Coordination strategies in the South African egg value chain: A review of chain performance and fragility

By

Letlama Setene

Submitted in partial fulfilment of requirements for the degree

MSc. Agric (Agricultural Economics)

in the

Department of Agricultural Economics, Extension & Rural Development

Faculty of Natural and Agricultural Science

University of Pretoria

South Africa

June 2020

DECLARATION

I, Letlama Setene, hereby declare that this dissertation which I submit for the degree of MSc. Agric (Agricultural Economics) at the University of Pretoria is my work and that it has not been previously submitted by me for a degree at this and or any institution of higher learning.

Signature ----------**L. Setene**----------

Date ----------**14--June--2020**----------

DEDICATION

To my late father, Mosokoso Johannes Setene

ACKNOWLEDGEMENTS

I send my sincere gratitude towards my supervisor Dr Daniel du Plessis Scheepers Jordaan for his guidance and useful critiques for the completion of this dissertation. My acknowledgement of Dr Jordaan is also for his concept of fragility in the agribusiness value chain, which has inspired this research in South African egg industry. It was my pleasurable privilege to be supervised and mentored by him and I'll treasure this source of pride fondly.

I extend sincerity to the Department of Agricultural Economics, Rural Development and Extension of the University of Pretoria for providing myself with an opportunity to enrol in the department. The department has equipped myself with needed information and knowledge for my career going forward and I feel privileged to be among its alumni. My appreciation is also extended to the Department of Research and Innovation of the University of Pretoria for academic writing assistance by organising writing retreats which made a huge contribution for completion of this dissertation.

My almost gratitude also goes to MasterCard Foundation for financially supporting me with all requirements needed to study at the University of Pretoria and I am forever in its debt. I would also like to send my gratitude to the African Economic Research Consortium (AERC) through its Collaborative Masters in Agricultural and Applied Economics (CMAAE) programme for awarding myself with research funding for this dissertation. I salute the South African Poultry Association for allowing me to conduct a study in the South African egg industry. Additionally, my great thanks go towards the chain players of the industry for their participation in this research.

Lastly but not least, I salute all my postgraduate peers and lecturers for contributing massively to my personal growth and exchanging of ideas in making the completion of this dissertation.

Coordination strategies in the South African egg value chain: A review of chain performance and fragility

By

Letlama Setene

Degree: MSc. Agric (Agricultural Economics)

Department: Agricultural Economics, Extension and Rural Development

Supervisor: Dr D. du P. S. Jordaan

ABSTRACT

The chain players in the South African egg industry pursue increased coordination which results in strategies that are lean and vertically integrated. These strategies include contracts specifications, vertical integration, the formation of alliances based on equity and relation. The strategies reduce transaction costs and risks the industry's value chain to improve its chain performance. These strategies improve chain performance and competitive advantage of business only under certain environmental circumstances.

This dissertation argued that under uncertainty the strategies become fragile due to the interdependencies between chain players. The interdependencies expose the industry's role players to unforeseen disruptive events that are detrimental to business continuity. The events are seemly rising and are associated with uncertainty which has a low probability of occurring but a large impact if it occurs. The uncertainty drives the chain vulnerability which accelerates throughout the whole chain as a harmful stressor, and that is referred to as chain fragility.

This study aimed to display the most common strategies of coordination in the South African egg industry and the map of its egg value chain. The strategies were divided into two configurations based on the levels of interdependencies between their chain players, which were either high levels or low levels. Then, the fragility measure of both configurations was performed, together with their comparative fragility analysis. The aim was reached by using

the heuristic stress-testing approach, which represented 17 chain fragility factors. A questionnaire was sent to the chain players in the South African egg industry and got completed by a sample size of 73 respondents, mainly retailers, egg producers and pullet rearers. The respondents were required to rate fragility factors as adverse events against their business continuity as they progressively deteriorated.

The results showed the fragility scores of each factor and their imperativeness to each chain player. Hence, factors such as information visibility and relationship with the supplier are imperative for retailers, while factors such as training of human resources and chain complexity are imperative to pullet rearers. Additionally, the factor that is imperative for egg producers is quality and safety performance requirements.

The fragility scores per factor were combined into a fragility composite index of each chain player. Subsequently, the composite index of fragility per chain players was combined into a final composite index that represents the fragility of each of the two configurations. The comparative fragility analysis of the configurations was performed using unequal variance t-test to determine the significant difference of the fragility means of the strategies. The performed t-test resulted in the rejection of the null hypothesis that statistically, there is no significant difference in the chains' fragility means of the two configurations. Precisely, the difference between the chains' strategies is associated with a variety of differences at the factor and chain player level that led up to 21% greater overall chain fragility of the chain with higher levels of interdependency.

The results concur with literature that considers lean and highly integrated strategies result in interdependencies due to increased coordination. Which in return act as catalysts or causes of agri-food chains fragility because they expose them to uncertainties that are disruptive and detrimental. The affirmation of the results of the analysis with the literature put down the central point of this dissertation that there is a trade-off between the chain performance and fragility.

The practical implication of the trade-off is that strategies of increased vertical coordination improve chain performance by reduction of transaction costs and risks within agri-food chains. However, the strategies multiply the fragility of the chains, under uncertainty. Hence, the important strategic choice for chain players of the South African egg industry and their value

chains, is to attain a suitable coordination strategy that balances chain performance and fragility.

This study concluded that the increased vertical coordination strategies improve chain performance under certain environment. But as uncertainty increases the strategies become fragile and contribute to the closure of businesses. Therefore, the following recommendations are made for the stockholders in the South African egg industry; First, a chain structure and its coordination strategies be decentralised in an organisation's value chain management. Second, developing a "layered organisational" structure, which allows for containment of adverse impacts within the system and facilitates learning within and across different layers to drive survivorship. Third, planning for spare capacity. Last, considering which value chain strategy an organisation should pursue to improve chain performance and contain fragility.

Keywords: coordination strategies, chain performance, chain fragility, chain interdependencies, uncertainty, South Africa egg chain

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

LIST OF ACRONYMS

BFAP	Bureau for Food and Agricultural Policy
DAFF	Department of Agriculture, Forestry and Fisheries
DTI	Department of Trade and Industry
HPAI	Highly Pathogenic Avian Influenza
NAMC	National Agricultural Marketing Council
OECD	Organisation for Economic Co-operation and Development
SAPA	South African Poultry Association
SMMEs	Small, Medium, and Micro enterprises
TCE	Transaction Cost Economics
US	United States of America
Weather SA	Weather South Africa

CHAPTER 1
INTRODUCTION

1.1. BACKGROUND

The South African egg industry is represented by very few producers that have integrated strategies or subsidiaries and several small, medium, and micro enterprises (SMMEs) (DAFF, 2018; SAPA, 2017). The production of eggs occurs throughout all nine provinces of the country; however, KwaZulu-Natal appears to be the top pullet-rearing province (DAFF, 2018). The industry makes the production of eggs the fourth-largest animal product in South African agriculture: over the past ten years, the industry's annual gross turnover has averaged R8.1 billion (DAFF, 2018). The domestic egg chain is dominated by a small number of big retailers, which buy the largest share of the South African production of eggs.

South African egg producers started 2017 with a fresh vision and relief after experiencing a severe and sustained drought and rapidly increasing feed prices, which had made it hard to trade (SAPA, 2017). However, in mid-2017, South Africa experienced its very first outbreak of highly pathogenic avian influenza (HPAI) (SAPA, 2017; DAFF, 2018; NAMC, 2019). The outbreak was first recorded in the broiler industry in Mpumalanga province, and the egg industry's first case was in Standerton in Mpumalanga (SAPA, 2017). Consequently, control measures were put in place to prevent further outbreaks in most South African provinces. But the outbreaks still occurred, with the worst-hit sector being commercial layers (SAPA, 2017).

The South African Poultry Association's report of 2017 noted that over 70 outbreaks had been recorded (including ostrich farms) and that about 4.7 million layers died or were selectively slaughtered. Millions of table eggs were destroyed if they were "produced by hens placed under quarantine" (SAPA, 2017). Furthermore, SAPA (2017) reported that the Department of Agriculture, Forestry and Fisheries (DAFF) had agreed to "compensate farmers for uninfected birds culled as a result of measures to prevent the spread" of HPAI. According to SAPA (2017), the Bureau for Food and Agricultural Policy (BFAP) (2018) estimated the financial effect of the HPAI outbreak in biological losses and direct costs to be around R1.87 billion. This financial effect occurred because the outbreak represented 18% of the gross value of egg production and 76% of income lost (SAPA, 2017).

The outbreak of HPAI caused several egg farms in the country to close down, resulting in job losses, the closure of farms, losses in the export market, and a decline in consumption (NAMC, 2019). Product recalls also had to be done, resulting in over three million eggs being removed from the market and egg retail prices increasing by between 15% and 20% (SAPA, 2017). This shows that the HPAI outbreak was a detrimental event that exposed how fragile a value chain can be. The outbreak also showed that a detrimental event to a value chain contributes to the closure of businesses. The egg industry not only faced this outbreak, but other challenges, such as lingering drought, compliance and regulatory requirements, feed costs, and economic, social, and political crises. These events exposed the vulnerability of the industry and forced several firms in the industry to close their businesses (SAPA, 2017).

These detrimental events are thus disruptive to the normal functioning of the agri-food chain. The disruption is influenced by the coordination strategies of the chain, which result in interdependencies between chain players (Jordaan, 2017). Assessing the influence of coordination strategies on the fragility of the South African egg chain, therefore, seems more practical than assessing which of the above-mentioned events could expose its fragility. Some authors, such as Jordaan and Kirsten (2019), Aven (2015), Jordaan (2017), and Taleb (2012), emphasise that it is quite uncomplicated to discover whether a complex system such as an agri-food chain is fragile, rather than determining various events that would expose its fragility.

