncertainty beyond the boundaries of firms, and accounts for risk and uncertainty in, and as a result of, the extended value chain. In this way, the thesis enables an approach that allows for consideration of both

risk and fragility as measures in characterising, measuring and managing adverse events in agribusiness value chains.

6.3.2 Implications for management

The implications of the research also extend into the management domain, as a blend of counterintuitive and thought-provoking implications emerge from the thesis. The principal managerial contribution of this thesis is that the fragility of agribusiness value chains is a phenomenon that can hardly be disregarded, especially in a context where uncertainty and complexity are multiplicative and the evidence of lumpy, non-linear consequences abounds. It is therefore essential that organisations gain a firmer understanding of the vulnerability of their chains, given the very pronounced emphasis on sustainability and the need to address fragility to avert devastation (or unsustainability) in the long run.

Closely linked to the gravity of fragility in value chains, is the need for organisations to strike a conscious balance between chain efficiency and fragility because of the juxtaposed ambitions of these approaches. Driven by profit motives, contemporary agricultural value chains are being organised in ways that are lean and efficient, and often robust against uncertainty. As a result, these chains become progressively integrated, with greater levels of interdependency and rigidity between links in the chain. However, increasing interdependency through more tightly aligned coordination also introduces new and less concrete risks, and tends to make the system increasingly fragile. The reverse is also true and illustrates the need for organisations to find an optimal trade-off between these two masters, cognisant of the fact that fragility propagates and diminishes more explosively than efficiency.

A combination of two managerial lines of attack is encouraged to address fragility in the context of value chains. The first covers a set of principles with regard to chain architecture, and the second a set managerial principles. The first architectural principle is the promotion of a decentralised approach in organising and managing value chains because decentralised systems allow for the containment of adverse impacts. The second, and practically an extension of the first principle, is the development of layered

organisational architecture. This layered organisational architecture also allows for the containment of adverse impacts within the system and facilitates learning within and across different layers so as to drive survivorship forward. The philosophical premise of this principle is that the anti-fragility of a system is derived from the fragility of its differentiated parts, as in nature where the demise of an individual contributes to the antifragility of the collective. The third principle is to plan for redundancy and overcompensation in value chain capacity. Redundancy or spare capacity is argued to be at the heart of managing fragility and is essential in dealing with unanticipated events – opportunistically, when these events are positive, and in the interest of survival, when these events are a negative. Redundancy in this sense is apparent inefficiency in the chain including having idle or spare capacity, ensuring the availability of a buffer of raw materials, unused parts, stocks, and having some resources that are not put to work but held to establish optionality (Taleb *et al.*, 2009). While these principles target the reduction of fragility at all costs, they would also typically drive up transaction costs, as fragility declines. Therefore, in plotting a value chain strategy, it is essential for organisations to strike a balance between reducing transaction costs to increase efficiency and enduring some transaction costs to contain fragility, as noted earlier. The need to find this balance is affirmed by the mantra that notes that risk is inherent in the pursuit of opportunity, and that the one cannot be had without the other.

The first managerial principle is to manage chains with basic rules similar to the coordination intensity, typical of the "invisible hand" in the vertical coordination continuum. Given the inescapabilty of bounded rationality and incomplete contracts in the coordination of value chains, the argument is that responding to complexity with complex rules is counterproductive to containing fragility. Combinations of complexity are inclined to reinforce fragility and to produce multiplying cascades of unintended consequences. The second managerial principle is to resist the compulsion to eliminate uncertainty from the value chain. While uncertainty is disruptive and troublesome for chain efficiency, the rationale of this principle is the paradox that efforts to eliminate uncertainty will only increase the fragility of such chains to harm from uncertainty. The third managerial principle to address fragility is to effectively design and manage incentives so that all stakeholders have "skin in the game". The rationale is that everyone must be compelled to face the consequences of their actions in the

organisation and management of value chains, including tolerating failures and reaping successes. This will ensure that each participant will be motivated to learn as rapidly as possible and to not take unwarranted risks. The thesis also applied these managerial principles to recommend a high-level strategy to address fragility in the South African lamb chain.

In concluding the managerial implications of the thesis, the dire influence of human compulsion and frailty in dealing with the future and its uncertainty is conceivably and paradoxically the greatest known managerial factor in a sea of known and unknown unknowns. It is, in fact, debateable whether the human factor can ultimately be outmanoeuvred in the design and management of sustainable, value creating chains, and herein lies the greatest challenge to sustained durability for individuals, organisations, systems, economies, societies and civilisations.

6.3.3 Implications for further research

In concluding the contribution of the thesis, it is logical to highlight the future research needs that stem from the thesis and to chart a research agenda for agribusiness value chain fragility. As discussed in the respective analytical chapters of this thesis, value chain fragility, as a phenomenon, is under-discovered in the stream of value chain risk, uncertainty, resilience, and robustness literature, and specifically in an agribusiness and food value chain context.

The first dimension that requires further exploration comprises the factors that cause agribusiness value chain fragility. While there is a sound basis for the factors presented in this thesis, there is ample latitude for the depth, width and length of these factors to be interrogated in a variety of different contexts, and with different goals in mind. Practically, there is scope to consider and compare these factors in an agribusiness context for different markets, commodities, territories, chain configurations, stakeholders, etc. Evidently, there is an opportunity to explore these fragility factors in much greater depth because it is critical for advancing the new frontier of value chain analysis and because of the shortcomings in the thesis that are noted in this regard. The ideal outcome of this theme would be a further refinement of the fragility-causing

factors for detecting and measuring agribusiness value chain fragility. This thesis manages to introduce the idea from the original concepts from Taleb (2012), but significant fortification of the concepts is required.

Further exploration of the approach to the measurement of value chain fragility is also required to extend the outcomes from this thesis. The measurement approach used in this thesis is but one approach, and additional approaches to measure the phenomenon would strengthen the robustness of the analysis and would allow for tailor-making specific measures to specific contexts. Exploration of, for example, subjective versus objective and quantitative versus qualitative approaches and their convergence and divergence would extend the theory building and analytical capacity to research value chain fragility.

On a practical note, there is also a significant opportunity for exploring and interrogating the managerial aspects of fragility and to adjust and deepen the tools and principles to deal with fragility, as the domain develops. It is specifically noted that the trade-off between fragility and efficiency in value chains, as portrayed in this thesis, requires specific attention because of the inescapable paradox between these two dimensions of chain performance. Exclusively pursuing efficiency multiplies fragility, and exclusively pursuing antifragility diminishes efficiency, and consequently finding a measured balance between these opposing goals in the management of value chains is essential.

Additional exploration and integration of the human factors that perpetuate fragility is also required to broaden and deepen the understanding of the human dimension in the context of facing uncertainty. The human dimension presents a specific opportunity for a multi-disciplinary approach to examining the dilemma and may include fields such as psychology, behavioural economics, and sociology. The critical point in this regard is that if human reason is left to its own devices, it will certainly be trapped by misconceptions and methodical errors in reasoning. Therefore, to be poised to make better decisions in designing and managing complex systems like agribusiness value chains, it is clearly essential to be acutely aware of these human shortcomings and to have predetermined methods to overcome these inadequacies.

Lastly, the interaction between value chain fragility, efficiency and coordination warrants further exploration, since the coordination mechanism is ultimately the apparatus that is employed to optimise the coordination of exchanges in the value chain. While this thesis has explored the interaction in a specific context, there is significant opportunity to extend this analysis so that the nuances in the troika of fragility, efficiency and coordination can be expanded to inform both literature and management with tools for a sustainable approach in research and decision-making. The underlying rationale in this regard aligns to the theoretical argument tendered in this thesis that the coordination strategy for value chains cannot be limited to a naïve application of TCE theory. More work is required to explore value chain coordination strategies that consider the trade-off between efficiency and fragility, as opposed to focusing on efficiency alone – according to the traditional approach to the coordination question. Moreover, the proposed extensions to the traditional TCE approach proposed in this thesis will also add fragility, as an additional dimension, to the factors that explain coordination strategies. In this sense, awareness of fragility, as an additional dimension to the coordination puzzle, could be helpful in explaining specific coordination strategies retrospectively, rather than predictively as argued first. In the end, it is clear that fragility is relevant to the coordination of exchanges in value chains, and as such, invites further examination of the phenomenon in the context of value chains.

6.4 SHORTCOMINGS OF THE RESEARCH

Research is not without limitations, and it is evident that this thesis suffers some shortcomings worth mentioning, so as to highlight the strengths and weaknesses of the study. These shortcomings relate to the limits of generalisability, application to practice, and usefulness of the findings and recommendations because of the ways in which the research was designed and methodologically approached.

The first noteworthy shortcoming is that fragility, as a phenomenon, proved to be particularly awkward and counterintuitive to deal with, both in terms of the material in the thesis and in engaging with respondents. This limitation affects the applicability of the research to practice, and is ascribed to the pervasive influence and embeddedness of the impact and probability mantra of traditional risk analysis. The impact of the

counterintuitive nature of fragility on the thesis's results is, however, expected to be limited, since the concept was introduced and discussed in detail. This limitation specifically points to the need for greater awareness of fragility as a phenomenon and its introduction into the value chain analysis and management vocabulary.

The second important shortcoming is that determining the factors that cause agribusiness value chain fragility is potentially fraught with inadequacies in relation to the depth and breadth and width of the factors that contribute to this fragility. This limitation relates to the generalisability of the research and it exists because of the diversity in many aspects (commodity, territory, number of links, complexity, etc.) within and across value chains, inasmuch as factors might be improperly included or excluded in an analytical framework to assess value chain fragility. The dimension reduction techniques applied in this thesis, while essential to broadly exploring the concept, also compound this shortcoming by fleeting over or hiding essential factors in specific value chains. The impact of this shortcoming in the context of this thesis has been limited by the specific setting of the analysis and the value chains that were analysed, but the specific framework may prove to be improper in another context. The specific point to note is that the framework of fragility factors is at risk of being either too specific or not specific enough for a particular context, and should be applied with care and awareness of the context where it is, and is not, appropriate. This shortcoming is aligned to the need for a stream of research that should be developed as a result of this thesis and be related to developing tailor-made frameworks.

The third notable shortcoming is that the particular measure used to gauge value chain fragility in the context of this thesis is not beyond reproach. This thesis relied on respondents' perceptions to gauge value chain fragility. While certainly not a fatal flaw, a range of other measures of fragility could be equally justified. This limitation affects both the applicability and generalisability of the research. Whilst case was taken to use respondents' perception as a measure of fragility, equally strong arguments can be made to apply inanimate and more objective measures, like accounting metrics. However, notwithstanding the range of possible approaches to the measurement of fragility, none, applied in isolation, may prove completely comprehensive. Consequently, any fragility analysis would need to either expressly note the shortcomings of the specific

measurement or to combine a number of measurement approaches to become able to triangulate the results and interpretation.

The fourth prominent shortcoming of the research relates to limits of the context of the analysis presented in the thesis. The thesis attempted to explore agribusiness value chain fragility very broadly but, inescapably, there are limits to the broadness of the fragility assessment which, unavoidably, influences the applicability and generalisability of the results and the recommendations to all agribusiness value chains under all circumstances. This shortcoming is a typical scope-related challenge that may need further interrogation to discover applicability and generalisability, or the need for refinement to a particular context. In this regard, the approach in the thesis is not fatally flawed, but it is potentially exposed to some weaknesses that have been noted in the scope for further research.

6.5 CLOSING REMARKS

Accelerating volatility, complexity and scrutiny will be the norm in the landscape for agribusiness value chains as the future unfolds. Evidence of this new landscape is clear from the extent and complexity of global food and fibre value chains, the rise of consumerism, and the prominence of the sustainability and responsibility narrative. As a result, agribusinesses and their value chains are compelled to evolve to meet the challenges and opportunities that this new landscape presents.

However, agribusinesses and their value chains generally seem lethargic to adapt to this new environment and are consequently every so often ensnared by a cascade of effects that emphasise the volatile, complex and scrutinising challenges for these value chains. Confirmation of these cascading effects is evident from the range of food scandals, product recalls, instantaneous bankruptcies, and reputation and brand devastation, where unexpected events lead to these, and other, non-linear payoffs that ripple through these agribusiness value chains. The conspicuous occurrence of these events with non-linear impacts is indicative of fragility in these chains and specifically highlights the rationale for detailed exploration of fragility, as a phenomenon, in agribusiness value chains.

This thesis explored the generalisable factors that contribute to agribusiness value chain fragility and found that those factors that contribute to the efficiency of value chains are also the factors that drive the fragility of these chains. This finding exposed a juxtaposition between value chain efficiency and fragility and the need to find a measured balance between these approaches to achieve and sustain chain goals. The thesis also developed a framework to measure agribusiness value chain fragility and applied this framework to the South African lamb value chain.

The institutional economics discipline has played a key role in guiding the coordination of economic activities, as in the case of value chains, considering the frequency, asset specificity and uncertainty dimensions of the exchange. However, transaction cost economics seems to be applied casually or without the due care to assist in organising value chains to deal with a context that is increasingly uncertain and increasingly characterised by interdependencies and cascading spillovers. The result is that value chains have tended to become overly coordinated. Unlimited coordination intensity to control uncertainty and to drive forward a thesis of efficiency although the result is that such chains silently become fragile. The growing phenomenon of fragile chains endangers value chain sustainability in the long run, which is detrimental both to investors in the value chain and consumers of the goods and services from a value chain who are interdependent on the value that chains deliver. This notion is highlighted by the inability of the discipline to ensure the durability of organisations and value chains. Consequently, there is a particular need to understand and measure the fragility of value chains in general, and agricultural value chains in particular.

Therefore, to chart a path of sustainability in an environment that increasingly undermines sustainability requires a fresh approach and the challenging of a range of norms in the coordination of value chains, as discussed. Overall, the outcome of the thesis is a suggested design for chains that are more sustainable, less fragile and better suited to the environment in which they are required to operate. Some scholars like Taleb (2012) advocate for an even more severe stance on fragility, noting that mitigating system fragility should not be optional, but indispensable to durability, given the brutally punishing and terminal effects of fragility. In the end, given the

irreversibility of harm, the key consideration is survival first, before pursuing any other goals.

In the end, complex systems like agribusiness value chains are unavoidably exposed to human frailties in their design and management, notwithstanding all the effort aimed at avoiding or containing their influence. Humanity appears challenged in coping with complexity, and as a result, the coordination of value chains oscillates between hubris and nemesis in pursuit of coordination precision – sailing too close to the wind and then crying foul when the inevitable happens. In closing this thesis, the emphasis on life's capriciousness and human frailties, and the very essence of the treatise that is presented, is captured by "O Fortuna", a medieval poem that protests the inevitability of fortune, and not human endeavour, which rules both gods and men in mythology.

"O Fortune,
like the moon
you are changeable,
ever waxing
and waning;
hateful life
first oppresses
and then soothes
as fancy takes it;
poverty
and power
it melts them like ice.

Fate, monstrous
and empty,
you whirling wheel,
you are malevolent,
well-being is vain
and always fades to nothing,
shadowed
and veiled

you plague me too;
now through the game
I bring my bare back
to your villainy.

Fate is against me
in health
and virtue,
driven on
and weighted down,
always in chains.
So at this hour
without delay
pluck the vibrating strings;
since Fate
strikes down the strong man,
everyone weep with me!”

Toe Daniël uit die leeukuil gehaal is, was daar geen letsel aan hom nie, omdat hy op sy God vertrou het.

Daniel 6:24

Hy sê toe vir my “Moenie bang wees nie, Daniël, want van die eerste oomblik af dat jy jou ingespan het om insig te kry en jou voor jou God verootmoedig het, is jou gebede verhoor. Ek het gekom in antwoord op jou gebede.

Daniel 10:12

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ANNEXURE 1

ANNEXURE 2

APPENDIX 1

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Value chain fragility and anti-fragility : Danie Jordaan : PhD (Agricultural Economics) research

1. Welcome to this PhD research survey

Dear Respondent,

Thank you for your time. You are invited to participate in a research study about fragility in agribusiness value chains. This study is being conducted by Mr Danie Jordaan from the Department of Agricultural Economics, Extension and Rural Development at the University of Pretoria, under the supervision of Prof Johann Kirsten. This study is part of a dissertation for a PhD in Agricultural Economics at the Department of Agricultural Economics, Extension and Rural Development at University of Pretoria in South Africa.

Thank you for your willingness to participate in this survey. Your highly valued inputs are important to the success of the research, the dissertation and in advancing the field of agribusiness value chain research.

Please send any queries to:
Danie Jordaan
danie.jordaan@up.ac.za
+27 83 785 2857

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2. Disclaimer

As an expert resource person the information you provide in this questionnaire will be used to develop a tool that can be used to assess agribusiness value chain fragility or anti-fragility across a range of contexts (industries, chains, geographies, markets, levels, etc). You will be asked to adjudicate the influence of a number of factors on the fragility or anti-fragility of agribusiness value chains. The purpose of the exercise is to funnel theoretical factors down to a practical number of factors in a tool to assess fragility or anti-fragility in agribusiness value chains.