1.2. PROBLEM STATEMENT

The South African egg value chain, like most agri-food chains, has an integrated chain management system (Jordaan, 2017) with vertical linkages (coordination) between chain players (Bailey, 2016; Ncube, 2018); lean logistics operations (Maslaric *et al.*, 2013); just-in-time supply (Maslaric *et al.*, 2013); and globalised chains (Enyinda, 2009; Bosman, 2006). The concept of chains pursuing an integrated chain management system is mainly driven by the transaction costs economics (TCE) theory – that chain players intend to reduce the cost of transacting resulting from f environmental and behavioural uncertainties by using strategies of coordination that are intensively tight and vertically linked (Williamson, 1979, 1987, 2008).

Transaction costs are influenced by three key elements: how frequently transactions occur; the specificity of assets involved in the transaction; and uncertainty surrounding the transaction (Hobbs, 1996; Kirsten *et al.*, 2009; Williamson, 2008). Therefore, risk acts as a vital component

in all these above-mentioned elements (Jordaan, 2017). The statement drives two arguments; the first one is that increased uncertainty and increased asset specificity transaction costs increase which tends to make transactions 'less efficient'. The second one is that higher transaction costs can be offset by selecting a more coordinated mode of governance, such as higher levels of vertical integration. Hence, the TCE theory underpins that "there is an economic rationale and therefore benefit" that is attained through increased coordination (Håkansson & Persson, 2004).

The literature also shows that there are challenges other than transaction costs that influence the adoption of increased coordination strategies by chain players. These include "input/output price risks, quantity/quality risks, and safety/health risks", (Jordaan, 2017) as well as the increasing concerns about food safety, product quality (Martinez & Zering, 2004), and traceability of products (Van der Merwe *et al*, 2018). The increased vertical linkages of chain activities between chain players are believed to enhance chain performance and result in the competitive advantage of a chain (Anand & Grover, 2015; Bailey, 2016; Liu *et al.*, 2012; Storey *et al.*, 2006).

The intrinsic belief in improved chain performance suggests that the development of partnerships or ownership of the value chain results in better product flow, information transparency, and money-flow throughout the chain (Martinez, 2002a, 2002b; Mentzer *et al.*, 2001; Peterson *et al.*, 2001). Martinez (2002a) adds that vertical coordination strategies such as vertical integration and contracts enhance production efficiency in the US poultry sector, due to better information transparency. Louw *et al.* (2017) highlight that increased vertical linkages in the South African commercial broiler industry enable the industry to accommodate and manage advanced technological changes, due to better product flow and information transparency.

Although increased vertical coordination contributes considerably to the performance and competitiveness of value chains by reducing transaction costs, it also results in interdependencies between chain players (Wever *et al.*, 2012a). The existence of interdependencies between chain players (Jordaan, 2017; Lazzarini *et al.*, 2001; Wever *et al.*, 2012a) can be either by types or channels (Thompson, 2003). For instance, chain players can be interdependent through their involvement in similar systems of quality management (Van

Plaggenhoef, 2007; Wever *et al.*, 2010). The other example is whereby, different layers produce for one egg brand either owned by a retailer or cooperation (Raynaud *et al.*, 2005).

The interdependencies are common in South Africa because most of the big supermarkets use their "distribution centres to centrally source and internally distribute fresh produce and other merchandise from contracted farmers and or suppliers" (Louw *et al.*, 2007; Louw *et al.*, 2008). The nature and extent of the interdependency between chain players is an aspect of the reciprocal action between risks and their impacts across the entire chain (Wever *et al.*, 2010). High levels of interdependency between chain players expose the value chain vulnerability to new forms of risks (disruptive risks) resulting from chain vertical linkages (Elms & Low, 2013). These new forms of risks are inappropriately named 'systemic risks' and can cause the collapse of a value chain if one link is disrupted (Martínez-Jaramillo *et al.*, 2010). These systematic risks are referred to as "detrimental events that cause disruptive chaos to the normal functioning of a chain" (Jordaan, 2017). For example, the outbreak of HPAI in South African caused misfunctioning of the poultry value chain, by resulting in the closure of many egg farms (Davids *et al.*, 2018; NAMC, 2019; BFAP, 2018; SAPA, 2017).

Value chains face disruptive events that have the lowest probabilities of occurrence with the highest impacts. That is, businesses and their chains face uncertainties that are hard to predict and even to manage (Jordaan, 2017; Vilko *et al.*, 2014). These uncertain events such as a drought, a default in payment, a demand-side shock such as panic buying, a closure of farms or something more extreme such as a disease outbreak that wipes out suppliers like HPAI. They result in irreparable, disastrous outcomes that threaten the continuity of the business and their value chains' sustainability (Engber, 2012; Kleindorfer & Saad, 2005; Leat & Revoredo-Giha, 2013; Zsidisin *et al.*, 2005). Therefore, the consideration of value chain vulnerability relates to its exposure to detrimental disruptions (Christopher *et al.*, 2002), and escalating vulnerability as harmful stressor relates to chain fragility (Jordaan, 2017).

For clarity, Jordaan (2017) defines chain fragility by putting it in context. He emphasises that "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". This means that the unforeseen detrimental event's impact on one link in the chain can have similar effects on the next chain players because of "sequential interdependencies" between these chain members brought on by increased coordination (Jordaan & Kirsten, 2019). Chain fragility, therefore,

threatens business continuity (Engber, 2012; Zsidisin *et al.*, 2005) because a fragile chain facing detrimentally disruptive events lead to the closure of most of its chain players' businesses (Jordaan & Kirsten, 2019).

It has been reported numerous times by different centres, media, associations, and organisations that the South African poultry industry is experiencing detrimental events that threaten business continuity and chain sustainability. The obvious events that have been reported by SAPA (2017), DAFF (2018), and NAMC (2019) are an outbreak of HPAI, crippling drought, and broiler imports. Most of these events are reported to have resulted in the closure of some farms and processing centres (SAPA, 2017) and the removal of several products from the market (NAMC, 2019; SAPA, 2017).

This dissertation aims to discuss the most common coordination strategies adopted in the South African egg industry and to map its value chain structure. Both chain structure and coordination strategies assist with the empirical assessment of the industry's chain fragility since there is a relationship between the coordination strategies and chain fragility (Jordaan, 2017). Other researchers focussed only on-chain performance while neglecting fragility. Given the trade-off between performance and fragility, it is important to consider both when recommending coordination strategies to role-players in any particular industry. The lack of research considering both performance and fragility in the egg industry suggest that there is no scientific evidence to recommend a coordination strategy that balances performance and fragility in the South African egg industry. Therefore, the purpose of this study is to address this missing gap in the existing knowledge.

Adding more to the study's purpose is to popularise the fragility of the chain as a phenomenon because, as emphasised by Jordaan (2017), fragility remains an "awkwardly counter-intuitive" concept to the majority of value chains players. Using the South African egg value chain as a case study is believed to enhance the application of the concept of fragility by practitioners, and to make fragility a familiar concept under "traditional risk and uncertainty discourse" (Jordaan, 2017).

It has become increasingly important to address the unforeseen detrimental risks, together with their consequential impacts on the egg value chain, and to bring in information that helps to develop strategies and policies that can overcome these catastrophic events. Since it seems very

difficult to manage and predict these worst-case scenarios, it becomes imperative to address the role of coordination strategies in risk management and the fragility of the egg chain.

1.3. CONCEPTUAL FRAMEWORK

Agri-food chains are unique compared with other industries' chains – such as automotive, manufacturing, and digital – because of their characteristically biological nature (Clay & Feeney, 2019; Sporleder & Boland, 2011). Agri-food chains possess products that are perishable by nature (Behzadi *et al.*, 2018; de Keizer *et al.*, 2017; Weseen *et al.*, 2014), are highly varied in their quality (Akerlof, 1970; Martinez & Zering, 2004; Migliore *et al.*, 2015), and are exposed to uncertainty (Assefa *et al.*, 2015; Behzadi *et al.*, 2017).

A widely known and distinct feature of agribusiness systems is the biological nature of their chains (Jordaan, 2017), which influences the chain managers or practitioners to adopt vertically tight coordination strategies as to reduce transaction costs and risks associated with the systems (Gereffi, 2014; Handayati *et al.*, 2015; Ye *et al.*, 2018). The vertically intense coordination of value chains is influenced by technological advances, compliance, regulatory changes, and socio-economic elements (Contò *et al.*, 2013; King *et al.*, 2010; Sexton, 2012).

Furthermore, agri-food chains face other challenges such as "input/output price risks, quality/quantity risks" (Jordaan, 2017), and food safety concerns which influence increased coordination (Jordaan, 2017). For example, the food safety concerns were most prevalent under open market strategies (Hobbs, 1996) which ultimately increased transaction costs to ensure safe food. Ultimately it was less costly to rather enter into formal contracts or even vertical integration to ensure safe food compared to the alternative (Hobbs, 1996; Kirsten *et al.*, 2009; Peterson *et al.*, 2001; Weseen *et al.*, 2014; Williamson, 2008).

The transaction costs are influenced mainly by three attributes: investment in relationship-specific assets, the frequency of economic exchange, and uncertainty surrounding that exchange (Crook *et al.*, 2013; Hobbs, 1996; Masten, 1996; Weseen *et al.*, 2014; Williamson, 1979). Consequently, increasing vertical coordination is based on economising on the costs of transacting, and therefore assisting in enhancing the performance of value chains (Bijman *et al.*, 2011; Martinez, 2002b; Wang *et al.*, 2006; Zhong *et al.*, 2018).

However, improving chain performance seems to be possible only under conditions that do not involve uncertainty (Jordaan, 2017; Sexton, 2012) because vertically integrated chains conceal risks that are detrimental and disruptive as a result of the interdependencies and interconnectedness (Wever *et al.*, 2012a) between those chain players (Christopher *et al.*, 2002; Jordaan, 2017; Wagner & Bode, 2006; Wagner & Neshat, 2010).

The interdependencies and interconnectedness (Jordaan, 2017; Lazzarini *et al.*, 2001; Wever *et al.*, 2012a) come with "systematic risks and complex payoffs" (Jordaan, 2017) that are vulnerable to "convexity effects" (Jordaan, 2017) under an uncertain environment within and around the value chains (Sexton, 2012). As a consequence, the chains are defined as fragile (Jordaan, 2017; Peck, 2005), since fragile chains "introduce new strategic risks which will require additional analysis and/or skills to manage or mitigate those risks" (Gray & Boehlje, 2005) far beyond what is normally known.

Modern agri-food chains face unpredictable and risky events that are hard to manage and that cause irreversible damage to these chains (Jordaan, 2017). It is thus imperative to improve the risks management strategies of the value chains because they are a crucial part of business continuity (Leat & Revoredo-Giha, 2013). The conceptual framework (Figure 1-1) of this dissertation considers the fragility of the South African egg value chain. In essence, it is strategically important for the agri-food chain players "to deal with the trade-off between the high performance and the fragile value properties of value chains" (Jordaan, 2017).

The argument for a trade-off focuses centrally on the coordination of the agri-food chains, and, in particular, "where the pursuit of chain performance is juxtaposed against the inevitable ruin of any vulnerable system" (Jordaan, 2017). The argument of Taleb (2012) supports this point by stating that anything fragile will break as time goes on. The conceptual framework provides a way to explore fragility as a phenomenon in the South African egg value chain and provides guidelines to address the trade-off considering the chain coordination.

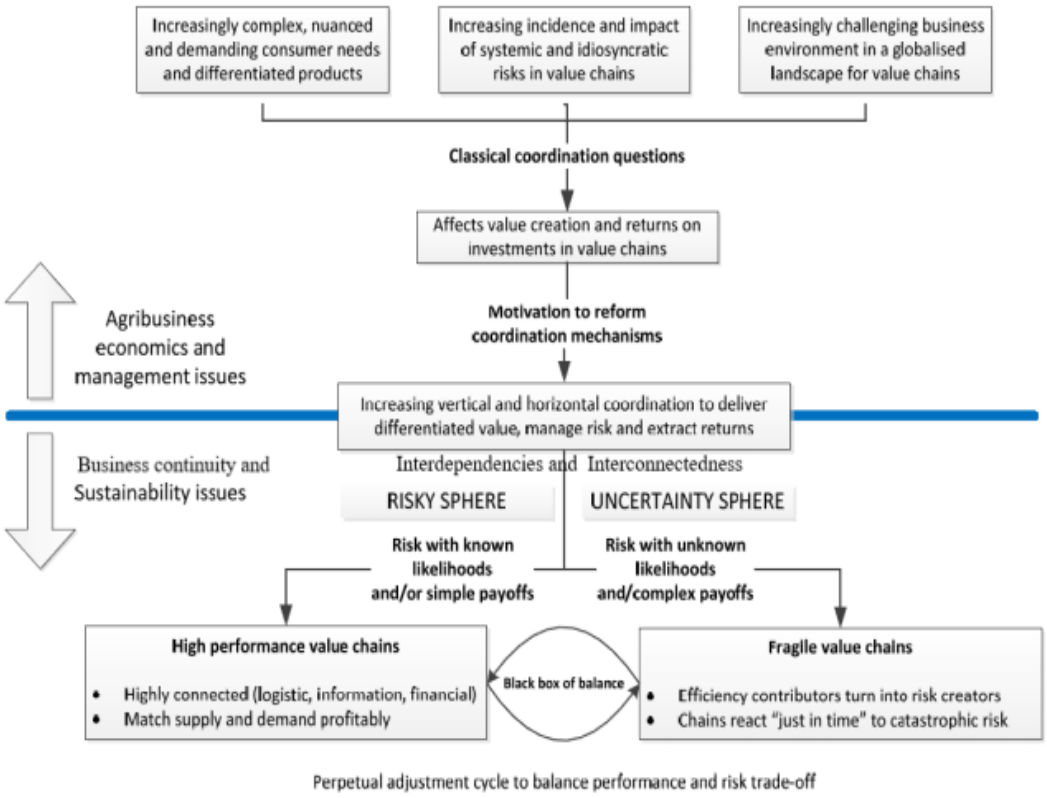


Figure 1-1: The conceptual framework of increasing vertical coordination and fragility

Source: Adopted from Jordaan (2017) with the researcher's own additions

Profit generation is the main goal of any economic exchange. Thus, risk management and business survival are subordinate goals for economic operations that generate profits (Jordaan, 2017). Taleb (2012) makes a strong argument that "what is missed is the strong logical precedence of the survival over success". Jordaan (2017) adds that fragility mitigation is a crucial and compulsory activity of doing business. Although the arguments sound obvious, they are insufficiently emphasised.

Consequently, the chapters of the dissertation that follow provide details and contribute to this conceptual framework. The framework provides a roadmap for the chapters to explore fragility as a phenomenon in the South African egg value chain. This is the domain of the dissertation and its research objectives.

1.4. RESEARCH OBJECTIVES

The main objective was to discuss the trade-off between chain performance and fragility, considering the South African egg value chain's coordination strategies. The objective was achieved through the following specific objectives:

1. To display the most common strategies of coordination in the South African egg industry and the map of its egg value chain.
2. To use the Jordaan (2017) framework to measure the fragility of the South African egg value chain.
3. To perform a comparative fragility analysis of the two main coordination strategies (configurations) of the South African egg chain.

1.5. RESEARCH HYPOTHESES

Jordaan and Kirsten (2019) state that "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 increased fragility of these chains". This study's hypotheses are therefore influenced by the existing interdependencies between chain players as a result of increased coordination strategies that are lean and highly integrated (Jordaan, 2017; Jordaan & Kirsten, 2019). The following hypotheses are related to the third objective of the study:

- **Null hypothesis:** Statistically, there is no significant difference in the means of chain fragility of the two South African egg value chain strategies.
- **Alternative hypothesis:** Statistically, there is a significant difference in the means of chain fragility of the two South African egg value chain strategies.

1.6. CONTRIBUTION AND JUSTIFICATION OF THE STUDY

The dissertation presents an argument that there is a trade-off between chain performance and fragility. The practical implication of this trade-off is that highly integrated and lean strategies improve chain performance by the reduction of transaction costs and risks in agri-food chains. However, the strategies multiply the fragility of the chains (Jordaan, 2017; Maslaric *et al.*, 2013; Wagner & Neshat, 2010, 2012). The important strategic choice among the following coordination strategies, contract specifications, vertical and horizontal integration, alliance formations based on either trust or equity and cooperation memberships for chain players in

the South African egg industry, and their value chains is thus to find a suitable coordination strategy that positions chain performance and fragility at the equilibrium (Jordaan, 2017; Nooraie & Parast, 2016). The concept of a trade-off between chain performance and fragility in the literature is minimally noted. For instance, Brede and de Vries (2009) highlight that efficient systems (chains with improved chain performances) are not robust (they are fragile), while robust systems are inefficient.

The argument is that both chain performance and fragile chain structures necessitate imperative requirements in the design of agri-food chains (Brede & de Vries, 2009; Jordaan, 2017). Consequently, a trade-off is vital to the coordination of agri-food chains, signalling that there is an equilibrium between chain performance and fragility (Jordaan, 2017). The conceptual framework of the dissertation is a central argument for the trade-off. Moreover, the contemplation of this trade-off is essential to reassessing the TCE framework as it has commonly been applied in agribusiness research (Jordaan, 2017); as well as being a guide for the coordination question (Peterson *et al.*, 2001) in agri-food chains to issue a new framework (Jordaan, 2017; Maslaric *et al.*, 2013; Vlajic *et al.*, 2012). The new framework would position the impacts of chain performance and fragility at a strategic equilibrium in the design of agri-food chains and their management (Jordaan, 2017; Maslaric *et al.*, 2013).

The dissertation contributes to the popularisation of the concept of fragility in agri-food chains. This is because Jordaan (2017) states that fragility "seems awkwardly counter-intuitive to average" chain players. Last, the dissertation aims to inform the chain players' management in the South African egg industry, particularly when it comes to strategising on value chain coordination to avoid closure of businesses and decrease fragility, but still improve chain performance.

1.7. THE OUTLINE OF THE STUDY

This section provides information about the six chapters of the dissertation. Following this is Chapter 2, which provides the literature on value chain coordination, chain performance, interdependencies within value chains, risks and uncertainties within value chains, and chain vulnerability and fragility. The third chapter provides an overview of the South African egg industry And, in particular, the strategies that are used for coordinating within the industry, its value chain structure, and the most common risks and uncertainties. The chapter aims to attain

the first objective of the dissertation and to state the prevailing risks and uncertainties that are used to explain unforeseen detrimental events that are disruptive to the egg chain. The fourth chapter describes the methods and procedures used in the dissertation and describes the data sources. The fifth chapter presents the fragility analysis of the results and a discussion based on the information in Chapter 4. The sixth and final chapter concludes the dissertation, notes the limitations of the study and offers recommendations for South African egg chain players and further research on related issues.