The questionnaire should take no more than about 1 hour to complete.

There are no known risks if you decide to participate in this research study. There are also no costs to you for participating in the study. No personal or commercial harm is foreseen as a result of participating in the study. The information collected may not benefit you directly, but the information learned in this study should provide more general benefits to the agribusiness field of study and the general agribusiness sector.

This survey will remain confidential, although absolute anonymity cannot be guaranteed over the Internet. No one will be able to identify you, your business or your answers, and no one will know whether or not you participated in the study. Should the data be published, no individual information will be disclosed.

Your participation in this study is voluntary. By completing and submitting the web based survey you are voluntarily agreeing to participate. You are free to decline to complete the questionnaire for any reason.

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3. Overview of research

INTRODUCTION

The environment in which agribusiness value chains must deliver value and derive returns on investment, is becoming increasingly challenging. These challenges are mainly as a result of increasing complexity and interconnectedness. The result is that adverse value chain events are not only more frequent, they are also having a larger impact. Decisions must also increasingly be made in an environment of growing risk and uncertainty.

Moreover, the greater integration of agribusiness chains to more tightly aligned mechanisms is expected to introduce new strategic risks which will require additional analysis and skills to manage and/or mitigate. The gravity of the phenomenon is that adverse events increasingly have a multiplicative rather than an additive impact on value chains and their goals.

Whereas the negative impacts (fragility) of events are often the focal discussion point it is also noted and highlighted that positive impacts of events (anti-fragility) are equally relevant. Gains or benefits from disorder are just as appropriate to the discussion as setbacks.

GOALS

In light of the increasingly complex operating environment this PhD research aims to develop a framework to assess how sensitive, fragile or anti-fragile, agribusiness value chains are to adverse events. In lay terms this means identifying that factors that can cause positive or negative domino effects or accelerating impacts in value chains.

The goal of this specific questionnaire is to consult strategic value chain stakeholders for informed views on the relevance and importance of a range of factors that make chains susceptible to domino effects or accelerating impacts. This process is aimed at reducing a range of theoretical factors. identified from literature, to a practical tool to assess fragility or anti-fragility. Being able to identify and quantify these factors will enable improved decision making for value chain stakeholders.

DEFINITION

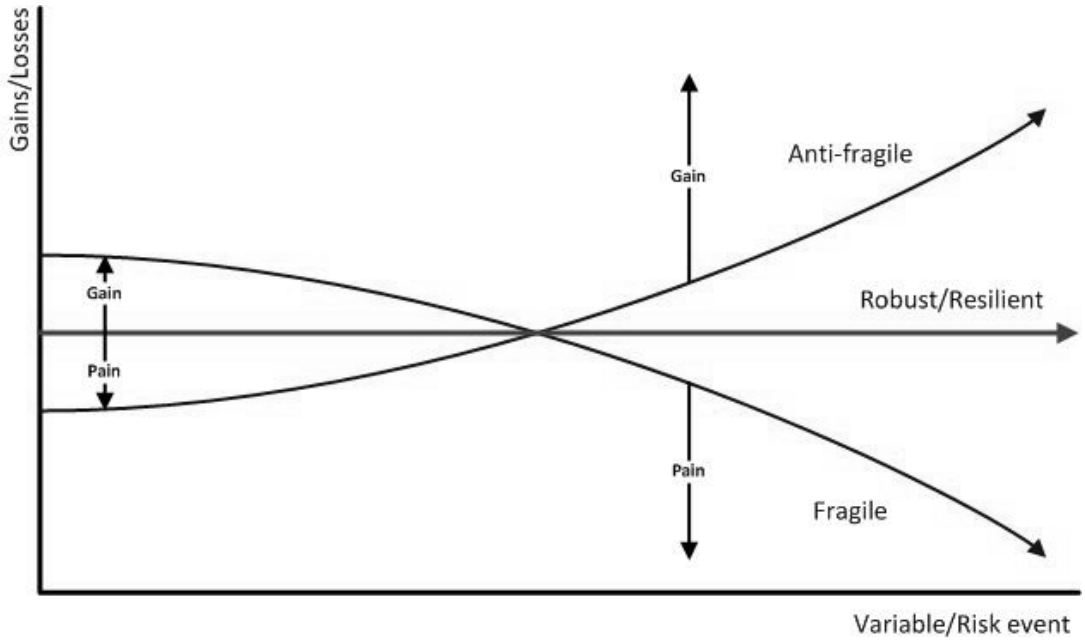
A fragile thing - like a fine crystal wine glass - is easily broken when subjected to a stressor, such as being dropped. An anti-fragile thing - like a human being - gains from being subjected to a specific type of stressor, like exercise.

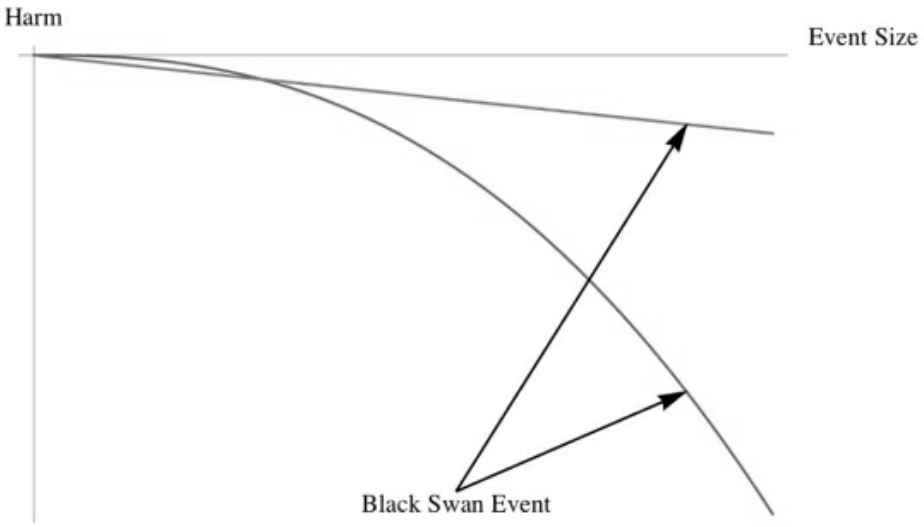
Fragility, in the context of value chains, therefore describes a value chain that exhibits a disproportionate response to an adverse event. This is similar to a domino or ripple effect that spills into the chain and has an impact throughout a chain.

Fragility is also defined as an accelerating **negative sensitivity** to a harmful stressor. As such fragility is observed as a concave curve in losses in reaction to random events and mathematically culminates in more losses than gains from random risky events.

Conversely, anti-fragility is defined as an accelerating **positive sensitivity** to a harmful stressor. As such anti-fragility is observed as a convex curve in gains in reaction to random events and mathematically culminates in more gains than losses from random risky events.

The two images below illustrate the principles of fragility and ant-fragility graphically. Fragility is often also associated with the term "black swan" event, in the case of harmful events and impacts.





EXAMPLE

The following example illustrates fragility and anti-fragility in action.

Adverse event

- In January 2013 inspectors found horse DNA in frozen beef burgers in a UK supermarket

Accelerating impacts

- Stores and suppliers removed all processed meat products labelled as beef from their shelves.
- Some products contained up to 100% horse meat
- Frozen burger sales tumbled 41%, frozen ready meals saw a sharp drop in sales, falling 11% in March and 15% in April
- Three meat processing plants closed down
- Consumer habits changed irreversibly, 25% of consumers bought less processed meat products
- Twelve retailers in Britain, France, Sweden Czech Republic, Belgium, the Netherlands and Portugal were affected
- The reputation of the main retailers declined by up to 20%
- Butchers and farmers' markets, where a clear link between products and their source is visible, boomed (**anti-fragile response**) at the expense of retailers where the source of the products is not so visible

INSTRUCTIONS

Please complete all of the following questions, in the context of your frame of reference in the agribusiness value chain environment, by considering the **relevance** and the **importance** of each of these factors as an indicator of their influence in determining value chain fragility or anti-fragility.

The factors are grouped into three categories: Internal, External and Chain factors.

Please keep in mind that the response or impacts of an event in a chain can be negative (fragile), unaffected (robust or resilient) positive (anti-fragile). The purpose is to specifically focus on factors that influence fragility or anti-fragility.

Please also note that the concepts of fragility and anti-fragility can be relevant to dimensions of **finance**, **economics**, **reputation**, **safety and quality**, **relationships**, etc. in chains.

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4. Introduction

Agricultural value chain risk and fragility measurement

1. Profile information

Resondent's name	
Company	
Address	
Address 2	
City / Town	
State / Province	
ZIP / Postal Code	
Country	
Email	
Phone	

2. Given your participation in the research you have the option to choose to receive specific feedback about the outcome of the research. Please indicate your preference below.

- ◯ Yes, I would like to be updated with the results of the research
- ◯ No, I prefer not to be updated with the results of the research

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5. Enterprise profile

3. Please indicate your, your company or your business unit's function in the value chain (More than one option is available for vertically integrated operations)

- [ ] Input provider (Animal health, Seed, Fertilizer, Crop protection, etc)
- [ ] Farmer/Producer
- [ ] Level 1 Processing/Value addition (Abattoir, Packhouse, Topmaker)
- [ ] Level 2 Processing/Value addition (Meat packer, Butchery, Re-packer, Spinner, Processor)
- [ ] Level 3 Processing/Value addition (Weaver)
- [ ] Level 4 Processing/Value addition (Garment maker)
- [ ] Wholesaler/Distributor
- [ ] Retailer
- [ ] Intermediary/Support function (Broker, Financier, Insurer, Re-insurer, Advisor, Consultant, Industry body, State agencies)
- [ ] Third party (Academic)
- [ ] Other (please specify)

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6. INTERNAL FACTORS INFLUENCING FRAGILITY

4. Which **management** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Presence, or not, of risk committee at board level	○	○	○	○	○
Risk appetite of board	○	○	○	○	○
Risk appetite of management	○	○	○	○	○
Presence, or not, of risk analysis	○	○	○	○	○
Presence, or not, of a risk and disaster management plan	○	○	○	○	○
Presence, or not, of a risk and recovery plan	○	○	○	○	○
Risk culture of enterprise	○	○	○	○	○
Ethical principles and morals of enterprise	○	○	○	○	○

5. Which **inbound logistic** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Breakdowns	○	○	○	○	○
Damage en-route	○	○	○	○	○
Shipping mishaps	○	○	○	○	○
Accidents	○	○	○	○	○
Outsourcing	○	○	○	○	○

6. Which **operational** factors influence fragility

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Product shelflife	○	○	○	○	○
Product quality and safety standards	○	○	○	○	○
Specific storage requirements	○	○	○	○	○
Customer concerns about safety and quality	○	○	○	○	○
Customization level required	○	○	○	○	○
Differences between own products	○	○	○	○	○
Reliance on environmental events	○	○	○	○	○
Sector legislation	○	○	○	○	○
Heterogeneity (similarity) of raw materials	○	○	○	○	○
Number of processes	○	○	○	○	○
Number of process steps	○	○	○	○	○
Number of setups	○	○	○	○	○
Specificity of process	○	○	○	○	○
Number/range of different equipment required	○	○	○	○	○
Technical constraints	○	○	○	○	○
Number of critical control points	○	○	○	○	○
Product and process design	○	○	○	○	○
Production capacity	○	○	○	○	○
Operational disruption	○	○	○	○	○
Increasing product assortment or specifications	○	○	○	○	○
Reliability of operations	○	○	○	○	○

7. Which **outbound logistics** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Breakdowns	○	○	○	○	○
Damage en-route	○	○	○	○	○
Shipping mishaps	○	○	○	○	○
Accidents	○	○	○	○	○

8. Which **marketing and sales** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Concentration of buyers	○	○	○	○	○
Failure of buyer	○	○	○	○	○
Buyer quality problems	○	○	○	○	○
Buyer off-take problems	○	○	○	○	○
Significant decrease in prices	○	○	○	○	○
Limitation in agreements	○	○	○	○	○
Lean inventory	○	○	○	○	○
Product quality hazards	○	○	○	○	○
Product safety hazards	○	○	○	○	○

9. Which **procurement** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Variability in the supply of raw materials	○	○	○	○	○
Heterogeneous raw materials	○	○	○	○	○
Concentration of suppliers	○	○	○	○	○
Failure of suppliers	○	○	○	○	○
Supplier quality problems	○	○	○	○	○
Supplier delivery problems	○	○	○	○	○
Significant increases in prices	○	○	○	○	○
Limitation in agreements	○	○	○	○	○

10. Which **financial** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Cash flow risk	○	○	○	○	○
Financial leverage position (Debt ratio)	○	○	○	○	○

11. Which **firm infrastructure** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Sophisticated equipment/infrastructure restrictions	○	○	○	○	○
Relationship specific assets with suppliers	○	○	○	○	○
Relationship specific asests with buyers	○	○	○	○	○
Infrastructure to facilitate information sharing	○	○	○	○	○
Lack of information visibility	○	○	○	○	○
Varying Information, Communication Technology (ICT) standards/capability	○	○	○	○	○

12. Which **human resources** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Labour	○	○	○	○	○
Training	○	○	○	○	○
Professionalism	○	○	○	○	○
Culture and ethics	○	○	○	○	○

13. Which **technology** factors influence fragility?

	Non influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Information security	○	○	○	○	○
Intellectual property	○	○	○	○	○

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7. EXTERNAL FACTORS INFLUENCING FRAGILITY

14. Which **economic** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Market price fluctuation	○	○	○	○	○
State of the economy	○	○	○	○	○
Interest rate	○	○	○	○	○
Foreign exchange rate	○	○	○	○	○

15. Which social/societal factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Political unrest	○	○	○	○	○
Criminal acts	○	○	○	○	○
Negative public relations	○	○	○	○	○
Industrial action	○	○	○	○	○
Changing consumer attitudes towards product/process	○	○	○	○	○

16. Which **geo-political** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Terrorism	○	○	○	○	○
Weaponizing of finance	○	○	○	○	○
Weak political leadership	○	○	○	○	○
Global political instability	○	○	○	○	○
Local political instability	○	○	○	○	○

17. Which **regulatory** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Changes in laws and regulations	○	○	○	○	○
Changes in company dependent rules	○	○	○	○	○
Certifications and compliance	○	○	○	○	○

18. Which **infrastructure** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Poor transport infrastructure	○	○	○	○	○
Insufficient capacity	○	○	○	○	○
Uneven level of technological development/capability	○	○	○	○	○
Third party dependency	○	○	○	○	○

19. Which **environmental** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Natural disasters	○	○	○	○	○
Biological factors	○	○	○	○	○
Man-made hazards	○	○	○	○	○
Unpredictable hazards	○	○	○	○	○

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8. CHAIN FACTORS INFLUENCING FRAGILITY

20. Which chain **collaboration complexity** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Alignment with key suppliers' chain strategy	○	○	○	○	○
Alignment with key buyers' chain strategy	○	○	○	○	○
Relations with key suppliers (coordination)	○	○	○	○	○
Relations with key buyers (coordination)	○	○	○	○	○
Ability to replace key suppliers	○	○	○	○	○
Ability to replace key buyers	○	○	○	○	○
Level of trust and openness with key suppliers	○	○	○	○	○
Level of trust and openness with key buyers	○	○	○	○	○
Similarity of business culture with key suppliers (corporate culture, size & structure)	○	○	○	○	○
Similarity of business culture with key buyers (corporate culture, size & structure)	○	○	○	○	○
Extent of influence on each other's chain decisions (suppliers)	○	○	○	○	○
Extent of influence on each other's chain decisions (buyers)	○	○	○	○	○

21. Which chain **coordination complexity** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Level of information sharing with key suppliers	○	○	○	○	○
Level of information sharing with key buyers	○	○	○	○	○
Integration level of logistic processes with key suppliers	○	○	○	○	○
Integration level of logistic processes with key buyers	○	○	○	○	○
Independence of entities in making logistics decisions (Suppliers)	○	○	○	○	○
Independence of entities in making logistics decisions (Buyers)	○	○	○	○	○
Variability between orders and delivery from key suppliers	○	○	○	○	○
Variability between orders and delivery to key buyers	○	○	○	○	○
Extent of long term orders with suppliers	○	○	○	○	○
Extent of long term orders from buyers	○	○	○	○	○
Degree of communication between multiple tiers of the chain (Supply side)	○	○	○	○	○
Degree of communication between multiple tiers of the chain (Demand side)	○	○	○	○	○
Information technology used with key suppliers	○	○	○	○	○
Information technology used with key buyers	○	○	○	○	○

22. Which chain **configuration complexity** factors influence fragility

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Number of value adding tiers in the chain	○	○	○	○	○
Number of logistics channels in the chain	○	○	○	○	○
Complexity of linkages with suppliers (connections to many other partners with many other channels)	○	○	○	○	○
Complexity of linkages with buyers (connections to many other partners with many other channels)	○	○	○	○	○
Geographical spread of supplier network	○	○	○	○	○
Geographical spread of buyer network	○	○	○	○	○
Duration of exchange relationship with suppliers	○	○	○	○	○
Duration of exchange relationship with buyers	○	○	○	○	○
Level of inter-dependency on key suppliers	○	○	○	○	○
Level of inter-dependency on key buyers	○	○	○	○	○
Rigidity in planning in the chain	○	○	○	○	○

23. Which **information** factors influence fragility?

	Not influential at all	Slightly influential	Somewhat influential	Very influential	Extremely influential
Inadequate decision support system	○	○	○	○	○
Slow information transfer and processing	○	○	○	○	○
Late detection of disturbances	○	○	○	○	○
Lack of data about disturbances	○	○	○	○	○
Inaccuracy of data	○	○	○	○	○
Insufficient data analysis	○	○	○	○	○
Inability to interpret results	○	○	○	○	○
Intellectual property risk	○	○	○	○	○

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9. Optional, open ended feedback

Please provide optional, open ended feedback or recommendations for the research in relation to the specific topics in boxes below.