CHAPTER 2
LITERATURE REVIEW

2.1. INTRODUCTION

Agribusinesses seem to exhibit high levels of vertical coordination (linkages) due to the uncertainties surrounding transactions, the frequency of transaction occurrences, and investments in specific assets (Hobbs, 1996; Weseen *et al*., 2014). These challenges are widely known as transaction cost attributes (Williamson, 1979, 1987, 1991, 1993). Transaction cost economics (TCE) is a well-known paradigm used to counteract these challenges to reduce transaction costs (Williamson, 2008; Hobbs, 1996). Many agricultural value chains, therefore, seem to be leaner and more highly integrated to attain better chain performance (Anand & Grover, 2015; Boehlje *et al.*, 2011; A. Louw *et al.*, 2011; Ncube, 2018; Vorley *et al.*, 2016). The leaner and highly integrated these chains become, the more the interdependencies between their chain players increase (Jordaan, 2017; OECD, 2013)

The interdependencies between the chain players reveal a certain structure of the value chain (Srai & Gregory, 2008) and the chain structure seems to be prone to chain disruption (Gray & Boehlje, 2005; Wagner *et al.*, 2009). Chain disruption is influenced by unforeseen events that expose the value chain's vulnerability (Wagner & Bode, 2006). The chain vulnerability concerns about the exposure of the chain relate to any detrimental disruptive event (Christopher *et al*., 2002). The rapid spread of this vulnerability through the entire chain also relates to the chain's fragility (Jordaan, 2017).

It is quite clear that the risk and uncertainty faced by agricultural chains and their coordination strategies influence chain fragility, which threatens business continuity (Leat & Revoredo-Giha, 2013). Therefore, this chapter positions the dissertation in the context of currently relevant information about the strategies of value chain coordination, interdependencies, chain performance, vulnerability, fragility, risk, and uncertainty to justify the dissertation's empirical fragility analysis.

2.2. VERTICAL COORDINATION, TRANSACTION COSTS, AND CHAIN PERFORMANCE

The lean and highly integrated strategies of increased coordination act as the way for agricultural chains to reduce the cost of transacting and to attain production efficiency (improved chain performance) (Martinez, 2002b). The reduction of transaction costs via vertical linkages, as mentioned earlier, can be influenced by transaction attributes (Hobbs, 1996), while the achievement of improved chain performance via increased coordination can be because of market uncertainties such as price and quality instability (Martinez, 2002b), technological advances (Louw *et al*., 2017; Martinez, 2002b), and production expectations (Ncube, 2018).

Many studies support the idea that a reduction of transaction costs is obtained by increased coordination. For instance, the arguments of Fischer *et al*. (2009) and Gulati (1995) support the frequency of a transaction by stating that frequent transacting between trading partners creates trust between them, such that the behavioural uncertainty and transaction costs of those individuals are reduced by the trust that has developed between them for their subsequent alliance relationship. Also, Fischer *et al*. (2009) highlighted that repeated economic exchanges build trust. They also observed that a high frequency of transactions in the ethanol supply chain led to increased coordination.

The specificity of an asset, as stated before, leads to high transaction costs (Hobbs, 1996; Riordan & Williamson, 1985). The different types of asset specificity are mainly physical, temporal, and site-related (Martinez, 2002b). The investment in specific assets leads to limited alternative uses; and users of the assets, which means it is difficult or very costly to use the assets outside of the specific transaction and parties to the transaction are vulnerable to hold-up[1] (Fan, 2000; Martinez, 2002b). Therefore, Klein *et al.* (1978) propose that "vertical integration is one solution to the hold-up problem because unified ownership suppresses the holdup possibility". The arguments that Klein *et al*. (1978) make are supported by an empirical study by Weseen *et al*. (2014), which indicates that increased vertical coordination is a

[1] Hold-up arises when part of the return on an agent's relationship-specific investments is ex post expropriable by his trading partner. The hold-up problem has played an important role as a foundation of modern contract and organization theory, as the associated inefficiencies have justified many prominent organizational and contractual practices (Che & Sákovics, 2006; Rogerson, 1992).

preferred coordination strategy to reduce transaction costs against investment in specific assets. The study by Weseen *et al*. (2014) reveals that the role players in the Western Canada ethanol industry vertically integrate or contract as needed to seek ways to reduce transaction costs due to the threat of opportunistic behaviour[2].

The degree of uncertainty around a transaction – whether environmental or behavioural uncertainty – can lead to high transaction costs (Williamson, 2008). Environmental uncertainty may arise due to "technological changes, unpredictable changes in consumer preferences, and random acts of nature" (Jordaan, 2017), while behavioural uncertainty is likely to arise due to strategic behaviour "regarding nondisclosure, disguise, or distortions of information" (Martinez, 2002b).

Therefore, the higher the level of uncertainty surrounding an economic exchange, the more preferred increased vertical linkages will be (Masten, 1996). The findings of Fan (2000) support the above statement, that the extent of vertical integration by petrochemical firms in their input stages is influenced by input price uncertainty. Fan's (2000) findings relate to the argument of Cembalo *et al.* (2014) that increased vertical coordination assists farmers to reduce price risk. Watabaji *et al.* (2016) highlight that uncertainty in exchange situations between a farmer and a trader, and also between a malt factory and a trader, has a positive correlation with value chain integration. Thus, farmers and traders go for integration to avoid or minimise any possible risks in their transactions.

The frequency of a transaction, as stated earlier, affects transaction costs, and can influence agribusinesses' choice of vertical coordination (Hobbs, 1996; Weseen *et al*., 2014). The point that Weseen *et al*. (2014) make is that frequent economic exchanges develop themselves into highly vertical linkages because of similarities and developed trust; and so, relationship-based coordination results (Kwon *et al.*, 2012; Williamson, 1993). This means that the number of times a transaction occurs between exchange partners reduces the cost of transacting, develops trust between them, and then automatically results in increased coordination. Fischer *et al*. (2009) and Gulati (1995) argue that frequent transacting between trading partners causes trust

[2] Opportunism is a foundational assumption of many economic theories that claims human beings are generally self-interested and will take advantage of others when possible (Noorderhaven, 1996).

between them, such that the behavioural uncertainty and transaction costs of those individuals are reduced for their subsequent alliance relationships.

The increased vertical linkages, such as contracting, alliance formations and vertical integration, seem to be the most preferred coordination strategies that significantly reduce transaction costs in businesses' value chains (Cadot, 2015; Pieri & Zaninotto, 2013; Martinez, 1999, 2002b; Goncharuk & Gamma, 2013; Zhong *et al*., 2018; Weseen *et al*., 2014). However, even though they are preferred because they reduce transaction costs, they seem to introduce agency costs[3] into the businesses (Cadot, 2015; Bontems & Fulton, 2009; Shleifer & Vishny, 1989). Still, businesses conclude "that the internal transactions costs associated with owning stages of the chain (agency costs, influence costs, increased production risks, employee risks) are less than the external transactions costs (moral hazard, adverse selection, and risk premia)[4]" (Jordaan, 2017). This explains why they prefer higher vertical linkages as coordination strategies (Gray & Boehlje, 2005; Jordaan, 2017). That statement is supported by the findings of Cadot (2015) that vertically integrated firms in the French wine industry have lower agency costs than non-vertically integrated firms. Also, Wever *et al*. (2012a) highlight that a coordination strategy is only regarded as efficient if its implementation costs are lower than not implementing it at all. In other words, if the implementation costs of the new coordination strategy are lower than the transaction costs associated with the current coordination strategy, then it is regarded as efficient.

As stated before, the increased vertical coordination of agribusinesses contributes not only to the reduction of transaction costs but also to production efficiency (improved chain performance) (Martinez, 1999, 2002a, 2002b). Martinez (2002b) states that "reducing transaction costs, contracts, and vertical integration are also associated with gains in production efficiency and more value-added product offerings of consistent quality". There are other challenges that agri-food chains face and that have an influence on the agribusinesses' chains ability to pursue intensively tight coordination strategies. These challenges include

[3] An agency cost is a type of internal company expense which comes from the actions of an agent acting on behalf of a principal. Agency costs typically arise in the wake of core inefficiencies, dissatisfactions and disruptions, such as conflicts of interest between shareholders and management. Payment of the agency cost is to the acting agent (Ang *et al.*, 2000).

[4]Moral hazard occurs when there is asymmetric information between two parties, but where a change in the behaviour of one party is exposed after a deal is struck. Adverse selection occurs when there's a lack of symmetric information *prior* to a deal between a buyer and a seller (Quiggin *et al.*, 1993).

input/output price risks, quantity/quality risks, and safety/health risks (Jordaan, 2017) and increasing concerns about food safety, products' quality, and the traceability of products to their point of origin (Bailey, 2016; Jordaan, 2017; Van Der Merwe *et al*., 2018). Consequently, the results of intensively linked value chains are increased interdependencies between the value chain players (Bailey, 2016; Jordaan, 2017; Jordaan & Kirsten, 2019; Wever *et al.*, 2010; Wever *et al.*, 2012b).

2.3. INTERDEPENDENCIES IN VALUE CHAINS

The nature of agri-food chains involves the specific exchange relationships that make most firms or chain players not internally self-sufficient concerning strategic and critical resources, resulting in interdependencies between activities (Kembro, 2015; Kembro *et al.*, 2014; Peterson *et al.*, 2001). Therefore, firms purposefully seek to manage these interdependencies by adopting an efficient coordination strategy for them – mainly strategies that are vertical and lean, such as contracts and vertical integration (Paulraj & Chen, 2007; Ulrich & Barney, 1984; Petersen *et al*., 2008).

As discussed earlier, firms seek to reduce the costs of transacting that arise because of investments in specific assets and uncertainty surrounding their exchange relationships, by involving their activities in vertically linked transactions (Martinez, 2002b). This point is supported by Malone and Crowston (1990), who say that coordination and vertical linkages in chains are the management strategies of "interdependencies between activities, and where there are no interdependencies there is nothing to coordinate". Furthermore, these coordination strategies act as alternatives for chain players and as an integral part of value chain coordination (Barbarosoglu, 2000). Although the vertical coordination assists firms to manage these interdependencies between activities, they create interdependencies between chain players (Petersen *et al.*, 2008; Skipper *et al.*, 2008). Therefore, those interdependencies expose the individual players and their chains to risks that emerge as a result of the lean and highly integrated strategies that arise from increased coordination.