24. Variables that may have been omitted

25. Relevance and practicality of fragility as a concept

26. Abstractness and/or complexity of concepts

27. Clarity of the questions

28. Any other matters related to this topic

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10. Thank you

Thank you for your valued time and respected inputs!

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Value chain fragility measure

Welcome to this PhD research survey

Dear Respondent,

Thank you for your time. You are invited to participate in a research study about fragility in agribusiness value chains. This study is being conducted by Mr Danie Jordaan from the Department of Agricultural Economics, Extension and Rural Development at the University of Pretoria. This study is part of a dissertation for a PhD in Agricultural Economics at the Department of Agricultural Economics, Extension and Rural Development at University of Pretoria in South Africa.

Thank you for your willingness to participate in this survey. Your highly valued inputs are important to the success of the research, the dissertation and in advancing the field of agribusiness value chain research. There are no known risks if you decide to participate in this research study. There are also no costs to you for participating in the study. No personal or commercial harm is foreseen as a result of participating in the study. The information collected may not benefit you directly, but the information learned in this study should provide more general benefits to the agribusiness field of study and the general agribusiness sector.

This survey will remain confidential, although absolute anonymity cannot be guaranteed over the Internet. No one will be able to identify you, your business or your answers, and no one will know whether or not you participated in the study. Should the research be published, no individual information will be disclosed.

Your participation in this study is voluntary. By completing and submitting the web based survey you are voluntarily agreeing to participate. You are free to decline to complete the questionnaire for any reason.

Please send any queries to:
Danie Jordaan
+27 83 785 2857

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Value chain fragility measure

Overview

INTRODUCTION

The environment in which agribusiness value chains must deliver value and derive returns on investment, is becoming increasingly challenging. These challenges are mainly as a result of increasing complexity and interconnectedness. The result is that adverse value chain events are not only more frequent, they are also having a larger impact. Decisions must also increasingly be made in an environment of growing risk and uncertainty.

GOALS

The goal of this specific questionnaire is to **measure and model the fragility of specific value chains**. Being able to measure fragility will enable improved decision making for value chain stakeholders.

DEFINITION

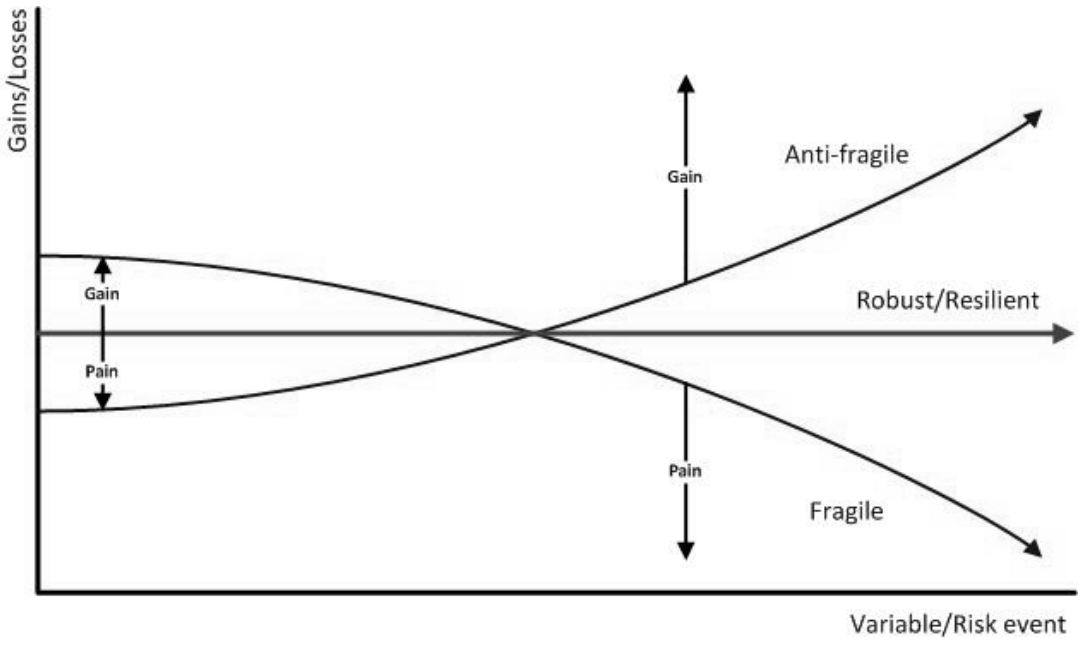
A fragile thing - like a fine crystal wine glass - is easily broken when subjected to a stressor, such as being dropped. An anti-fragile thing - like a human being - gains from being subjected to a specific type of stressor, like exercise.

Fragility, in the context of value chains, therefore describes a value chain that exhibits a disproportionate response to an adverse event. This is similar to a domino or ripple effect that spills into the chain and has an impact throughout a chain.

Fragility is also defined as an accelerating negative sensitivity to a harmful stressor. As such fragility is observed as a concave curve in losses in reaction to random events and mathematically culminates in more losses than gains from random risky events.

Conversely, anti-fragility is defined as an accelerating positive sensitivity to a harmful stressor. As such anti-fragility is observed as a convex curve in gains in reaction to random events and mathematically culminates in more gains than losses from random risky events.

The image below illustrates the principles of fragility and ant-fragility graphically.



AGRIBUSINESS VALUE CHAIN FRAGILITY FACTORS

The following factors were identified as the most influential factors in causing agribusiness value chain fragility. These factors will be used to quantify your specific value chain's fragility.

Chain factors

- Supplier relationship and alignment
- Buyer relationship and alignment
- Information sharing with buyers
- Degree of chain-wide communication
- Degree of chain complexity
- Adequate, accurate, timely data, analysis and decision making

External factors

- State of the economy and prices
- Social stability and public relations
- Changes in public and private compliance requirements
- Quality and adequacy of supporting infrastructure

Internal factors

- Operational reliability
- Product quality & safety performance
- Supplier reliability
- Buyer reliability
- Quality and training of human resources
- Cash flow position
- Information visibility

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Value chain fragility measure

Enterprise profile

1. Please provide details of your company profile

Respondent's name	
Company	
Address	
Address 2	
City/Town	
State/Province	
ZIP/Postal Code	
Country	
Email Address	
Phone Number	

2. Please indicate your, your company or your business unit's function in the value chain (More than one option is available for vertically integrated operations)

- [ ] Input provider (Animal health, Seed, Fertilizer, Crop protection, etc)
- [ ] Farmer/Producer
- [ ] Level 1 Processing/Value addition (Abattoir, Packhouse, Topmaker)
- [ ] Level 2 Processing/Value addition (Meat packer, Butchery, Re-packer, Spinner, Processor)
- [ ] Level 3 Processing/Value addition (Weaver)
- [ ] Level 4 Processing/Value addition (Garment maker)
- [ ] Wholesaler/Distributor
- [ ] Retailer
- [ ] Intermediary/Support function (Broker, Financier, Insurer, Re-insurer, Advisor, Consultant, Industry body, State agencies)

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Value chain fragility measure

Overview of relational interdependecies

3. Please list your **specific supplier and buyer**, **by their name**, in **your value chain** (e.g. 300 John's Organic Lambs OR Danie's Meat Deli)

The specific details are to ensure a full analysis of the specific value chain by surveying every link in the chain. In the case of vertically integrated enterprises please list the preceding function or business unit name.

Supplier/Preceding function. Please name the specific companies or persons to include in further analysis.

Buyer/Consequential function. Please name the specific companies or persons to include in further analysis.

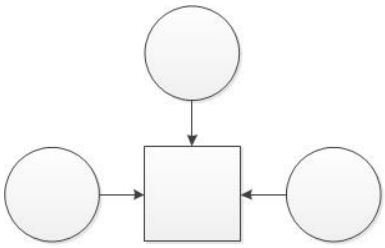
4. What is the nature of the interdependency with your specific supplier (please see diagram below)

- [ ] Pool interdependency (eg. joint marketing, cooperative)
- [ ] Sequential interdependency (eg. standard chain)
- [ ] Reciprocal interdependency (eg. production finance, chain finance)
- [ ] Channel interdependency (eg. brand, quality mark, certification mark)

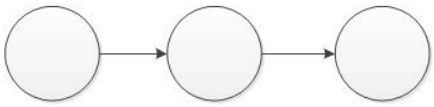
5. What is the nature of the interdependency with your specific buyer (please see explanatory diagram below)

- [ ] Pool interdependency (eg. joint marketing, cooperative)
- [ ] Sequential interdependency (eg. standard chain)
- [ ] Reciprocal interdependency (eg. production finance, chain finance)
- [ ] Channel interdependency (eg. brand, quality mark, certification mark)

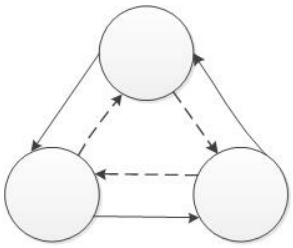
Type of interdependencies



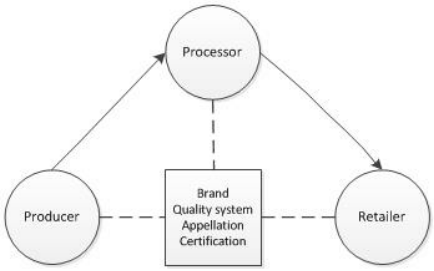
Pooled Interdependencies



Sequential Interdependencies



Reciprocal Interdependencies



Channel Interdependencies

6. What is the degree of interdependency with your specific supplier

- Not interdependent at all/Independent
  (Characterised by self interest, short-term, opportunism, limited information sharing, flexibility)
- Slighlty interdependent
- Somewhat interdependent
- Very interdependent
- Extremely interdependent
  (Characterised by mutual interest, long-term, shared benefits, open information sharing, stability)

7. What is the degree of interdependency with your specific buyer

- Not interdependent at all/Independent
  (Characterised by self interest, short-term, opportunism, limited information sharing, flexibility)
- Slightly interdependent
- Somewhat interdependent
- Very interdependent
- Extremely interdependent
  (Characterised by mutual interest, long-term, shared benefits, open information sharing, stability)

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Value chain fragility measure

Instructions

Please complete all of the following questions, in the context of the agribusiness value chain that you are involved in. Please specifically indicate the impact of changes in each of the factors on your business continuity. The factors are grouped into three categories: Internal, External and Chain factors.

Please keep in mind that **business continuity is defined as a position where a business's operations can continue and that products and services are delivered at predefined levels, that brands and value-creating activities are protected, and that the reputations and interests of key stakeholders are safeguarded whenever disruptive incidents or disturbances occur in the value chain.**

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Value chain fragility measure

Chain factors

8. Please indicate the impact of a deterioration in the**strength and alignment of the relationship with the supplier** (business culture, ethics, size, goals, duration of relationship, quality of relationship) on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

9. Please indicate the impact of a deterioration in the **strength and alignment of the relationship with the buyer** (business culture, ethics, size, goals, processes, duration and quality of relationship, trust) on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

10. Please indicate the impact of a deterioration in **information sharing with buyers** (prices, volume, requirements, disputes, trends, joint planning) on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

11. Please indicate the impact of a deterioration in the **degree of chain-wide communication** (market prices, consumer trends, industry events (like drought, floods, diseases) on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

12. Please indicate the impact of an increase in the **degree of chain complexity** (number of links, number of suppliers, number of buyers, number of products, etc.) on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
10% increase in complexity	○	○	○	○	○	○	○	○	○	○
20% increase in complexity	○	○	○	○	○	○	○	○	○	○
30% increase in complexity	○	○	○	○	○	○	○	○	○	○
40% increase in complexity	○	○	○	○	○	○	○	○	○	○
50% increase in complexity	○	○	○	○	○	○	○	○	○	○
60% increase in complexity	○	○	○	○	○	○	○	○	○	○
70% increase in complexity	○	○	○	○	○	○	○	○	○	○
80% increase in complexity	○	○	○	○	○	○	○	○	○	○
90% increase in complexity	○	○	○	○	○	○	○	○	○	○

13. Please indicate the impact of a deterioration in the **adequacy, accuracy and timeliness of data, analysis and decision making in the chain** (strategic management information) on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

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Value chain fragility measure

External factors

14. Please indicate the impact of a deterioration in the **state of the economy and prices** (interest rates, economic growth rate, consumer spending, consumer debt, market prices, etc.) on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

15. Please indicate the impact of a deterioration in **social stability and public relations of your business** (strikes, protests, socio-economic-political conditions, business's public image, etc), on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

16. Please indicate the impact of **changes in the numner and intensity of public and private compliance requirements (laws, regulations, certifcations, specifications, etc.)** on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
10% increase in number and complexity	○	○	○	○	○	○	○	○	○	○
20% increase in number and complexity	○	○	○	○	○	○	○	○	○	○
30% increase in number and complexity	○	○	○	○	○	○	○	○	○	○
40% increase in number and complexity	○	○	○	○	○	○	○	○	○	○
50% increase in number and complexity	○	○	○	○	○	○	○	○	○	○
60% increase in number and complexity	○	○	○	○	○	○	○	○	○	○
70% increase in number and complexity	○	○	○	○	○	○	○	○	○	○
80% increase in number and complexity	○	○	○	○	○	○	○	○	○	○
90% increase in number and complexity	○	○	○	○	○	○	○	○	○	○

17. Please indicate the impact of a deterioration of the **quality and adequacy of supporting infrastructure** (roads, electricity, water, communication, exchanges, etc.) on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

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Value chain fragility measure

Internal factors

18. Please indicate the impact of a deterioration in your**business's operational reliability** on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

19. Please indicate the impact of a deterioration in your**business's product quality & safety performance** on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

20. Please indicate the impact of a deterioration in the **quality and training of you business' human resources** on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

21. Please indicate the impact of a deterioration of **information visibility** (business management system) on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

22. Please indicate the impact of a deterioration of **cashflow position** on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

23. Please indicate the impact of a deterioration of **supplier reliability** (failure to perform, quality, delivery, prices) on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

24. Please indicate the impact of a deterioration of **buyer reliability** (failure to perform, prices) on your business' continuity in the following scenarios

	0 to -10% impact	-10% to -20% impact	-20% to -30% impact	-30% to -40% impact	-40% to -50% impact	-50% to -60% impact	-60% to -70% impact	-70% to -80% impact	-80% to -90% impact	-90% to -100 impact
Deterioration by 10%	○	○	○	○	○	○	○	○	○	○
Deterioration by 20%	○	○	○	○	○	○	○	○	○	○
Deterioration by 30%	○	○	○	○	○	○	○	○	○	○
Deterioration by 40%	○	○	○	○	○	○	○	○	○	○
Deterioration by 50%	○	○	○	○	○	○	○	○	○	○
Deterioration by 60%	○	○	○	○	○	○	○	○	○	○
Deterioration by 70%	○	○	○	○	○	○	○	○	○	○
Deterioration by 80%	○	○	○	○	○	○	○	○	○	○
Deterioration by 90%	○	○	○	○	○	○	○	○	○	○

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Value chain fragility measure