As firms in the value chains increasingly coordinate and integrate their activities with other firms, this results in exposure to risks within chains and firms. Also, these risks emerge from the interconnectedness and interdependencies of chain players in the chains (Jordaan, 2017). The risks that emerge from the chains are those that would certainly lead to a chain-breaking

down because the risks can escalate through the entire chain due to chain players' interconnectedness and interdependencies (Garvey *et al.*, 2015; Jordaan, 2017). Therefore, the interdependencies resulting from tightly linked value chains somehow contribute to the vulnerability of the chains to disruptive events (Elms & Low, 2013; Martínez-Jaramillo *et al*., 2010).

The value chain is composed of a dyad that represents different relationships between chain players (Capaldo & Giannoccaro, 2015). Dyadic relationships involve complex interdependencies that influence the behaviours and performance of chain players (Nair *et al.*, 2009). Also, the interdependencies become evident when the behaviour of the chain players in a dyad, and the outcomes of their behaviour, depending on the behaviour of other chain players in the chain (Jordaan, 2017; Wever *et al*., 2012a, 2012b). Thus, there are some differences between the interdependencies that can be decided between the 'type' (Figure 2-1) and the 'channel' (Figure 2-2) in that all dyadic relationships among chain players are formed (Wever *et al*., 2012b).

The differentiation of interdependencies between chain players by 'type', as shown by the work of Thompson (2003), can be pooled (that is, independent), sequential, or reciprocal, depending on the dyadic relationships between those chain players (Dubois *et al.*, 2004; Kembro, 2015; Lazzarini *et al.*, 2001; Paulraj & Chen, 2007; Segerstedt *et al.*, 2010; Skipper *et al.*, 2008; Wever *et al.*, 2012a, 2012b). The independent (pooled) interdependency is regarded as a weak form of interdependence (Skipper *et al*., 2008) because chain players work together as more-or-less completely independent individuals who are loosely linked because they share common resources (Kembro, 2015; Wever *et al*., 2012a) – for example, egg layers using the same feeds from a single provider; thus all would be affected by the demand for the feeds.

Sequential interdependency involves direct linkages between chain players, whereby the inputs of one chain player are directly dependent on the output of another chain player (Wever *et al*., 2012a; Kembro, 2015; Skipper *et al*., 2008). In other words, sequential interdependence can be seen where activities of one chain player precede those of another (Lazzarini *et al*., 2001). For example, the broiler producer delivers broilers to an abattoir that then delivers them to a processor. These chain players have direct sequential linkages.

Last but not least, reciprocal interdependency occurs when the inputs of one chain player are directly dependent on the outputs of another chain player and *vice versa* (Lazzarini *et al*., 2001); (Skipper *et al*., 2008; Wever *et al*., 2012a). Furthermore, there is a mutual exchange of inputs and outputs between chain players (Kembro, 2015). For a simple illustration, the figure below shows the different interdependencies defined above.

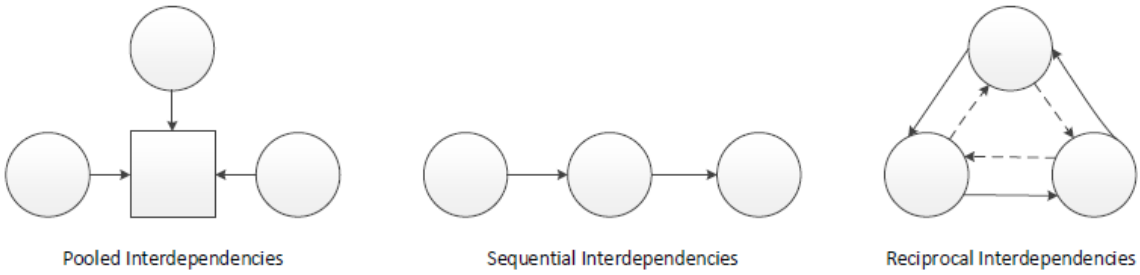


Figure 2-1: Different types of interdependencies between chain players

Sources: Wever *et al*. (2012a); Lazzarini *et al*. (2001); Jordaan (2017)

The differentiation of interdependencies between chain players by 'channel' is a situation in which chain players may be interdependent via several interfaces (Borgatti & Li, 2009). The chain players can be directly or indirectly linked because of their engagement in systems such as quality management schemes (Martinez & Zering, 2004; Wever *et al*., 2010), or there may be some linkages between them because they produce for the same brand (Raynaud *et al*., 2005). Therefore, there is a connection between types and the channel of interdependencies. This means that there can be more than one interdependency type between chain players when their dyadic relationships are linked via multiple channels (Wever *et al*., 2012a). Also, Wever *et al*. (2012a) state that the channel in which chain players are interdependent influences the interdependency types between chain players, and *vice versa*. The figure below illustrates channel interdependency.

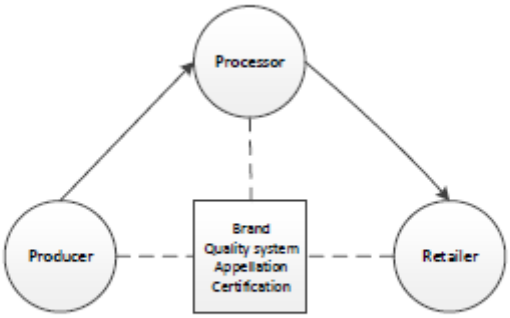


Figure 2-2: Channel interdependencies between chain players

Sources: Jordaan (2017); Wever *et al*. (2012a)

The intensity of interdependencies between chain players affects systemic risks, as these interdependencies can contribute to the vulnerability of a chain that involves a series of interdependent economic exchanges (Mentzer *et al*., 2001). Wever *et al*. (2012a) support this by indicating that the type and the channel via which chain players are directly or indirectly linked model how these players would be influenced by externalities. Thus, the interdependencies expose agri-food chains to uncertainties and risks that may arise either internally or externally and cause disruptions (Jordaan, 2017).

2.4. RISK, UNCERTAINTY, AND DISRUPTIONS IN VALUE CHAINS

2.4.1. Definitions and categorisation of risk and uncertainty

'Risk' and 'uncertainty' can be defined in numerous ways (Hardaker *et al*., 2015), and they are often confused and used interchangeably (Bailey, 2016; Miller, 1992). Thus, it is imperative to define them and locate them in the context of agri-food chains.

Hardaker *et al*. (2015) define 'risk' as deficient information with well-known probabilities of possible results, and 'uncertainty' as still deficient information with unknown probabilities of possible results. The definitions of risk and uncertainty by Hardaker *et al*. (2015) relate to the classification of risk and uncertainty by Knight (2012), for whom risk is classified as measurable, while uncertainty is not measurable. Holton (2004) brings in the concept of exposure by stating that "risk requires both exposure and doubt dimensions about a proposition or event". Therefore, risk and uncertainty involve the measurement of a probability

distribution, an event exposure, and the state of being joined or linked through that exposure (Jordaan, 2017; Taleb, 2005, 2009).

The risks and uncertainties have also been mainly categorised into two classes in a value chain context to treat them differently (Bailey, 2016). The most commonly used categories are internal and external sources of risk and uncertainty to value chains (Marchese & Paramasivam, 2013; Wu *et al.*, 2006). Internal sources relate to value chain demand and supply functions, while external sources involve political and environmental issues (Bailey, 2016; Jordaan, 2017). Trkman and McCormack (2009) are some authors that have used these categorising criteria to distinguish risk and uncertainty sources by classifying them as endogenous or exogenous to a value chain. Other authors include Rao and Goldsby (2009), Marchese and Paramasivam (2013), and Ritchie and Brindley (2007). These authors have distinguished the risk and uncertainty sources by emphasising that the internal sources involve risk and uncertainty that arise from the strategic risk management practices of value chain players – for example, the bull-whip effect[5] – while external sources involve unforeseen once-off or ongoing events that could be politically, economically, socially, or environmentally driven – for example, political unrest, new regulatory requirements, or natural disasters.

2.4.2. Uncertainty and risk in a value chain context

Modern value chains seem to face an increasing uncertainty that is mainly driven by how these chains are coordinated and strategized (Sodhi *et al*., 2012; Zsidisin *et al*., 2005; Sheffi & Rice Jr, 2005). Gray and Boehlje (2005) state that "the development of more tightly aligned supply chains creates new and less easily quantifiable risks for the participants in the supply chain". Kleindorfer and Saad (2005) mention that firms, together with their entire value chains, face rising vulnerability because their value chain design is intensive, lean, and efficient.

These increasing uncertainties are known to be major value chain disruptors (Bailey, 2016; Christopher *et al.*, 2002; Jordaan, 2017; Jüttner *et al.*, 2003; Kleindorfer & Saad, 2005; Simba *et al.*, 2017; Vanany *et al.*, 2009) and can contribute to the closure of some businesses (Kleindorfer & Saad, 2005; Jordaan & Kirsten, 2019; Engber, 2012; Leat & Revoredo-Giha,

[5] Bull-whip effect occurs when companies significantly cut or add inventories. Economists call it a bullwhip because even small increases in demand can cause a big snap in the need for parts and materials further down the supply chain (Lee *et al.*, 1997).

2013). In the South African context, these uncertainties include the outbreak of listeriosis that affected the South African pork value chain (NAMC, 2019), the deadly outbreak of avian influenza that affected the South African poultry industry (SAPA, 2017; BFAP, 2018), and poultry meat imports that affected the South African broiler industry (SAPA, 2017). These events with unknown occurrence probabilities have detrimental effects on firms and value chains (Bailey, 2016; Jordaan, 2017). Thus, disruptors such as these have caused 'black swan' events[6] (Taleb, 2007), highlighting the need for an assessment of very low probability events that could have catastrophic impacts.