Thank you

Thank you for your valued time and respected inputs!

```
FACTOR
  /VARIABLES IM2 IM3 IM7 IM8
  /MISSING MEANSUB
  /ANALYSIS IM2 IM3 IM7 IM8
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		IM2	IM3	IM7	IM8
Correlation	IM2	1.000	.313	.243	.175
	IM3	.313	1.000	.068	.194
	IM7	.243	.068	1.000	.385
	IM8	.175	.194	.385	1.000

Communalities

	Initial	Extraction
IM2	1.000	.598
IM3	1.000	.741
IM7	1.000	.733
IM8	1.000	.640

Extraction Method: Principal Component Analysis.

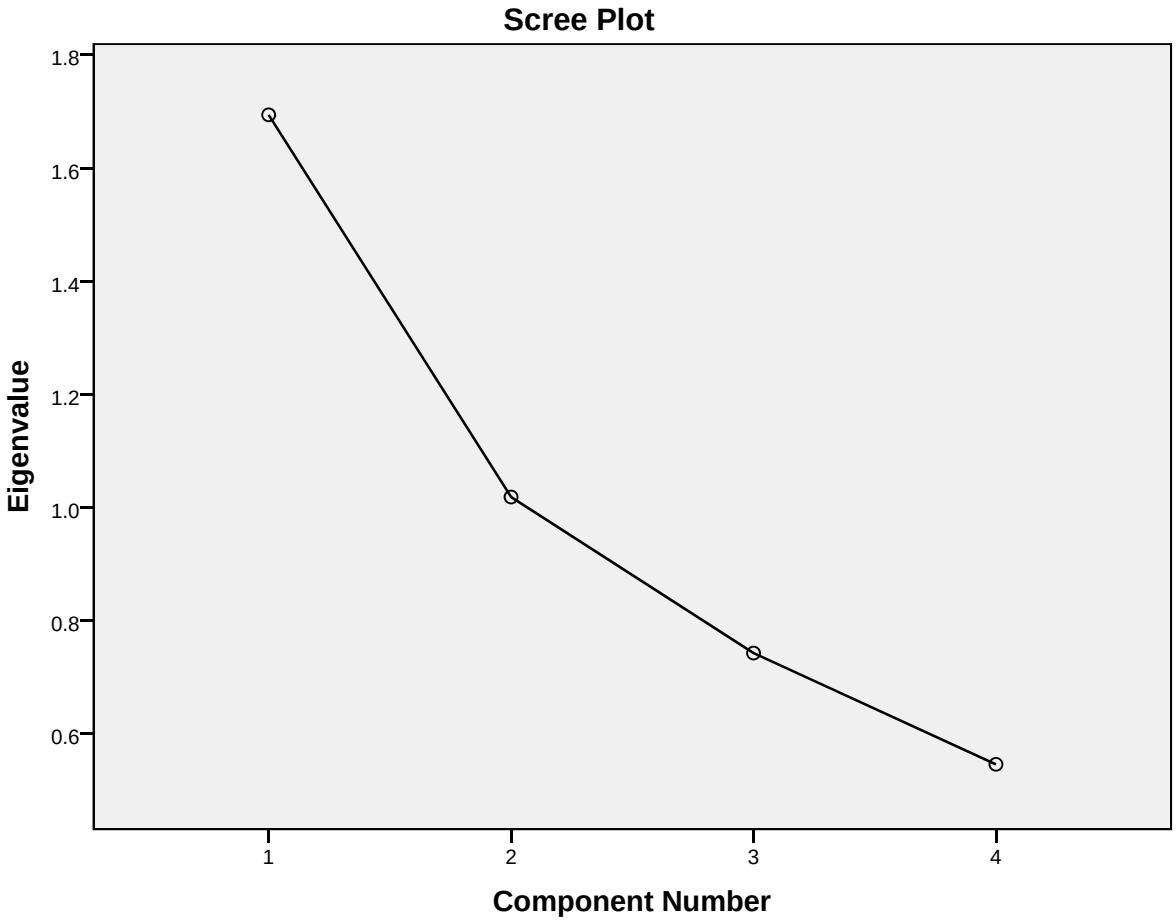
Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of ..
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	1.694	42.355	42.355	1.694	42.355	42.355	1.400
2	1.018	25.455	67.810	1.018	25.455	67.810	1.312
3	.742	18.555	86.365				
4	.545	13.635	100.000				

Total Variance Explained

Component	Rotation Sums of Squared Loadings	
	% of Variance	Cumulative %
1	35.009	35.009
2	32.801	67.810
3		
4		

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component	
	1	2
IM2	.664	.397
IM3	.560	.654
IM7	.674	-.528
IM8	.697	-.392

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
IM2	.237	.736
IM3	-.010	.861
IM7	.855	.047
IM8	.783	.164

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 3 iterations.

Component Transformation Matrix

Component	1	2
1	.752	.659
2	-.659	.752

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

```
FACTOR
  /VARIABLES IOPDC1 IOPDC2 IOPDC3 IOPDC4
  /MISSING MEANSUB
  /ANALYSIS IOPDC1 IOPDC2 IOPDC3 IOPDC4
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
```

```
/CRITERIA MINEIGEN(1) ITERATE(25)
/EXTRACTION PC
/CRITERIA ITERATE(25)
/ROTATION VARIMAX
/SAVE REG(ALL)
/METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		IOPDC1	IOPDC2	IOPDC3	IOPDC4
Correlation	IOPDC1	1.000	.243	.466	.337
	IOPDC2	.243	1.000	.419	.278
	IOPDC3	.466	.419	1.000	.448
	IOPDC4	.337	.278	.448	1.000

Communalities

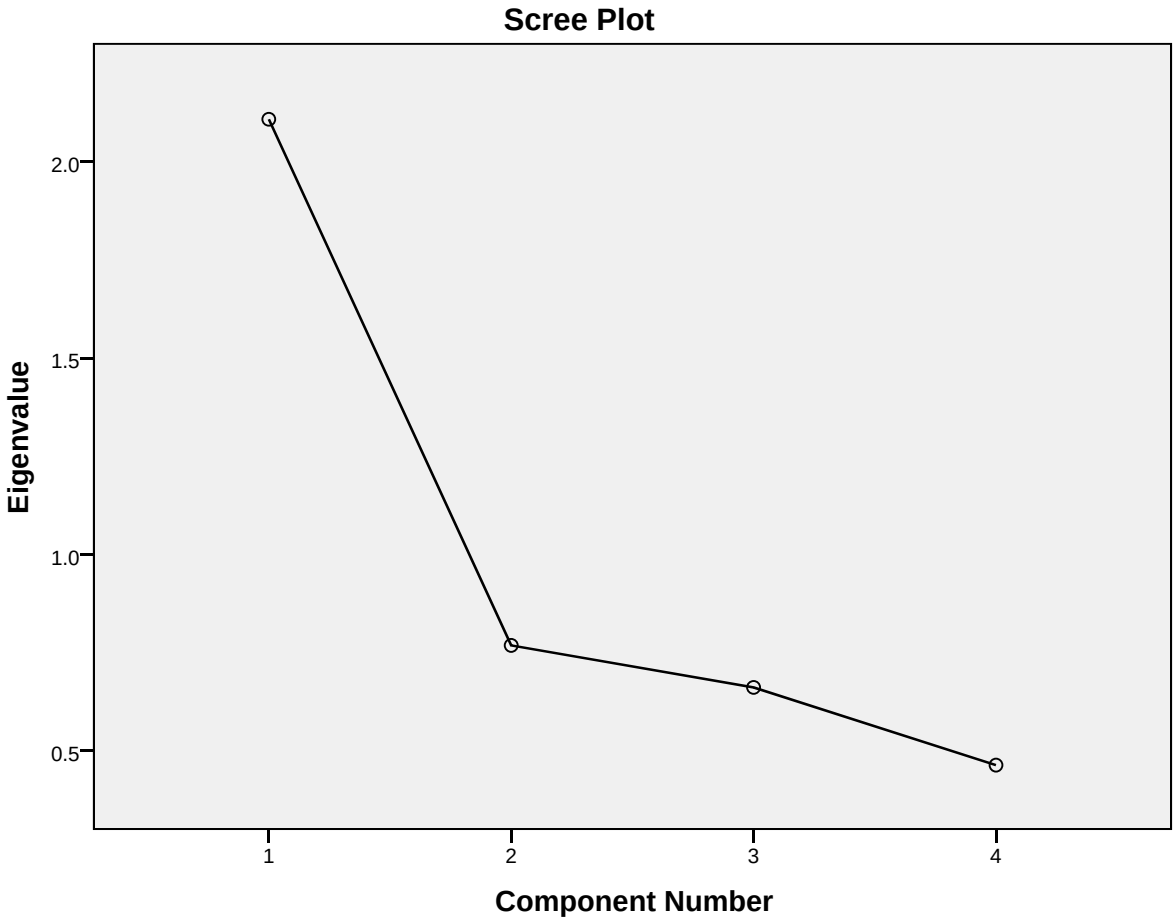
	Initial	Extraction
IOPDC1	1.000	.498
IOPDC2	1.000	.417
IOPDC3	1.000	.687
IOPDC4	1.000	.506

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.108	52.702	52.702	2.108	52.702	52.702
2	.768	19.198	71.900			
3	.661	16.524	88.425			
4	.463	11.575	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component
	1
IOPDC1	.706
IOPDC2	.646
IOPDC3	.829
IOPDC4	.711

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Rotated Component Matrix[a]

a. Only one component was extracted. The solution cannot be rotated.

```
FACTOR
  /VARIABLES IO2 IO3 IO4
  /MISSING MEANSUB
  /ANALYSIS IO2 IO3 IO4
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		IO2	IO3	IO4
Correlation	IO2	1.000	.504	.568
	IO3	.504	1.000	.373
	IO4	.568	.373	1.000

Communalities

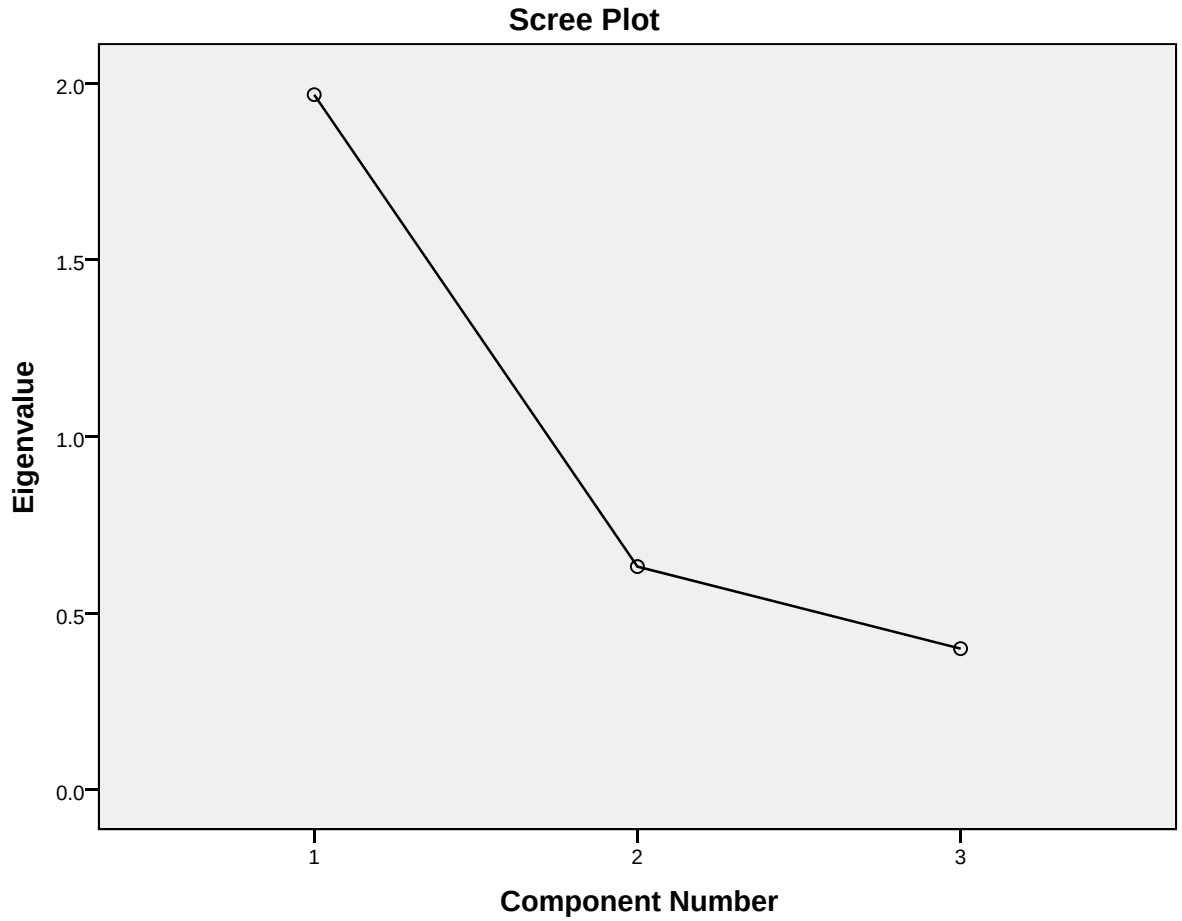
	Initial	Extraction
IO2	1.000	.750
IO3	1.000	.577
IO4	1.000	.642

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.968	65.593	65.593	1.968	65.593	65.593
2	.632	21.074	86.667			
3	.400	13.333	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component
	1
IO2	.866
IO3	.759
IO4	.801

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Rotated Component Matrix[a]

a. Only one component was extracted. The solution cannot be rotated.

```
FACTOR
  /VARIABLES IMK2 IMK3 IMK5 IMK8 IMK9
  /MISSING MEANSUB
  /ANALYSIS IMK2 IMK3 IMK5 IMK8 IMK9
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		IMK2	IMK3	IMK5	IMK8	IMK9
Correlation	IMK2	1.000	.626	.572	.463	.373
	IMK3	.626	1.000	.350	.549	.589
	IMK5	.572	.350	1.000	.340	.195
	IMK8	.463	.549	.340	1.000	.782
	IMK9	.373	.589	.195	.782	1.000

Communalities

	Initial	Extraction
IMK2	1.000	.789
IMK3	1.000	.682
IMK5	1.000	.802
IMK8	1.000	.814
IMK9	1.000	.889

Extraction Method: Principal Component Analysis.

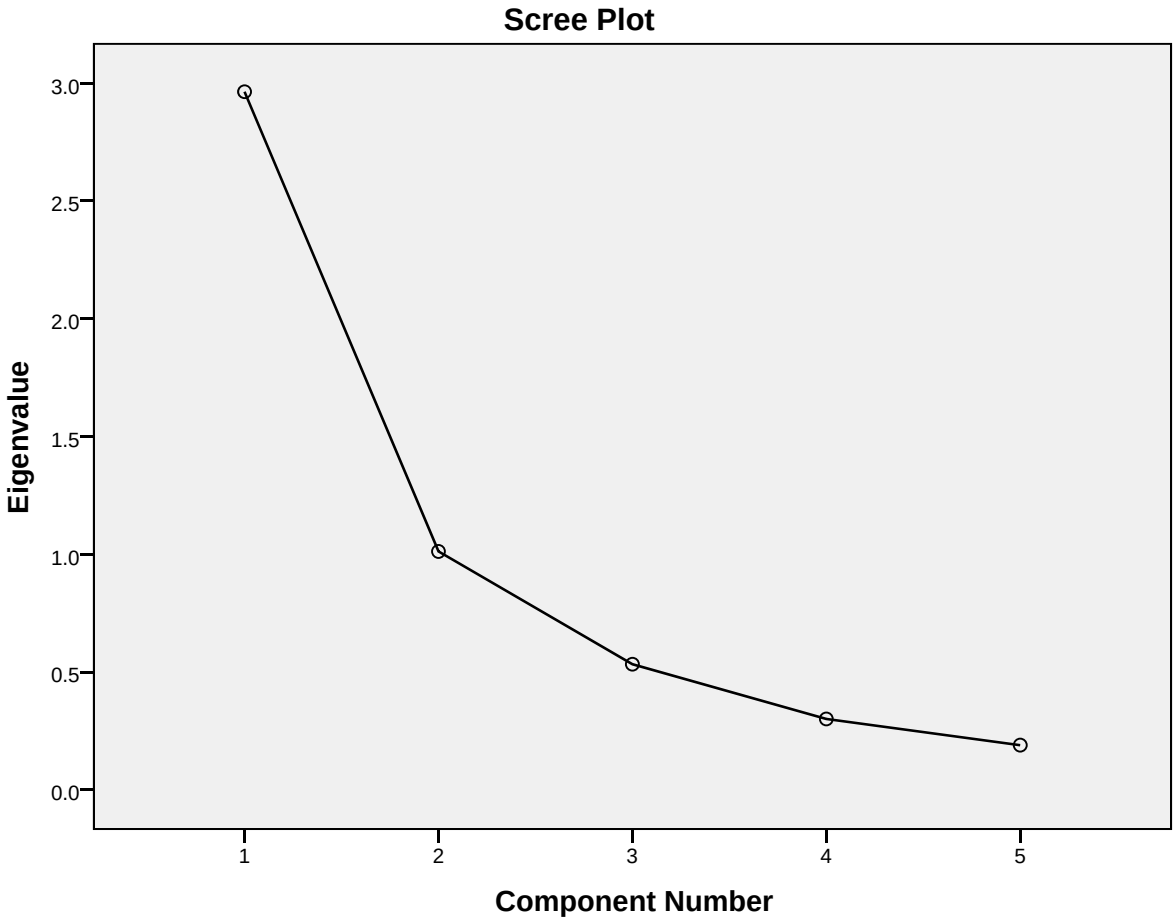
Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of ..
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	2.964	59.272	59.272	2.964	59.272	59.272	2.231
2	1.012	20.242	79.514	1.012	20.242	79.514	1.745
3	.533	10.667	90.181				
4	.301	6.021	96.202				
5	.190	3.798	100.000				

Total Variance Explained

Component	Rotation Sums of Squared Loadings	
	% of Variance	Cumulative %
1	44.612	44.612
2	34.902	79.514
3		
4		
5		

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component	
	1	2
IMK2	.783	.420
IMK3	.825	-.035
IMK5	.598	.667
IMK8	.833	-.348
IMK9	.787	-.519

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
IMK2	.362	.811
IMK3	.673	.478
IMK5	.064	.893
IMK8	.871	.236
IMK9	.940	.072

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 3 iterations.

Component Transformation Matrix

Component	1	2
1	.790	.613
2	-.613	.790

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

```
FACTOR
  /VARIABLES IP4 IP5 IP6 IP7
  /MISSING MEANSUB
  /ANALYSIS IP4 IP5 IP6 IP7
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		IP4	IP5	IP6	IP7
Correlation	IP4	1.000	.556	.617	.362
	IP5	.556	1.000	.791	.353
	IP6	.617	.791	1.000	.404
	IP7	.362	.353	.404	1.000

Communalities

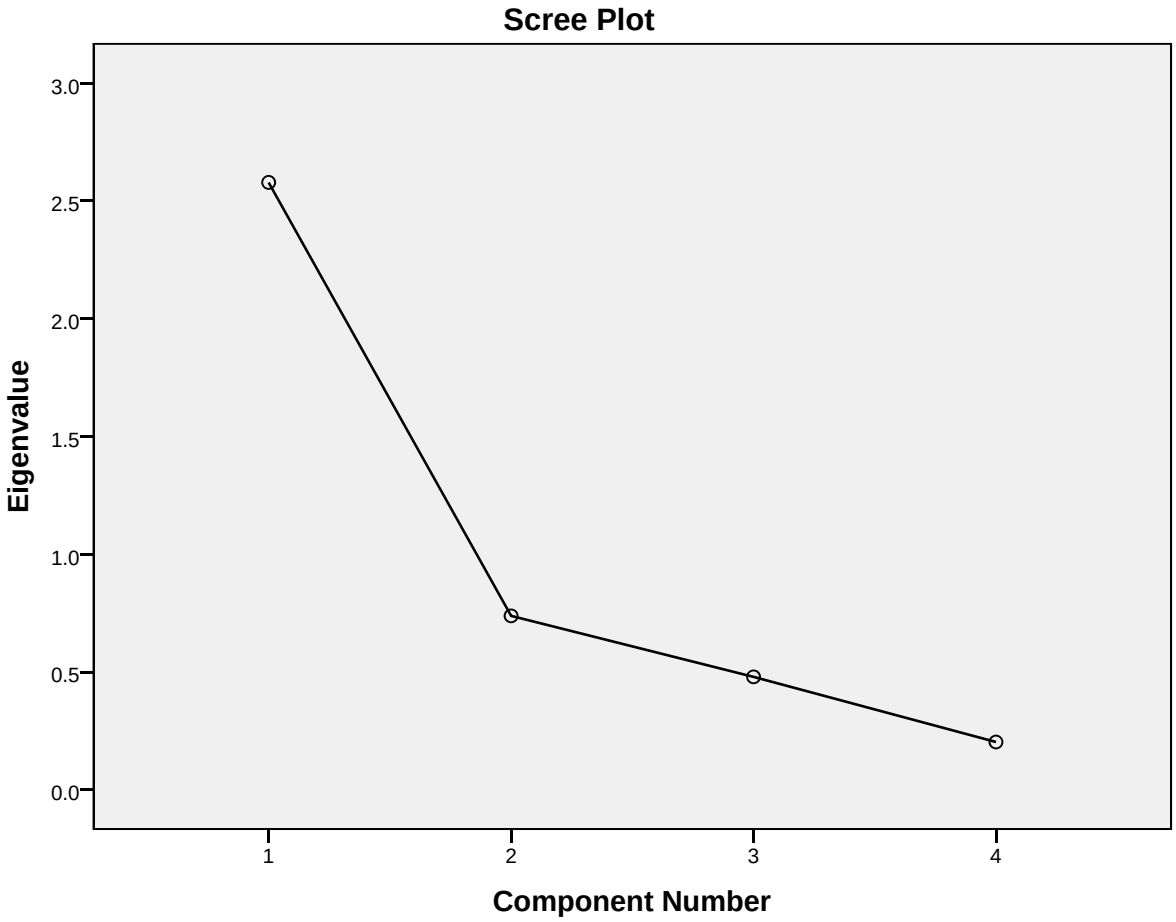
	Initial	Extraction
IP4	1.000	.637
IP5	1.000	.756
IP6	1.000	.815
IP7	1.000	.370

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.579	64.466	64.466	2.579	64.466	64.466
2	.739	18.463	82.929			
3	.480	11.993	94.922			
4	.203	5.078	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component
	1
IP4	.798
IP5	.869
IP6	.903
IP7	.608

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Rotated Component Matrix[a]

a. Only one component was extracted. The solution cannot be rotated.

```
FACTOR
  /VARIABLES IHR1 IHR2
  /MISSING MEANSUB
  /ANALYSIS IHR1 IHR2
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		IHR1	IHR2
Correlation	IHR1	1.000	.397
	IHR2	.397	1.000

Communalities

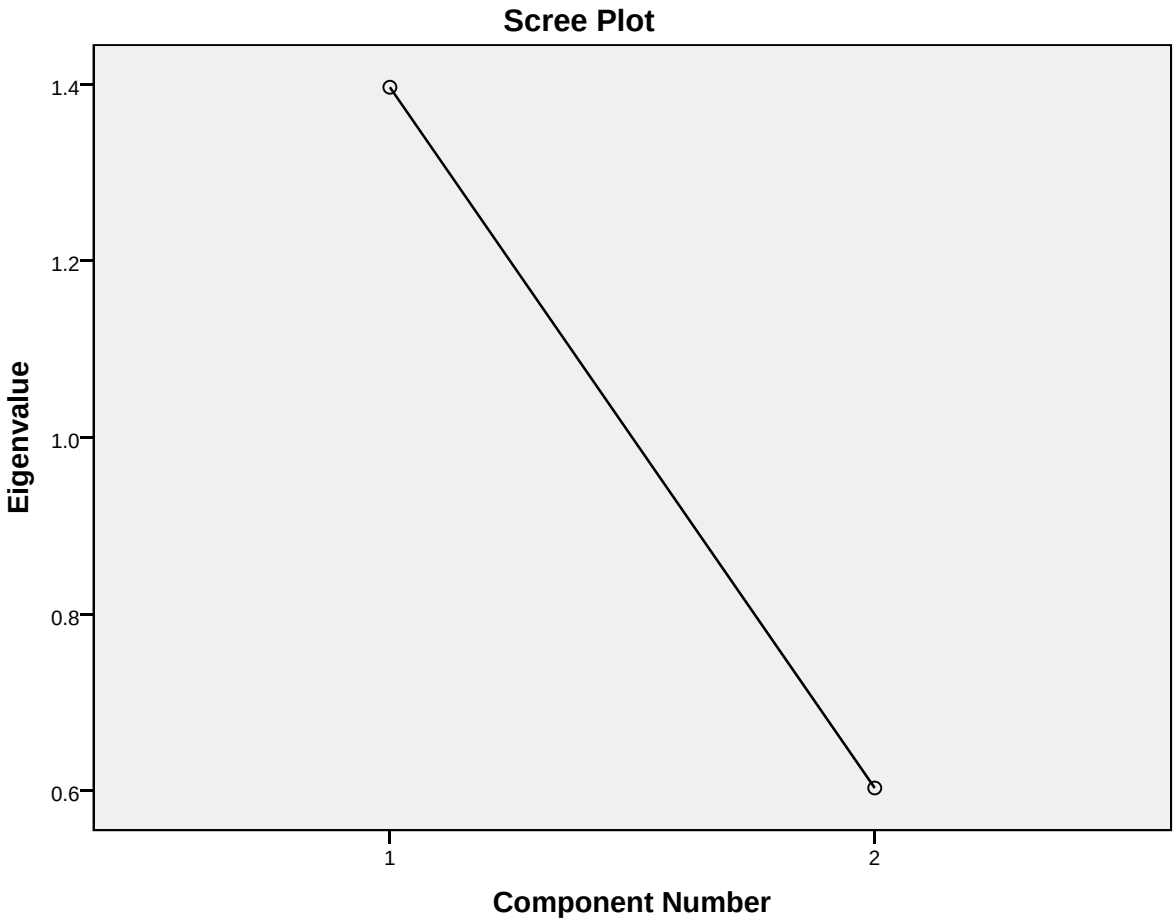
	Initial	Extraction
IHR1	1.000	.698
IHR2	1.000	.698

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.397	69.832	69.832	1.397	69.832	69.832
2	.603	30.168	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component
	1
IHR1	.836
IHR2	.836

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Rotated Component Matrix[a]

a. Only one component was extracted. The solution cannot be rotated.

```
FACTOR
  /VARIABLES EECR1 EECR2 EECR4
  /MISSING MEANSUB
  /ANALYSIS EECR1 EECR2 EECR4
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		EECR1	EECR2	EECR4
Correlation	EECR1	1.000	.634	.471
	EECR2	.634	1.000	.517
	EECR4	.471	.517	1.000

Communalities

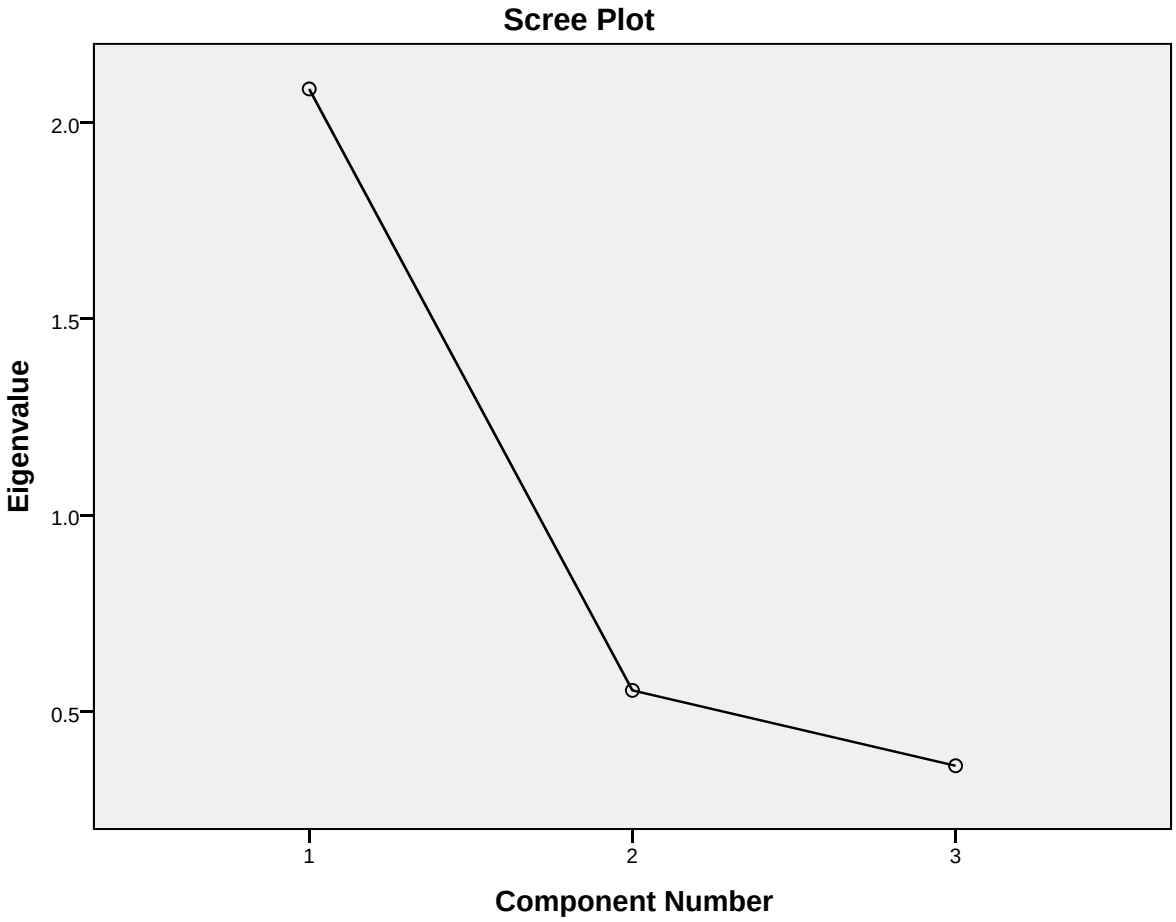
	Initial	Extraction
EECR1	1.000	.719
EECR2	1.000	.755
EECR4	1.000	.612

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.085	69.508	69.508	2.085	69.508	69.508
2	.553	18.447	87.955			
3	.361	12.045	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component
	1
EECR1	.848
EECR2	.869
EECR4	.782

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Rotated Component Matrix[a]

a. Only one component was extracted. The solution cannot be rotated.

```
FACTOR
  /VARIABLES ESCR1 ESCR3 ESCR4
  /MISSING MEANSUB
  /ANALYSIS ESCR1 ESCR3 ESCR4
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		ESCR1	ESCR3	ESCR4
Correlation	ESCR1	1.000	.308	.382
	ESCR3	.308	1.000	.439
	ESCR4	.382	.439	1.000

Communalities

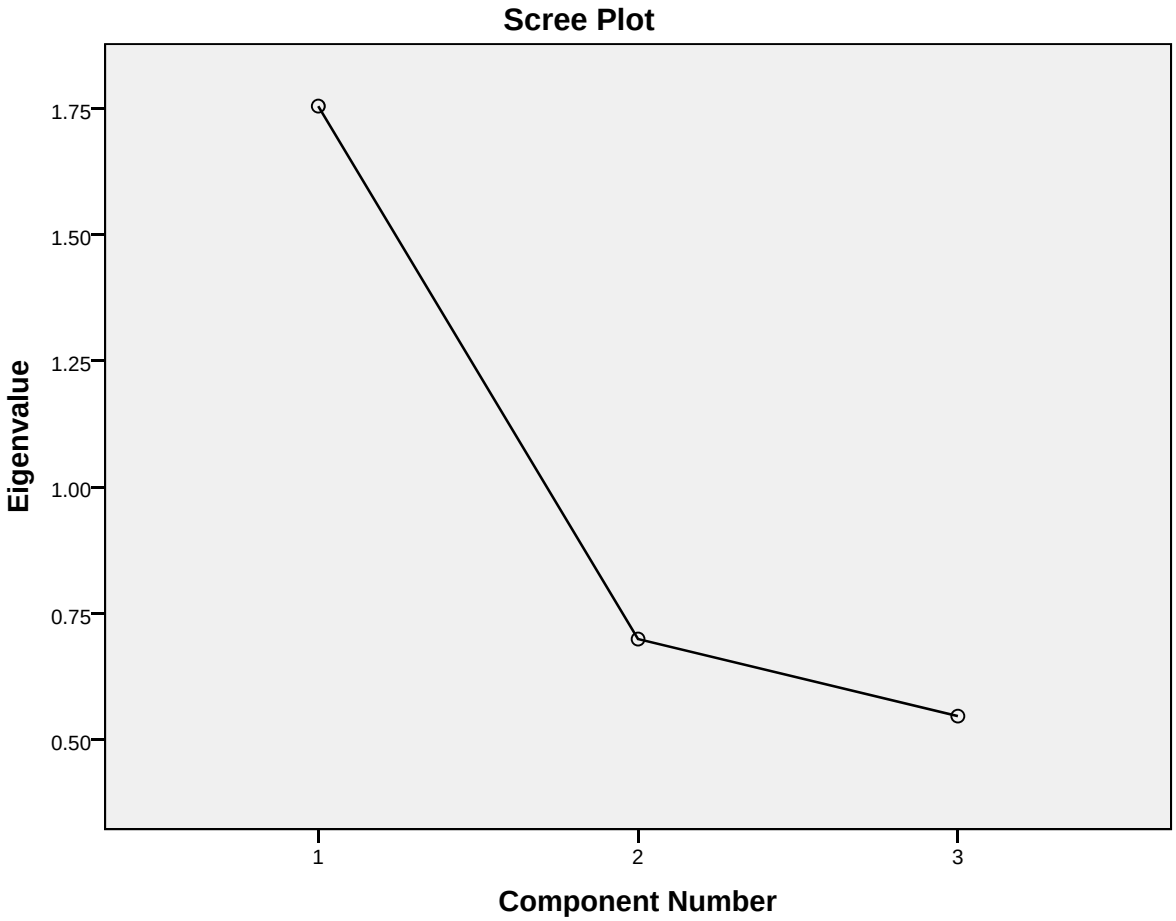
	Initial	Extraction
ESCR1	1.000	.518
ESCR3	1.000	.583
ESCR4	1.000	.653