Based on the different perspectives of risk and uncertainty, this dissertation aims to adopt the assessment of risk and uncertainty in the value chain context suggested by Vilko *et al.* (2014). They argue that the assessment of risk and uncertainty that is used in value chains, based on risk probabilities and impact, does not present a true picture because the probabilities are merely subjective. They state that the commonly used Knightian basic risk and uncertainty definitions make it impossible to quantify risk and uncertainty, and argue that "all influential environmental factors are therefore impossible and information based on which probabilities are formed is more or less imperfect". So, they emphasise that uncertainty in the context of value chains should be "examined through the lenses of substantive and procedural uncertainty". They give more clarity by defining both uncertainty concepts

> "Substantive uncertainty derives from the incompleteness of information set and it relates to a lack of information about environmental events and all information which would be necessary to make decisions with certain outcomes … [while] procedural uncertainty arises from the inability of agents to recognise and interpret the relevant information even when available. It concerns the competency gap in the problem solving and limitations on the computational and cognitive capabilities of agents to pursue unambiguously their objectives, given the available information" (Vilko *et al*., 2014).

The figure 2-3 below is a framework to illustrate the argument of Vilko *et al*. (2014).

[6] A black swan is an unpredictable event that is beyond what is normally expected of a situation and has potentially severe consequences. Black swan events are characterized by their extreme rarity, their severe impact, and the widespread insistence they were obvious in hindsight (Taleb, 2005, 2007a, 2007b). The most applicable example of black swan event is covid-19

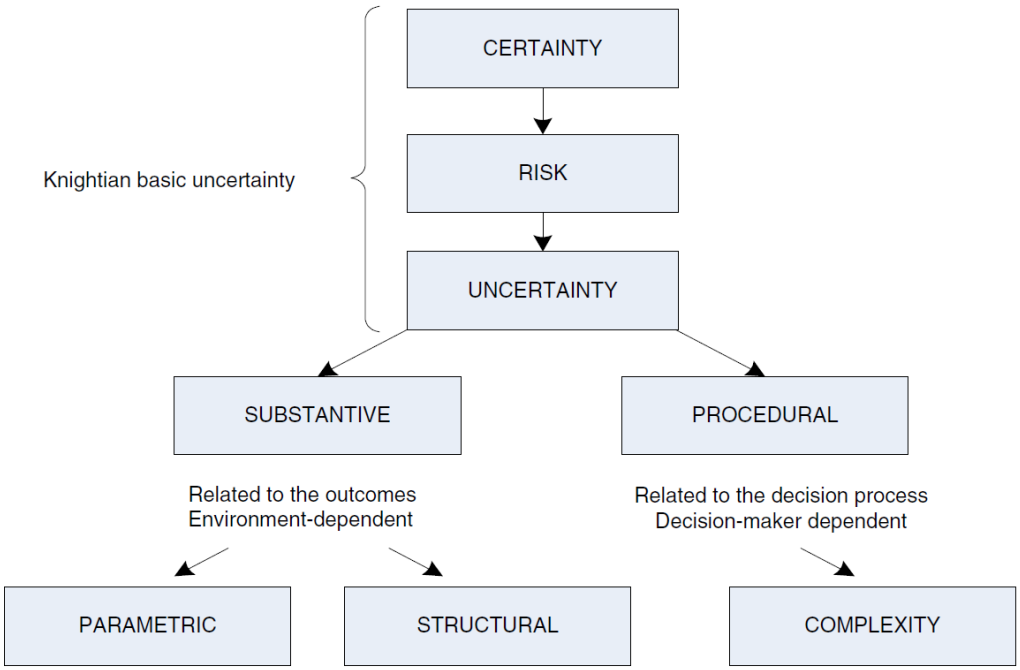


Figure 2-3: Certainty, risk, and uncertainty in the value chain

Source: Vilko *et al*. (2014)

The point that Vilko *et al*. (2014) make is that, within all the different categories of uncertainty noted above, the decision-maker has different information about environmental events, and also a different resource to cope with the uncertainty.

The Knightian basic uncertainty scenario offers a similar, if not the same, explanation as that given previously by Hardaker *et al*. (2015) and Holton (2004). There is also "parametric uncertainty", which is "environment-dependent", and it considers subjective risk probabilities and their impacts (Dosi & Egidi, 1991). This uncertainty is assessed subjectively; therefore, some events cannot be quantified by this method (Vilko *et al*., 2014). This means that there would not be a holistic picture of the value chain, and objective probabilities could not be quantified.

The other uncertainty is 'procedural uncertainty', which means that "the decision-makers are constrained by their computational and cognitive capabilities" (Vilko *et al*., 2014; Dosi & Egidi, 1991). These inabilities of decision-makers, together with incomplete information about upcoming events, limit them in carrying out their goals (Vilko *et al*., 2014). Therefore, this dissertation adopts a framework to perceive uncertainty in the value chain context (Vilko *et al*.,

2014). This is mainly because value chains face some of the unforeseen and detrimental events that cannot be quantified using probabilities, since doing so seems to be impossible, given the complexity of the risks and value chains.

These risks and uncertainties have given rise to a growing impetus for value chains to consider the risks and uncertainties that affect value chain management (Kleindorfer & Saad, 2005), and to consider the identification and mitigation of these uncertainties with low probabilities that have catastrophic impacts (Zsidisin *et al*., 2005; Norrman & Jansson, 2004). The detrimental disruptions caused by these uncertainties make value chains vulnerable because of the interdependencies that exist within them (Bailey, 2016; Jordaan, 2017), and expose the chains' vulnerability (Christopher *et al*., 2002). This vulnerability escalates because of the interdependencies within the chains as disruptions arise related to their fragility (Jordaan, 2017). Also, the chains' fragility, together with increasing detrimental disruptions, put chain players' businesses in jeopardy (Leat & Revoredo-Giha, 2013; Jordaan, 2017). Spiegler *et al.* (2012) agree that these detrimental risks and the consequent exposure of the vulnerability of businesses threaten their existence.

2.5. VULNERABILITY AND FRAGILITY OF VALUE CHAINS

2.5.1. Concept of vulnerability in a value chain

There needs to be a clear definition of vulnerability in the context of the value chain. Therefore, Wagner and Bode (2009) define 'chain vulnerability' as a situation in which value chain disturbances are activators of the risks that will arise. However, these disturbances are not the only deciders of the final loss in a chain. The susceptibility of the value chain is also a contributor to the chain's harm. This leads to the concept of value chain vulnerability. For greater clarity, Jüttner (2005) defines it as "exposure to serious disturbance arising from supply chain risks and affects the supply chain's ability to effectively serve the end customer market". However, these definitions seem to exclude the interdependencies within the chain and their contribution to chain vulnerability.

The concept of interdependencies is touched on by Svensson (2004), who emphasises the concept of vulnerability in terms of interdependencies between chain players. Svensson (2004) emphasises that the level of interdependencies is relevant when it comes to vulnerability because higher levels of interdependencies between chain players equate to higher levels of

susceptibility in the value chain. The definitions and the concept of 'interdependencies' show the urgent necessity for chain managers to observe and analyse chain vulnerability for the sake of their firm's survival. However, Wagner and Neshat (2012) highlight that the vulnerability of the value chain cannot be observed unless the factors (variables) that determine the vulnerability are understood. Therefore, Wagner and Neshat (2010) describe variables that can be used to determine vulnerability, including buyer and supplier dependencies, value chain complexity, and the globalised sourcing value chain.

Vlajic *et al*. (2012) add other variables by categorising the sources of chain vulnerability into either external or internal sources. The main influences from external sources – the value chain's environment – include natural disasters, political instability, unequal technological developments, market decline, and regional economic downturns. The internal sources exist within the value chain and include insufficient collaboration, information asymmetry, having only one key business partner, and the complexity of the chain (Vlajic *et al*., 2012). Also, Christopher and Peck (2004) agree that the exposure of a value chain to internal and external risks sources is exactly what chain vulnerability is about. Vilko *et al*. (2014) also agree with Christopher and Peck (2004) that chain complexity and specialisation emerge as major challenges that make a value chain vulnerable to exogenous and endogenous sources of vulnerability.

The design of the value chain, as previously stated, focuses more on maximising efficiency and speed by adopting cost-reducing strategies in fast-changing and competitive markets. However, focusing mostly on maximising efficiency results in chains vulnerable to detrimental events (Stecke & Kumar, 2009). Thus, these disruptions increase the vulnerability of the value chain. It is reasonable to conclude, therefore, that the vulnerability of a value chain is an "exposure to a harmful or serious disturbance or stressor, arising from risks within and external to the chain" (Christopher *et al*., 2002). Furthermore, the increased susceptibility of a chain extends into chain fragility (Jordaan, 2017). In other words, "fragility extends the concept of vulnerability and is defined as an accelerating vulnerability to a harmful stressor" (Taleb *et al.*, 2012).

2.5.2. Concept of value chain fragility

The concept of fragility has been addressed in many contexts, including complex networks that show interdependencies (Vespignani, 2010), investment funding (Thurner *et al.*, 2012), food

global system (Puma *et al.*, 2015), the 2008 financial crisis (Taleb *et al*., 2012), power systems' vulnerability in extreme weather (Panteli *et al.*, 2016), and the assessment of banks' financial fragility (Montesi & Papiro, 2018). In these contexts, the fragility of a system is argued to be the consequence of misjudged risks and the uncertainties of unanticipated random events that result in the probability of massive impacts.