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.755	58.492	58.492	1.755	58.492	58.492
2	.699	23.298	81.790			
3	.546	18.210	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component
	1
ESCR1	.720
ESCR3	.764
ESCR4	.808

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Rotated Component Matrix[a]

a. Only one component was extracted. The solution cannot be rotated.

```
FACTOR
  /VARIABLES ERR1 ERR3
  /MISSING MEANSUB
  /ANALYSIS ERR1 ERR3
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		ERR1	ERR3
Correlation	ERR1	1.000	.651
	ERR3	.651	1.000

Communalities

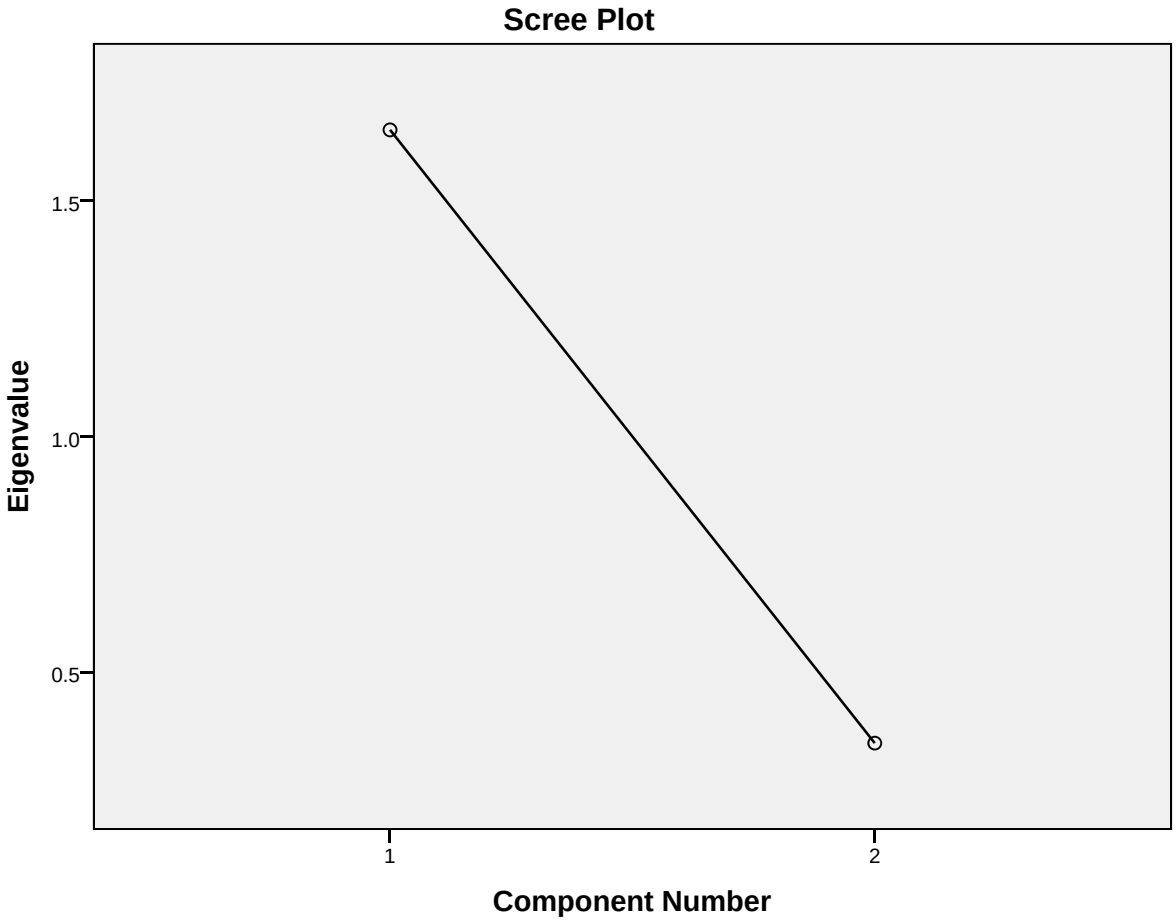
	Initial	Extraction
ERR1	1.000	.825
ERR3	1.000	.825

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.651	82.542	82.542	1.651	82.542	82.542
2	.349	17.458	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component
	1
ERR1	.909
ERR3	.909

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Rotated Component Matrix[a]

a. Only one component was extracted. The solution cannot be rotated.

```
FACTOR
  /VARIABLES EIR1 EIR2
  /MISSING MEANSUB
  /ANALYSIS EIR1 EIR2
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		EIR1	EIR2
Correlation	EIR1	1.000	.793
	EIR2	.793	1.000

Communalities

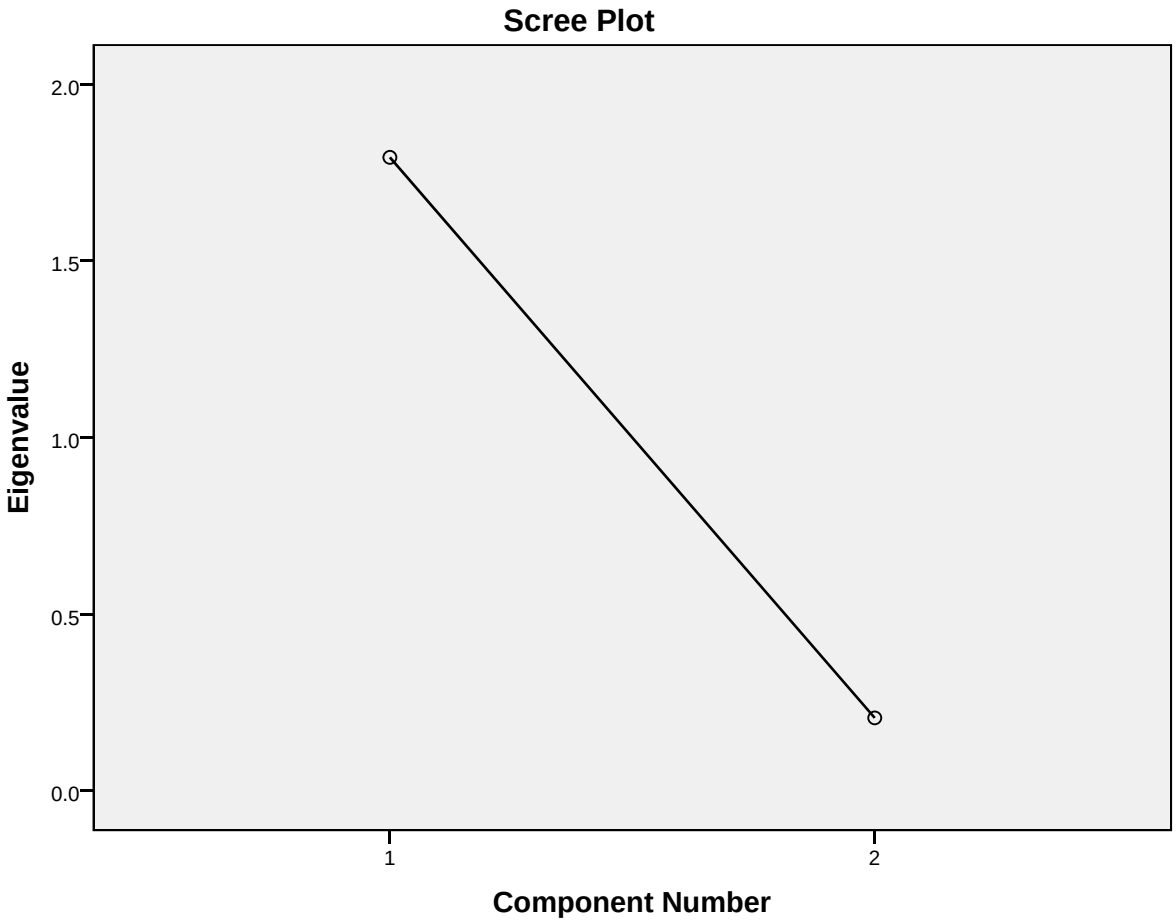
	Initial	Extraction
EIR1	1.000	.897
EIR2	1.000	.897

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.793	89.659	89.659	1.793	89.659	89.659
2	.207	10.341	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component
	1
EIR1	.947
EIR2	.947

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Rotated Component Matrix[a]

a. Only one component was extracted. The solution cannot be rotated.

```
FACTOR
  /VARIABLES CCOLC1 CCOLC2 CCOLC3 CCOLC4 CCOLC5 CCOLC6 CCOLC7 CCOLC8
  /MISSING MEANSUB
  /ANALYSIS CCOLC1 CCOLC2 CCOLC3 CCOLC4 CCOLC5 CCOLC6 CCOLC7 CCOLC8
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		CCOLC1	CCOLC2	CCOLC3	CCOLC4	CCOLC5	CCOLC6
Correlation	CCOLC1	1.000	.631	.685	.492	.569	.367
	CCOLC2	.631	1.000	.483	.750	.623	.627
	CCOLC3	.685	.483	1.000	.656	.541	.361
	CCOLC4	.492	.750	.656	1.000	.518	.610
	CCOLC5	.569	.623	.541	.518	1.000	.716
	CCOLC6	.367	.627	.361	.610	.716	1.000
	CCOLC7	.563	.417	.522	.256	.413	.182
	CCOLC8	.350	.636	.315	.666	.432	.604

Correlation Matrix

		CCOLC7	CCOLC8
Correlation	CCOLC1	.563	.350
	CCOLC2	.417	.636
	CCOLC3	.522	.315
	CCOLC4	.256	.666
	CCOLC5	.413	.432
	CCOLC6	.182	.604
	CCOLC7	1.000	.526
	CCOLC8	.526	1.000

Communalities

	Initial	Extraction
CCOLC1	1.000	.772
CCOLC2	1.000	.764
CCOLC3	1.000	.721
CCOLC4	1.000	.742
CCOLC5	1.000	.636
CCOLC6	1.000	.818
CCOLC7	1.000	.695
CCOLC8	1.000	.622

Extraction Method: Principal Component Analysis.

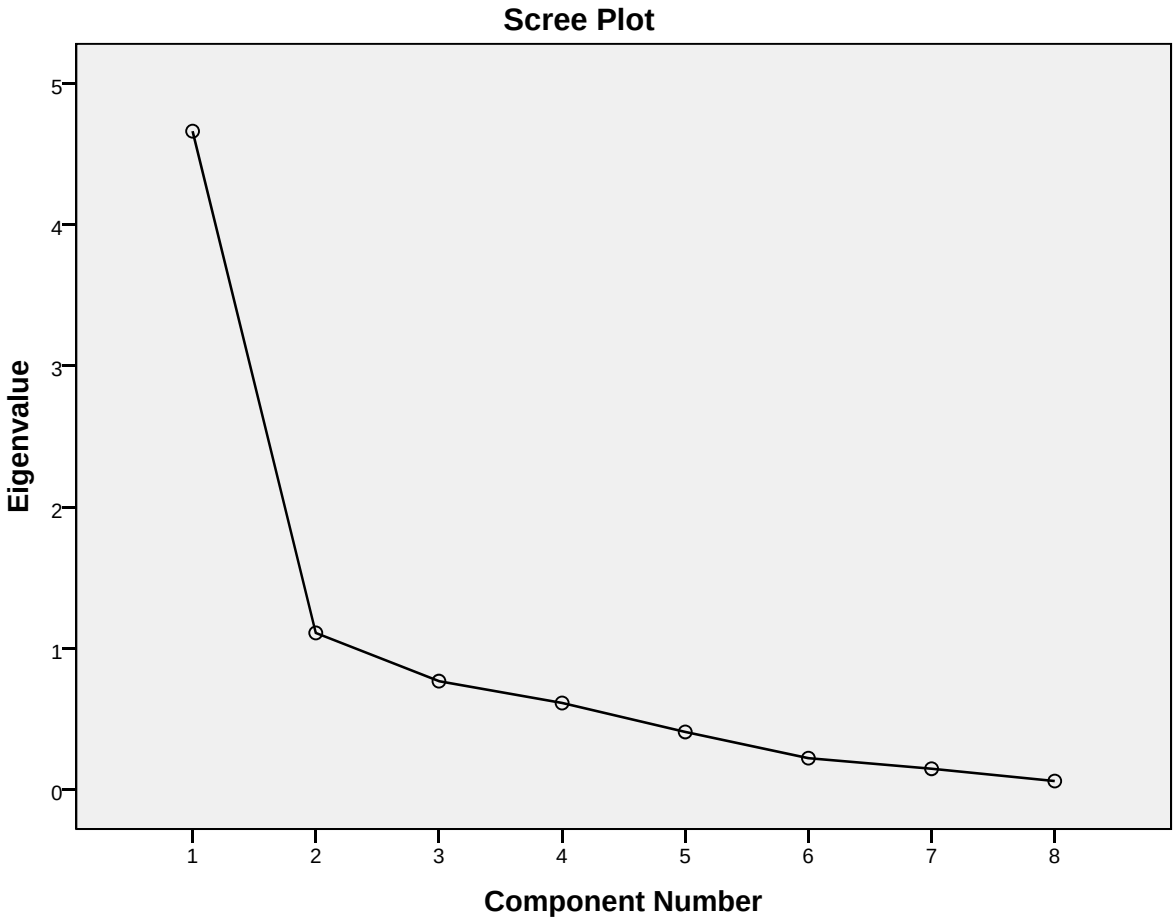
Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of ..
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.660	58.254	58.254	4.660	58.254	58.254	3.282
2	1.110	13.880	72.134	1.110	13.880	72.134	2.489
3	.769	9.615	81.749				
4	.615	7.682	89.431				
5	.410	5.121	94.551				
6	.224	2.802	97.354				
7	.149	1.865	99.219				
8	.063	.781	100.000				

Total Variance Explained

Component	Rotation Sums of Squared Loadings	
	% of Variance	Cumulative %
1	41.027	41.027
2	31.107	72.134
3		
4		
5		
6		
7		
8		

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component	
	1	2
CCOLC1	.761	.439
CCOLC2	.860	-.159
CCOLC3	.745	.407
CCOLC4	.826	-.245
CCOLC5	.793	-.078
CCOLC6	.743	-.516
CCOLC7	.612	.566
CCOLC8	.741	-.270

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
CCOLC1	.322	.818
CCOLC2	.772	.411
CCOLC3	.329	.783
CCOLC4	.798	.323
CCOLC5	.669	.433
CCOLC6	.903	.059
CCOLC7	.126	.824
CCOLC8	.748	.250

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 3 iterations.

Component Transformation Matrix

Component	1	2
1	.782	.623
2	-.623	.782

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

```
FACTOR
  /VARIABLES CCORC1 CCORC2 CCORC6 CCORC8 CCORC9 CCORC11 CCORC12
  /MISSING MEANSUB
  /ANALYSIS CCORC1 CCORC2 CCORC6 CCORC8 CCORC9 CCORC11 CCORC12
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		CCORC1	CCORC2	CCORC6	CCORC8	CCORC9	CCORC11
Correlation	CCORC1	1.000	.326	.029	.047	.497	.483
	CCORC2	.326	1.000	.628	.428	.438	.286
	CCORC6	.029	.628	1.000	.428	.354	.113
	CCORC8	.047	.428	.428	1.000	.376	-.036
	CCORC9	.497	.438	.354	.376	1.000	.445
	CCORC11	.483	.286	.113	-.036	.445	1.000
	CCORC12	.142	.451	.337	.166	.231	.581

Correlation Matrix

		CCORC12
Correlation	CCORC1	.142
	CCORC2	.451
	CCORC6	.337
	CCORC8	.166
	CCORC9	.231
	CCORC11	.581
	CCORC12	1.000

Communalities

	Initial	Extraction
CCORC1	1.000	.816
CCORC2	1.000	.722
CCORC6	1.000	.738
CCORC8	1.000	.691
CCORC9	1.000	.755
CCORC11	1.000	.849
CCORC12	1.000	.871

Extraction Method: Principal Component Analysis.

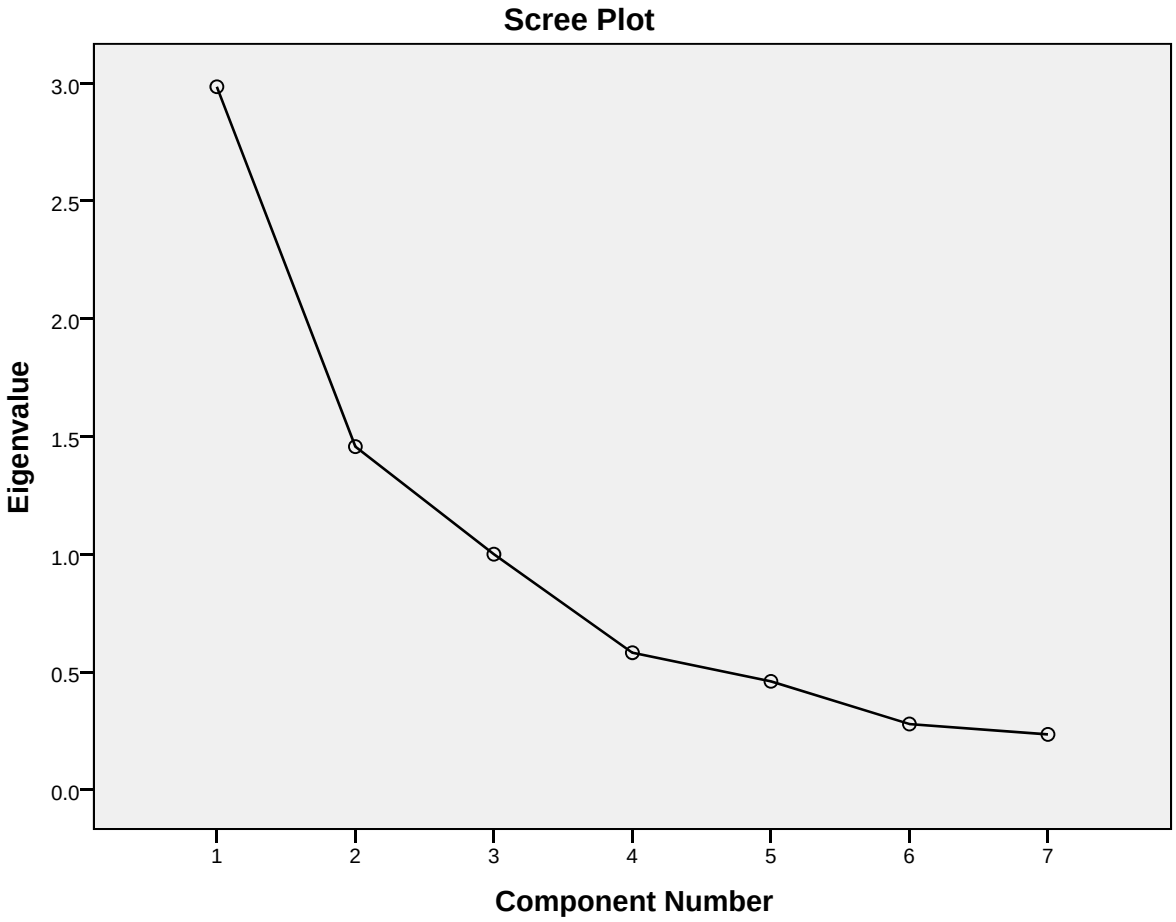
Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of ..
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	2.985	42.641	42.641	2.985	42.641	42.641	2.109
2	1.457	20.815	63.456	1.457	20.815	63.456	1.721
3	1.000	14.291	77.748	1.000	14.291	77.748	1.613
4	.582	8.316	86.063				
5	.461	6.580	92.643				
6	.280	3.993	96.636				
7	.235	3.364	100.000				

Total Variance Explained

Component	Rotation Sums of Squared Loadings	
	% of Variance	Cumulative %
1	30.123	30.123
2	24.586	54.709
3	23.038	77.748
4		
5		
6		
7		

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component		
	1	2	3
CCORC1	.539	.550	.473
CCORC2	.805	-.266	-.052
CCORC6	.650	-.541	-.150
CCORC8	.510	-.601	.263
CCORC9	.741	.115	.439
CCORC11	.630	.628	-.239
CCORC12	.645	.148	-.658

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

Rotated Component Matrix[a]

	Component		
	1	2	3
CCORC1	-.018	.895	.124
CCORC2	.723	.258	.365
CCORC6	.819	-.039	.257
CCORC8	.808	.114	-.155
CCORC9	.438	.745	.097
CCORC11	-.080	.534	.747
CCORC12	.254	.012	.898

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 5 iterations.

Component Transformation Matrix

Component	1	2	3
1	.655	.542	.526
2	-.751	.548	.369
3	.088	.637	-.766

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

```
FACTOR
  /VARIABLES CCONF1 CCONF2 CCONF9 CCONF10
  /MISSING MEANSUB
  /ANALYSIS CCONF1 CCONF2 CCONF9 CCONF10
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		CCONF1	CCONF2	CCONF9	CCONF10
Correlation	CCONF1	1.000	.759	.494	.383
	CCONF2	.759	1.000	.439	.223
	CCONF9	.494	.439	1.000	.524
	CCONF10	.383	.223	.524	1.000

Communalities

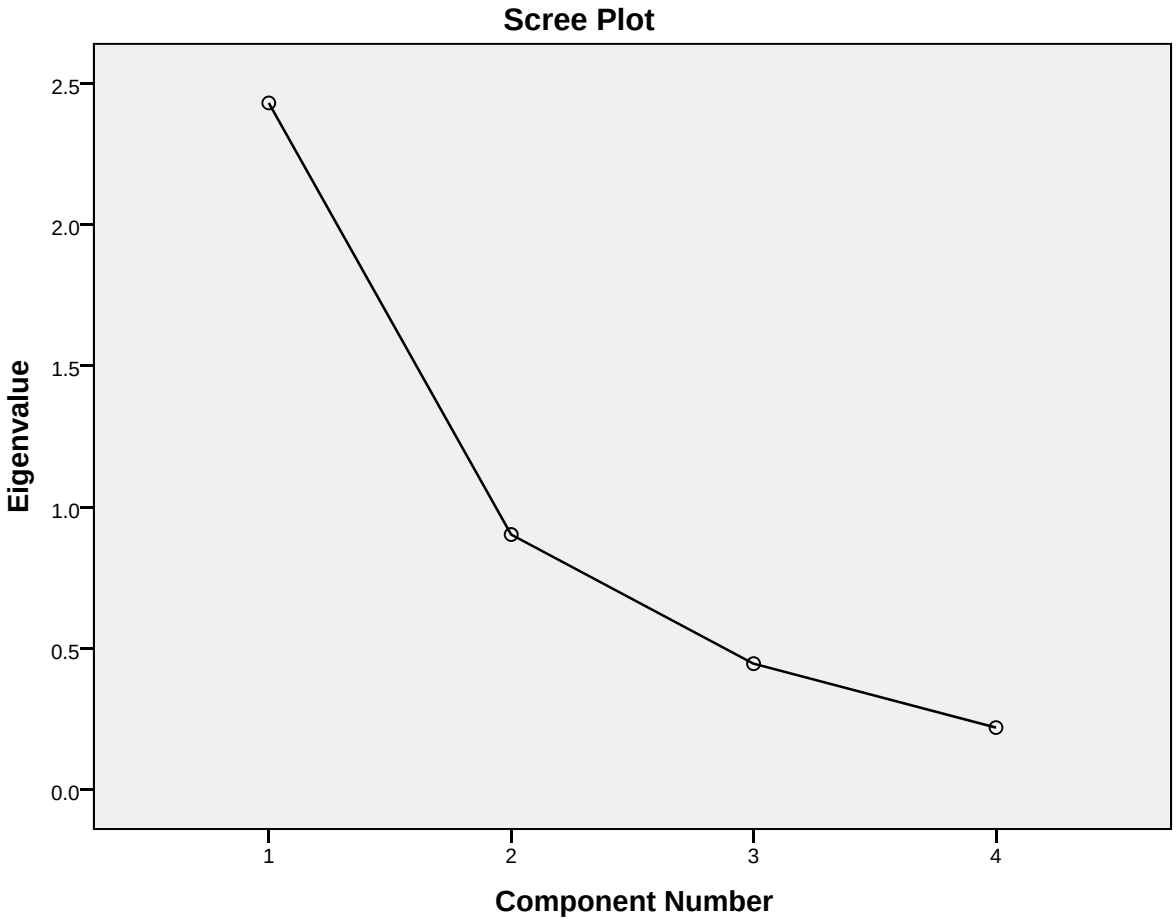
	Initial	Extraction
CCONF1	1.000	.756
CCONF2	1.000	.644
CCONF9	1.000	.614
CCONF10	1.000	.416

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.430	60.751	60.751	2.430	60.751	60.751
2	.903	22.581	83.332			
3	.446	11.159	94.491			
4	.220	5.509	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component
	1
CCONF1	.869
CCONF2	.803
CCONF9	.783
CCONF10	.645

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Rotated Component Matrix[a]

a. Only one component was extracted. The solution cannot be rotated.

```
FACTOR
  /VARIABLES CI1 CI3 CI4 CI5 CI6 CI7
  /MISSING MEANSUB
  /ANALYSIS CI1 CI3 CI4 CI5 CI6 CI7
  /PRINT INITIAL CORRELATION EXTRACTION ROTATION
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.
```

Factor Analysis

Correlation Matrix

		CI1	CI3	CI4	CI5	CI6	CI7
Correlation	CI1	1.000	.432	.429	.501	.553	.521
	CI3	.432	1.000	.797	.504	.409	.538
	CI4	.429	.797	1.000	.560	.401	.485
	CI5	.501	.504	.560	1.000	.597	.522
	CI6	.553	.409	.401	.597	1.000	.718
	CI7	.521	.538	.485	.522	.718	1.000

Communalities

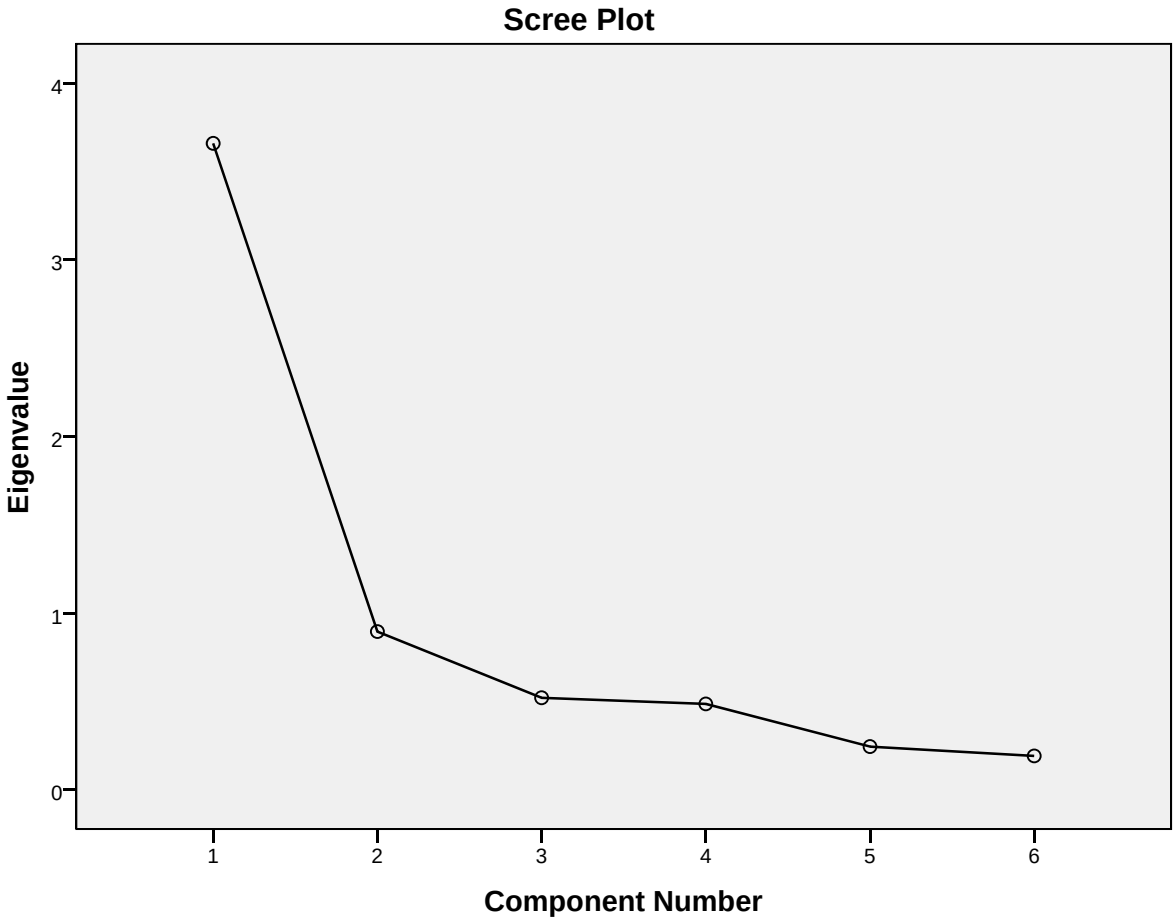
	Initial	Extraction
CI1	1.000	.526
CI3	1.000	.620
CI4	1.000	.616
CI5	1.000	.619
CI6	1.000	.618
CI7	1.000	.659

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.659	60.988	60.988	3.659	60.988	60.988
2	.896	14.932	75.920			
3	.521	8.688	84.608			
4	.486	8.107	92.715			
5	.245	4.083	96.798			
6	.192	3.202	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]

	Component
	1
CI1	.725
CI3	.788
CI4	.785
CI5	.787
CI6	.786
CI7	.812

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Rotated Component Matrix[a]

a. Only one component was extracted. The solution cannot be rotated.

```
RELIABILITY
  /VARIABLES=IFR1 IFI5 FAC1_1 FAC2_1 FAC1_2 FAC1_3 FAC1_4 FAC2_4 FAC1_5 FAC
1_6
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA.

RELIABILITY
  /VARIABLES=IFR1 IFI5 FAC1_1 FAC2_1 FAC1_2 FAC1_3 FAC1_4 FAC2_4 FAC1_5 FAC
1_6
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE ANOVA
  /SUMMARY=TOTAL MEANS VARIANCE COV CORR.
```

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	48	33.6
	Excluded[a]	95	66.4
	Total	143	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.679	.677	10

Item Statistics

	Mean	Std. Deviation	N
IFR1	3.833333	1.078481	48
IFI5	3.604167	.9618153	48
Risk appetite	-.039156	.9396792	48
Risk culture	-.048979	.9839224	48
Product complexity	-.050412	1.012834	48
Operational reliability	-.074692	1.004467	48
Buyer reliability & collapsing price	-.052458	1.004950	48
Product quality & safety	-.038173	1.013462	48
Supplier reliability	-.057208	.9441819	48
Labour & training	-.048088	.9826558	48

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	.703	-.075	3.833	3.908	-51.322	2.530	10
Item Variances	.987	.883	1.163	.280	1.317	.007	10
Inter-Item Covariances	.172	-.246	.579	.826	-2.351	.033	10
Inter-Item Correlations	.173	-.241	.611	.851	-2.538	.033	10

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
IFR1	3.195001	20.330	.400	.452	.643
IFI5	3.424167	21.784	.298	.349	.663
Risk appetite	7.067490	23.155	.149	.274	.688
Risk culture	7.077313	24.655	-.025	.136	.719
Product complexity	7.078746	21.287	.328	.329	.658
Operational reliability	7.103026	19.425	.559	.480	.612
Buyer reliability & collapsing price	7.080792	20.222	.459	.385	.632
Product quality & safety	7.066507	21.122	.347	.288	.654
Supplier reliability	7.085542	20.163	.510	.479	.624
Labour & training	7.076422	20.777	.406	.302	.643

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
7.028334	25.381	5.037995	10

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		119.293	47	2.538		
Within People	Between Items	1092.795	9	121.422	149.084	.000
	Residual	344.514	423	.814		
	Total	1437.309	432	3.327		
Total		1556.601	479	3.250		

Grand Mean = .7028334

```
RELIABILITY
  /VARIABLES=IFR1 IFI5 FAC1_2 FAC1_3 FAC1_4 FAC2_4 FAC1_5 FAC1_6
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE ANOVA
  /SUMMARY=TOTAL MEANS VARIANCE COV CORR.
```

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	48	33.6
	Excluded[a]	95	66.4
	Total	143	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.733	.734	8

Item Statistics

	Mean	Std. Deviation	N
IFR1	3.833333	1.078481	48
IFI5	3.604167	.9618153	48
Product complexity	-.050412	1.012834	48
Operational reliability	-.074692	1.004467	48
Buyer reliability & collapsing price	-.052458	1.004950	48
Product quality & safety	-.038173	1.013462	48
Supplier reliability	-.057208	.9441819	48
Labour & training	-.048088	.9826558	48

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	.890	-.075	3.833	3.908	-51.322	3.053	8
Item Variances	1.002	.891	1.163	.272	1.305	.007	8
Inter-Item Covariances	.256	-.023	.579	.603	-24.810	.022	8
Inter-Item Correlations	.256	-.023	.611	.634	-26.643	.021	8

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
IFR1	3.283136	16.890	.486	.406	.693
IFI5	3.512302	18.309	.380	.253	.715
Product complexity	7.166881	19.206	.240	.248	.742
Operational reliability	7.191161	16.727	.563	.466	.678
Buyer reliability & collapsing price	7.168927	17.708	.431	.373	.705
Product quality & safety	7.154642	18.403	.337	.245	.724
Supplier reliability	7.173677	17.241	.540	.462	.684
Labour & training	7.164557	17.714	.445	.298	.702

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
7.116469	22.364	4.729031	8

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		131.387	47	2.795		
Within People	Between Items	1025.849	7	146.550	196.461	.000
	Residual	245.418	329	.746		
	Total	1271.267	336	3.784		
Total		1402.654	383	3.662		

Grand Mean = .8895586