The conceptualisation of fragility in agri-food chains is vital because, just like businesses, a chain can be either fragile or anti-fragile (Jordaan, 2017). Jordaan and Kirsten (2019) have assessed the fragility of the South African lamb value chain to address the concept of fragility in the value chain context. So, Jordaan (2017) comments that "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". The 'non-linear feedback' or escalating sensitivity of an impact from an event implies the vulnerability of a system (Jordaan, 2017). As noted earlier by Taleb *et al*. (2012), "fragility extends the concept of vulnerability and is defined as an accelerating vulnerability to a harmful stressor". Thus, the analysis of fragility cannot be regarded simply as risk analysis (Jordaan, 2017).

2.5.3. Analysis of chain fragility

There are differences in analysing fragility and in analysing risk for risk management. The analysis of risk entails frameworks that could assist with risk identification, assessment and mitigation for risk management practices (Altay & Green III, 2006; Kleindorfer & Saad, 2005; Nishat Faisal *et al.*, 2006; Nooraie & Parast, 2016; Yeboah *et al.*, 2014). Therefore, for value chain managers to execute risk management practices through risk analysis, they would need frameworks that already have "reliable and accurate measures of risk" (Jordaan, 2017). This, in turn, can make it difficult or even impossible for chain managers to perform risk management because chains have recently faced risks and uncertainties that are said to be "structural and procedural" (Vilko *et al*., 2014).

On the other hand, 'fragility analysis' can be regarded as the opposite of 'risk analysis' (Jordaan, 2017). Jordaan (2017) emphasises that analysing chain fragility using a risk management approach involves ascertaining a chain's vulnerability to detrimental events rather than dealing with these events' probabilities and impacts. This concurs with the argument of

Taleb (2012) that "it is far easier to figure out if something is fragile than predict the occurrence of an event that may harm it" – that is if an event involves "structural and procedural" uncertainties (Vilko *et al*., 2014) that entail unpredictable probabilities and impacts. Consequently, analysing chain fragility is to be preferred over risk analysis in this dissertation. Some factors are either internal or external that drive the fragility of value chains (Jordaan, 2017).

2.5.4. Factors that drive chain fragility

There is a range of risks, and some are irrelevant to value chains (Manuj & Mentzer, 2008) – for instance, individual firms' risks. A risk's relevance to chains is dependent on the chains' attributes or features and the losses that firms incur due to the vulnerability of their chains arising from chain disturbances (Wagner & Bode, 2006). The complexity of the production process and of the chain itself (Hashemi *et al.*, 2013), together with a chain's operational risks and disruption risks (Tang, 2006; Kleindorfer & Saad, 2005), are regarded as crucial components of uncertainty that affect the coordination of agri-food chains and their management (Jordaan, 2017). Thus, these risks are fundamental issues that constitute factors which are believed to influence fragility differ from sector to sector and from organisation to organisation (Stonebraker *et al*., 2009).

The literature highlights different possible fragility factors. They mainly constitute internal and external factors relating to value chains. Internal factors mainly include management, marketing, logistics, and sales operations (Jüttner, 2005; Vlajic *et al*., 2012; Jordaan, 2017; Stonebraker *et al*., 2009; Wagner & Bode, 2008). These factors are elements that involve adding value to the different processes of product development through to delivery to the consumer (Jordaan, 2017). The table below presents operationalised internal fragility factors from Jordaan (2017), with some additions from Stonebraker *et al*. (2009).

Table 2-1: Internal fragility factors

Information and communication transparency
Training of labour force
Supplier reliability
Performance of product quality and safety
Physical logistics
Firm cash flow position
Behaviours of buyers

Sources: Jordaan (2017); Stonebraker *et al*. (2009)

The external factors mainly include compliance, legal and regulatory requirements, and social, economic, political, and environmental issues such as political unrest, natural disasters, and economic collapse (Chopra & Sodhi, 2004; Coleman, 2006; Jordaan, 2017; Stonebraker *et al.*, 2007, 2009; Vlajic *et al.*, 2010; Vlajic *et al.*, 2013). Such factors are known to arise from the environment within which the value chain is operating, and they have significant reverberations on some segments of the chain or the entire value chain (Jordaan, 2017). Jordaan (2017) adds that this set of factors is based on the judgement that they influence the success of value chain operations. The table below shows the operationalised external fragility factors presented by Jordaan (2017), with some additions from Stonebraker *et al*. (2009).

Table 2-2: External fragility factors

State of the country's economy
Quality of infrastructure
Political and social unrest
Changes of regulatory and compliance requirements in either the public sector or private sector
Competitors' behaviour
Natural disasters
Lack of cooperation

Sources: Jordaan (2017); Stonebraker *et al*. (2009)

Jordaan (2017) emphasises fragility factors that most studies do not consider: chain fragility factors. Their existence is the result of chains' complexities and how these chains are coordinated, together with the alignment between chain players (Jordaan, 2017). The coordination strategies and systems developed to cater for competitive issues (Luke & Heyns, 2018), food safety and traceability (Van Der Merwe *et al*., 2018), transaction costs (Hobbs, 1996), and operational efficiency (Martinez, 2002b) are also core elements that expose a chain's vulnerability and from which chain fragility factors emerge (Jordaan, 2017). Also, as much as the chain coordination strategies and the tight alignment of chain players contribute massively to efficient chain performance, they become sources of exposure (Gray & Boehlje, 2005) to chain susceptibility, resulting in a rippling impact caused by chain disruption (Jordaan, 2017). The table below shows the operationalised chain fragility factors identified by Jordaan (2017).

Table 2-3: Chain fragility factors

Supplier and buyer relationship and alignment
Information sharing with buyers
Degree of chain-wide communication
Degree of chain complexity
The adequacy, accuracy, and relevance of data, its analysis, and effect on decision making

Source: Jordaan (2017)

2.6. ALTERNATIVE APPROACHES TO ASSESS FRAGILITY

There are several ways in which an assessment of fragility has been taken, but the most closely common to this study approach is developed by Stonebraker *et al.* (2007, 2009), where they assess supply chain fragility based on the decisions taken by the management of stakeholders on cost evaluation as levels of threat and operational impact (fragility). The authors came up with The Goldhar- Stonebraker Supply Chain Fragility Index Matrix to assist with assessing sources and impact of fragility, together with sustainability in association with supply chain disturbances. However, this approach leaves out an important part of this study argument stated early about risk and uncertainty analysis in an attempt to comprehend supply chain disruptions rather than their results.

The other alternative approach closely related to this study's approach is developed by Korniyenko *et al.* (2017). The authors assess fragility using network analysis tools for evaluation and ranking traded goods' supply fragility. The network analysis does provide a piece of information to study risks associated with supply shocks in systems that are highly interconnected with each other (Korniyenko *et al.*, 2017). This approach relates to this study's method based on analysing fragility looking at the interconnectedness of the systems involved. However, the minor difference is that this approach assesses fragility of the supply shocks based on the characteristics of goods traded in the network systems.

2.7. SUMMARY

The literature has shown that most agri-food chains have coordination strategies that are vertically intensive and tightly integrated to improve their chains' performance (Anand & Grover, 2015). These coordination strategies are preferred for several reasons, such as a reduction in transaction costs (Hobbs, 1996), attaining production efficiency (Martinez, 2002b), production expansion (Ncube, 2018), restricting barriers to entry (Louw *et al*., 2017), catering for technological advances (Louw *et al*., 2017; Martinez, 2002b), catering for challenges that chains face such as "input/output price risks, quantity/quality risks, and safety/health risks" (Jordaan, 2017) and increasing concerns about food safety and traceability of products to their origins (Van der Merwe *et al*., 2018; Bailey, 2016).

However, the argument is that increased coordination strategies do not only improve chain performance but also expose the vulnerability of chains to unforeseen detrimental events or "substantive and procedural uncertainties" (Vilko *et al*., 2014) because of the interdependencies between the chain players (Stecke & Kumar, 2009; Wagner & Bode, 2006; Jordaan, 2017; Christopher *et al*., 2002; Bailey, 2016; Jüttner, 2005; Wagner & Neshat, 2010). Jordaan (2017) adds that the increasing and acceleration of chain susceptibility through the entire chain relates to the fragility in value chains.

The following chapter provides an overview of the South African egg industry And, in particular, the strategies that are used for coordinating within the industry, its value chain structure, and the most common risks and uncertainties.

CHAPTER 3
THE STRATEGIES OF COORDINATING IN THE SOUTH AFRICAN EGG INDUSTRY AND ITS VALUE CHAIN STRUCTURE: AN OVERVIEW

3.1. INTRODUCTION

South African poultry production remains the most developed and commercialised industry in the country's agricultural sector, with highly intensive production operations (NAMC, 2019). The poultry industry is described as the biggest contributor to the country's agricultural sector (Naidoo *et al.*, 2008). It consists of broiler production, egg production, and the ostrich, duck, goose, guinea fowl, and turkey industries (Nkukwana, 2018).

In 2017 the poultry industry contributed around 19.8% and 40% respectively to the total gross value of agriculture and animal products (SAPA, 2017). The SAPA report states that "the 19.8% contribution from poultry products breaks down into 15.9% from poultry meat and 3.9% from eggs". The poultry industry is crucial to employment in South Africa. This is because it provides about 112 000 jobs for South African people by either direct or indirect employment (SAPA, 2017). The industry is one of the biggest consumers in the maize industry and is a contributor to and fundamental supporter of several businesses related to it – mainly the upstream firms in its value chain (SAPA, 2017). For instance, the feed industry is particularly dependent on the poultry industry.

The chapter positions the dissertation in the context of currently relevant information to achieve the first specific objective – that is, to identify the most common coordination strategies in the South African egg industry. It then compares its strategies with the top egg-producing countries internationally. Identifying coordination strategies and mapping the egg value chain structure are the first steps towards measuring the fragility of the chain.