```
RELIABILITY
  /VARIABLES=IFR1 IFI5 FAC1_3 FAC1_4 FAC2_4 FAC1_5 FAC1_6
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE ANOVA
  /SUMMARY=TOTAL MEANS VARIANCE COV CORR.
```

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	48	33.6
	Excluded[a]	95	66.4
	Total	143	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.742	.742	7

Item Statistics

	Mean	Std. Deviation	N
IFR1	3.833333	1.078481	48
IFI5	3.604167	.9618153	48
Operational reliability	-.074692	1.004467	48
Buyer reliability & collapsing price	-.052458	1.004950	48
Product quality & safety	-.038173	1.013462	48
Supplier reliability	-.057208	.9441819	48
Labour & training	-.048088	.9826558	48

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	1.024	-.075	3.833	3.908	-51.322	3.394	7
Item Variances	.999	.891	1.163	.272	1.305	.008	7
Inter-Item Covariances	.291	-.023	.579	.603	-24.810	.017	7
Inter-Item Correlations	.291	-.023	.611	.634	-26.643	.017	7

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
IFR1	3.333547	13.709	.543	.398	.690
IFI5	3.562714	15.277	.400	.253	.724
Operational reliability	7.241573	13.889	.575	.462	.683
Buyer reliability & collapsing price	7.219338	15.419	.352	.235	.734
Product quality & safety	7.205054	15.546	.329	.212	.740
Supplier reliability	7.224088	14.561	.521	.454	.697
Labour & training	7.214969	14.622	.482	.293	.705

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
7.166881	19.206	4.382514	7

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		128.957	47	2.744		
Within People	Between Items	977.381	6	162.897	230.107	.000
	Residual	199.633	282	.708		
	Total	1177.013	288	4.087		
Total		1305.971	335	3.898		

Grand Mean = 1.0238401

```
RELIABILITY
  /VARIABLES=FAC1_7 FAC1_8 FAC1_9 FAC1_10 EEF1
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE ANOVA
  /SUMMARY=TOTAL MEANS VARIANCE COV CORR.
```

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	53	37.1
	Excluded[a]	90	62.9
	Total	143	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.757	.755	5

Item Statistics

	Mean	Std. Deviation	N
State of the economy and prices	.0000000	1.000000	53
Social stability and public relations	.0000000	1.000000	53
Changes in laws, regulations & compliance requirements	.0000000	1.000000	53
Poor or insufficient infrastructure	.0000000	1.000000	53
EEF1	4.113208	.8914202	53

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	.823	.000	4.113	4.113	-3.8E+16	3.384	5
Item Variances	.959	.795	1.000	.205	1.258	.008	5
Inter-Item Covariances	.368	.201	.570	.370	2.842	.012	5
Inter-Item Correlations	.381	.225	.570	.345	2.534	.010	5

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
State of the economy and prices	4.113208	7.891	.581	.376	.692
Social stability and public relations	4.113208	8.336	.488	.266	.726
Changes in laws, regulations & compliance requirements	4.113208	7.479	.672	.463	.657
Poor or insufficient infrastructure	4.113208	8.350	.486	.254	.727
EEF1	.0000000	9.209	.398	.172	.754

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
4.113208	12.157	3.486655	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		126.430	52	2.431		
Within People	Between Items	717.343	4	179.336	303.538	.000
	Residual	122.890	208	.591		
	Total	840.234	212	3.963		
Total		966.664	264	3.662		

Grand Mean = .8226415

```
RELIABILITY
  /VARIABLES=FAC1_11 FAC2_11 FAC1_12 FAC2_12 FAC3_12 FAC1_13 FAC1_14
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE ANOVA
  /SUMMARY=TOTAL MEANS VARIANCE COV CORR.
```

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	143	100.0
	Excluded[a]	0	.0
	Total	143	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.686	.686	7

Item Statistics

	Mean	Std. Deviation	N
Supplier relationship and alignment	.0000000	.6051423	143
Buyer relationship and alignment	.0000000	.6051423	143
Information sharing with suppliers and long term orders	.0000000	.6051423	143
Information sharing with buyers independence of buyer logistics and order variablity	.0000000	.6051423	143
Degree of chain communication	.0000000	.6051423	143
Number of chain links, channels and interdependecy	.0000000	.6051423	143
Sufficient, accurate, timely data, analysis and decision support	.0000000	.6051423	143

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	.000	.000	.000	.000	-1.322	.000	7
Item Variances	.366	.366	.366	.000	1.000	.000	7
Inter-Item Covariances	.087	-.007	.256	.263	-36.667	.006	7
Inter-Item Correlations	.238	-.019	.700	.719	-36.667	.041	7

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Supplier relationship and alignment	.0000000	4.579	.492	.618	.624
Buyer relationship and alignment	.0000000	4.911	.351	.414	.663
Information sharing with suppliers and long term orders	.0000000	4.988	.320	.536	.671
Information sharing with buyers independence of buyer logistics and order variablity	.0000000	5.064	.290	.397	.679
Degree of chain communication	.0000000	5.108	.272	.253	.684
Number of chain links, channels and interdependecy	.0000000	4.351	.595	.373	.594
Sufficient, accurate, timely data, analysis and decision support	.0000000	4.659	.457	.257	.634

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
.0000000	6.219	2.493866	7

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		126.164	142	.888		
Within People	Between Items	.000	6	.000	.000	1.000
	Residual	237.836	852	.279		
	Total	237.836	858	.277		
Total		364.000	1000	.364		

Grand Mean = .0000000

```
RELIABILITY
  /VARIABLES=FAC1_11 FAC2_11 FAC1_12 FAC2_12 FAC3_12 FAC1_13 FAC1_14 EEF1 F
AC1_7 FAC1_8 FAC1_9 FAC1_10 FAC1_3 FAC1_4 FAC2_4 FAC1_5 FAC1_6 IFR1 IFI5
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE ANOVA
  /SUMMARY=TOTAL MEANS VARIANCE COV CORR.
```

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	48	33.6
	Excluded[a]	95	66.4
	Total	143	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.866	.865	19

Item Statistics

	Mean	Std. Deviation	N
Supplier relationship and alignment	-.046779	1.035133	48
Buyer relationship and alignment	-.008064	1.025102	48
Information sharing with suppliers and long term orders	-.025940	1.007245	48
Information sharing with buyers independence of buyer logistics and order variablity	.0554141	.9525899	48
Degree of chain communication	-.039864	1.020797	48
Number of chain links, channels and interdependecy	-.023785	.9785622	48
Sufficient, accurate, timely data, analysis and decision support	-.060359	1.013326	48
EEF1	4.041667	.8981857	48
State of the economy and prices	-.083678	1.007081	48
Social stability and public relations	-.038323	.9941677	48
Changes in laws, regulations & compliance requirements	-.063662	1.005056	48
Poor or insufficient infrastructure	-.111415	.9725366	48
Operational reliability	-.074692	1.004467	48
Buyer reliability & collapsing price	-.052458	1.004950	48
Product quality & safety	-.038173	1.013462	48
Supplier reliability	-.057208	.9441819	48
Labour & training	-.048088	.9826558	48
IFR1	3.833333	1.078481	48
IFI5	3.604167	.9618153	48

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	.566	-.111	4.042	4.153	-36.276	2.110	19
Item Variances	.991	.807	1.163	.356	1.442	.006	19
Inter-Item Covariances	.252	-.201	.741	.942	-3.680	.026	19
Inter-Item Correlations	.252	-.220	.710	.930	-3.236	.026	19

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Supplier relationship and alignment	10.80887	95.440	.413	.829	.862
Buyer relationship and alignment	10.77016	95.196	.431	.579	.861
Information sharing with suppliers and long term orders	10.78803	98.980	.243	.650	.868
Information sharing with buyers independence of buyer logistics and order variablity	10.70668	97.217	.359	.549	.864
Degree of chain communication	10.80196	96.639	.358	.553	.864
Number of chain links, channels and interdependecy	10.78588	92.130	.627	.641	.853
Sufficient, accurate, timely data, analysis and decision support	10.82245	90.890	.670	.662	.851
EEF1	6.720425	100.292	.209	.584	.869
State of the economy and prices	10.84577	92.106	.608	.604	.854

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Social stability and public relations	10.80041	92.302	.606	.717	.854
Changes in laws, regulations & compliance requirements	10.82575	94.715	.467	.676	.860
Poor or insufficient infrastructure	10.87351	95.198	.459	.588	.860
Operational reliability	10.83678	94.074	.502	.645	.858
Buyer reliability & collapsing price	10.81455	96.870	.353	.493	.864
Product quality & safety	10.80026	94.154	.492	.686	.859
Supplier reliability	10.81930	95.670	.449	.695	.860
Labour & training	10.81018	93.668	.538	.530	.857
IFR1	6.928758	91.098	.612	.619	.854
IFI5	7.157925	94.861	.485	.559	.859

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
10.76209	104.863	10.24027	19

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		259.398	47	5.519		
Within People	Between Items	1822.834	18	101.269	136.971	.000
	Residual	625.486	846	.739		
	Total	2448.320	864	2.834		
Total		2707.718	911	2.972		

Grand Mean = .5664259

```
RELIABILITY
  /VARIABLES=FAC1_11 FAC2_11 FAC1_12 FAC2_12 FAC3_12 FAC1_13 FAC1_14 FAC1_7
 FAC1_8 FAC1_9 FAC1_10 FAC1_3 FAC1_4 FAC2_4 FAC1_5 FAC1_6 IFR1 IFI5
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE ANOVA
```

```
  /SUMMARY=TOTAL MEANS VARIANCE COV CORR.

RELIABILITY
  /VARIABLES=FAC1_11 FAC2_11 FAC2_12 FAC3_12 FAC1_13 FAC1_14 FAC1_7 FAC1_8
FAC1_9 FAC1_10 FAC1_3 FAC1_4 FAC2_4 FAC1_5 FAC1_6 IFR1 IFI5
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE ANOVA
  /SUMMARY=TOTAL MEANS VARIANCE COV CORR.
```

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	48	33.6
	Excluded[a]	95	66.4
	Total	143	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.871	.871	17

Item Statistics

	Mean	Std. Deviation	N
Supplier relationship and alignment	-.046779	1.035133	48
Buyer relationship and alignment	-.008064	1.025102	48
Information sharing with buyers independence of buyer logistics and order variablity	.0554141	.9525899	48
Degree of chain communication	-.039864	1.020797	48
Number of chain links, channels and interdependecy	-.023785	.9785622	48
Sufficient, accurate, timely data, analysis and decision support	-.060359	1.013326	48
State of the economy and prices	-.083678	1.007081	48
Social stability and public relations	-.038323	.9941677	48
Changes in laws, regulations & compliance requirements	-.063662	1.005056	48
Poor or insufficient infrastructure	-.111415	.9725366	48
Operational reliability	-.074692	1.004467	48
Buyer reliability & collapsing price	-.052458	1.004950	48
Product quality & safety	-.038173	1.013462	48
Supplier reliability	-.057208	.9441819	48
Labour & training	-.048088	.9826558	48
IFR1	3.833333	1.078481	48
IFI5	3.604167	.9618153	48

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	.397	-.111	3.833	3.945	-34.406	1.566	17
Item Variances	1.000	.891	1.163	.272	1.305	.004	17
Inter-Item Covariances	.285	-.063	.627	.690	-9.936	.020	17
Inter-Item Correlations	.285	-.067	.642	.709	-9.656	.020	17

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Supplier relationship and alignment	6.793144	86.624	.357	.591	.870
Buyer relationship and alignment	6.754429	84.991	.452	.578	.866
Information sharing with buyers independence of buyer logistics and order variablity	6.690950	86.996	.376	.543	.869
Degree of chain communication	6.786229	85.922	.403	.496	.868
Number of chain links, channels and interdependecy	6.770150	82.868	.604	.601	.860
Sufficient, accurate, timely data, analysis and decision support	6.806724	81.084	.683	.655	.856
State of the economy and prices	6.830042	82.665	.595	.604	.860
Social stability and public relations	6.784687	82.809	.596	.682	.860
Changes in laws, regulations & compliance requirements	6.810027	85.238	.449	.657	.866

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Poor or insufficient infrastructure	6.857779	85.440	.456	.545	.866
Operational reliability	6.821057	83.695	.537	.612	.863
Buyer reliability & collapsing price	6.798822	87.054	.348	.424	.871
Product quality & safety	6.784538	85.184	.447	.576	.867
Supplier reliability	6.803572	85.586	.464	.669	.866
Labour & training	6.794452	83.710	.551	.501	.862
IFR1	2.913031	81.386	.618	.618	.859
IFI5	3.142198	84.487	.519	.504	.864

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
6.746364	94.582	9.725340	17

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		261.492	47	5.564		
Within People	Between Items	1202.814	16	75.176	105.119	.000
	Residual	537.791	752	.715		
	Total	1740.606	768	2.266		
Total		2002.098	815	2.457		

Grand Mean = .3968450

```
RELIABILITY
  /VARIABLES=FAC1_11 FAC2_11 FAC2_12 FAC3_12 FAC1_13 FAC1_14 FAC1_7 FAC1_8
FAC1_9 FAC1_10 FAC1_3 FAC2_4 FAC1_5 FAC1_6 IFR1 IFI5
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE ANOVA
  /SUMMARY=TOTAL MEANS VARIANCE COV CORR.
```

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	48	33.6
	Excluded[a]	95	66.4
	Total	143	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.871	.871	16

Item Statistics

	Mean	Std. Deviation	N
Supplier relationship and alignment	-.046779	1.035133	48
Buyer relationship and alignment	-.008064	1.025102	48
Information sharing with buyers independence of buyer logistics and order variablity	.0554141	.9525899	48
Degree of chain communication	-.039864	1.020797	48
Number of chain links, channels and interdependecy	-.023785	.9785622	48
Sufficient, accurate, timely data, analysis and decision support	-.060359	1.013326	48
State of the economy and prices	-.083678	1.007081	48

Item Statistics

	Mean	Std. Deviation	N
Social stability and public relations	-.038323	.9941677	48
Changes in laws, regulations & compliance requirements	-.063662	1.005056	48
Poor or insufficient infrastructure	-.111415	.9725366	48
Operational reliability	-.074692	1.004467	48
Product quality & safety	-.038173	1.013462	48
Supplier reliability	-.057208	.9441819	48
Labour & training	-.048088	.9826558	48
IFR1	3.833333	1.078481	48
IFI5	3.604167	.9618153	48

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	.425	-.111	3.833	3.945	-34.406	1.656	16
Item Variances	1.000	.891	1.163	.272	1.305	.005	16
Inter-Item Covariances	.296	-.063	.627	.690	-9.936	.020	16
Inter-Item Correlations	.296	-.067	.642	.709	-9.656	.020	16

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Supplier relationship and alignment	6.845602	79.104	.374	.587	.869
Buyer relationship and alignment	6.806886	78.019	.441	.549	.866
Information sharing with buyers independence of buyer logistics and order variablity	6.743408	79.584	.386	.534	.868
Degree of chain communication	6.838686	78.861	.394	.493	.868
Number of chain links, channels and interdependecy	6.822608	75.869	.600	.581	.859
Sufficient, accurate, timely data, analysis and decision support	6.859182	74.315	.670	.615	.856
State of the economy and prices	6.882500	75.353	.611	.597	.858
Social stability and public relations	6.837145	75.696	.599	.664	.859
Changes in laws, regulations & compliance requirements	6.862485	78.135	.445	.631	.866
Poor or insufficient infrastructure	6.910237	78.164	.462	.520	.865
Operational reliability	6.873515	76.919	.518	.599	.863
Product quality & safety	6.836996	77.609	.471	.536	.865
Supplier reliability	6.856030	78.709	.445	.645	.866
Labour & training	6.846910	76.660	.548	.501	.861
IFR1	2.965489	74.318	.622	.609	.858
IFI5	3.194656	77.444	.513	.503	.863

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
6.798822	87.054	9.330294	16

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		255.722	47	5.441		
Within People	Between Items	1192.519	15	79.501	112.979	.000
	Residual	496.095	705	.704		
	Total	1688.614	720	2.345		
Total		1944.336	767	2.535		

Grand Mean = .4249264

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  /COMPRESSED.

SAVE OUTFILE='C:\Users\User\Desktop\PhD\Fragility data.sav'
  /COMPRESSED.
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