3.2. CLARIFICATION OF COORDINATION STRATEGY

In the context of value chains, it is clear that there are sequential activities required for the production of goods, their distribution, their marketing and other services like finances to ensure they reach the hands of the consumer (Hobbs, 1996; Jordaan, 2017; Van der Merwe,

2017). These activities involve transaction costs since they drive organisations' economic exchange via once-off market exchange to a wider range of the chain (Hobbs, 1996). The process in which these activities take place is called vertical coordination structure (Hobbs, 1996; Jordaan, 2017). Since the occurrence of the activities involves costs of transacting, then, the organisational objective is to economise on such costs in the chain (Hobbs, 1996).

The objective is attainable via suitable coordination strategic choice, which guarantees zero occurrences of coordination errors and is prevented by costly means of control and operation (Jordaan, 2017; Peterson *et al.*, 2001). Also, the success of the value chain in attaining its objective is driven by which coordination strategy is suitable (Jordaan, 2017). In consideration of this rationality, quoting Peterson *et al.* (2001), "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 underproduction concerning demand. Second, the coordination mechanism creates more operating cost than the cost reduction in coordination errors it is designed to control." Coordination strategy inevitably remains an important part of the managerial tool in methodising sequential economic exchange in chains to enhance performance (Jordaan, 2017). This brings in a coordination question in the egg chain involving different coordination strategies, on how the egg chain players determine which strategy to implement, in which economic exchange (Jordaan, 2017; Peterson *et al.*, 2001).

3.3. THE SOUTH AFRICAN EGG INDUSTRY'S CHAIN STRUCTURE AND ITS CHAIN PLAYERS'ACTIVITIES

The South African egg industry is the second-largest contributor, after the broiler industry, to the poultry sector's gross turnover (SAPA, 2017). The industry's product (eggs) ranks as the fourth largest animal product industry behind other agri-products in the South African agricultural sector, such as poultry meat, beef, and milk (SAPA, 2013). However, eggs' share of the gross value of animal products and all agricultural production declined from 8.5% to 7.9% and from 4% to 3.9% respectively (SAPA, 2017).

The decline may have been caused by several challenges, such as the 2017 outbreak of HPAI, the lingering drought, sky-rocketing feed costs, a decline in egg consumption, the closure of

other producers' operations, and the loss of foreign markets (SAPA, 2017; DAFF, 2018; Davids *et al.*, 2018; NAMC, 2019; BFAP, 2018; SAPA, 2017).

3.3.1. The South African egg industry's chain structure

The South African egg value chain is structured by different companies and individuals that use different strategies to coordinate the achieving of their chain objectives and to add value to their products (eggs). The value chain displayed below (Figure 3-1) shows the different stages that are involved in adding value to the products (eggs) until they are delivered to consumers. These stages mainly consist of breeders, parent stock, hatcheries, inputs to the egg industry (feed, financial, and veterinary services), and the market, which entails retailers and consumers.

The stages of egg production are placed strategically to enhance chain performance, and some are investment opportunities that have been taken. The South African egg chain is represented by a few integrated firms (retailers and commercial producers) and some small, medium, and micro enterprises (SMMEs), most of which operate with contracts, equity, or relationship-based alliances (DAFF, 2018; SAPA, 2017).

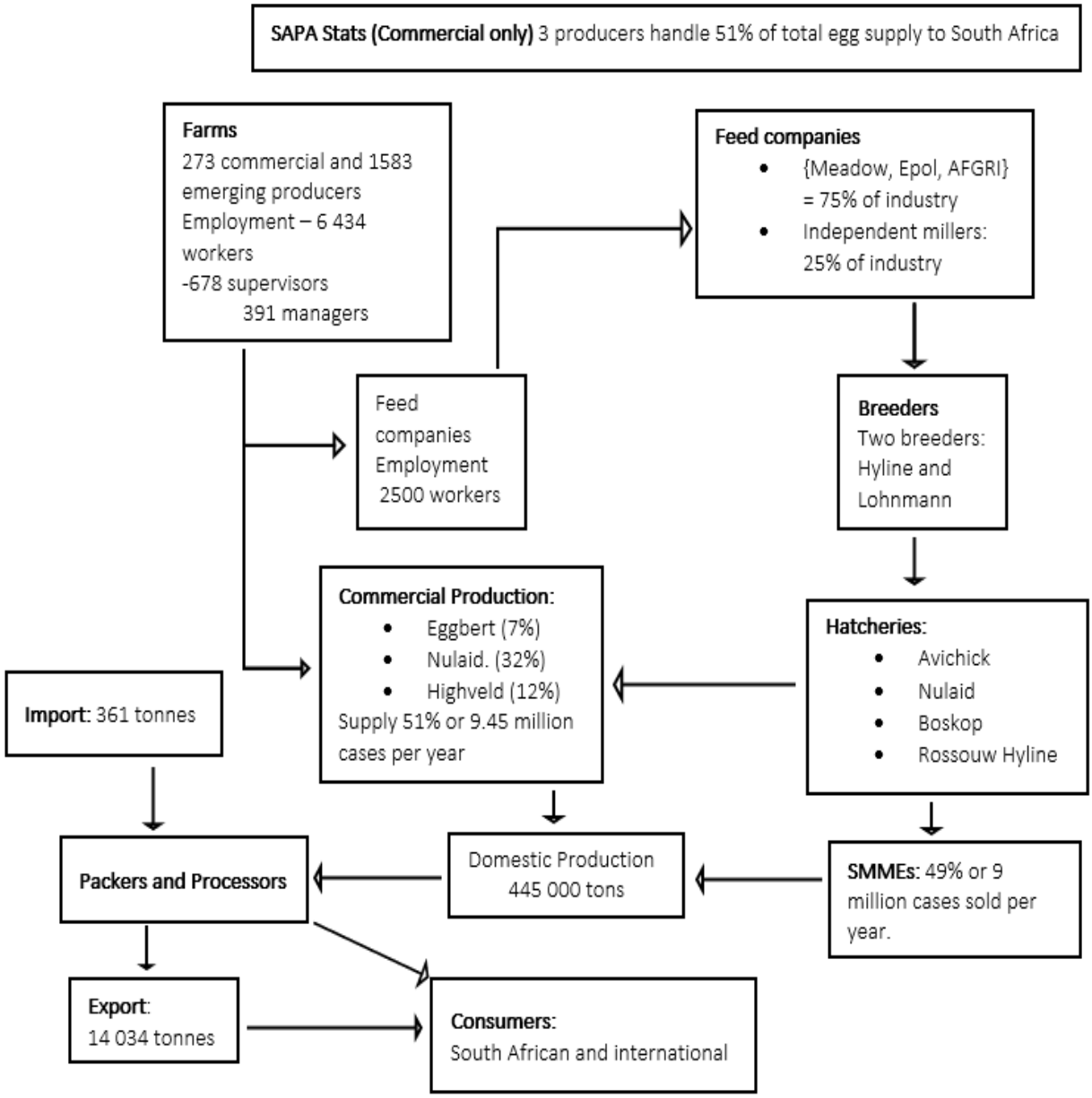


Figure 3-1: South African egg value chain in 2017

Source: Compiled from DAFF (2018) and SAPA (2017)

3.3.2. Activities of South African egg chain players

Breeding stock

The production of eggs in South Africa begins with the importation of breeders (grandparents), with the main breeds for the commercial market being Lohmann and Hyline (DAFF, 2018; SAPA, 2017). These breeds come from Europe and America respectively, and the breeding stock is distributed through companies such as Pioneer Foods and Golden Lay Farms, which pursue joint venture business strategies (DAFF, 2018). The grandparents are reared until they reach maturity and can lay hatching eggs, which produce day-old pullets (parents).

Parent stock and pullets

The parent stock (day-old pullets) are distributed through Nulaid Division and Avichick (DAFF, 2018). The day-old pullets are sold to some integrated and independent firms and are reared to lay eggs to produce pullets (called 'layers'), which mature in 21 weeks (DAFF, 2018). Many pullet-producing companies sell their pullets (layers) to independent egg producers that rear them as laying stock so that they mature to produce commercial eggs.

Laying stock and commercial eggs

Most South African egg producers rear their own laying stock. This is believed to be a crucial phase in the life of this stock, as issues that relate to hens' quality and their efficiency in producing eggs matter the most (DAFF, 2018). The other phase of egg production involves commercial eggs as the final product. This phase is dominated by a small number of big companies, which have a production share of about 51%. These companies are Eggbert, Nulaid, and Highveld Co-op (DAFF, 2018; SAPA, 2017). The remaining 49% of production is shared by small and medium-sized producers (DAFF, 2018; SAPA, 2017). The different eggs[7] – such as free-range eggs, barn eggs, and pasteurised eggs – are produced in different sizes, and graded and packaged (DAFF, 2018; SAPA, 2017). They are then distributed to several retailers or processors.

Retailers and processors

A small number of big retailers, processors, SMMEs, and informal traders dominate the South African market share of eggs (DAFF, 2018). These big retailers use strategies that incorporate several independent egg producers being in the quality management schemes and producing for the same brand (Louw *et al.*, 2007; Ortmann & King, 2010; Vermeulen *et al.*, 2008). There are some activities in egg production, such as packing and value addition (liquid egg), that are vital to the egg chain (DAFF, 2018). Therefore, the big retailers have either integrated strategies or subsidiaries to perform these production activities effectively, while small and independent producers are contracted to the big retailers (DAFF, 2018; SAPA, 2017; Vermeulen *et al.*, 2008).

[7] Eggs included in this study are mainly free-range eggs, barn eggs, and pasteurised eggs, therefore, the term "eggs" represents only these mentioned ones.

3.4. INTERNATIONAL EGG CHAIN COORDINATION STRATEGIES

Coordination of the poultry industry among producers in the egg- and broiler-producing countries "is explained by risk-sharing, technological progress and innovation dissemination, consumer demand for products reputation and uniform quality and access to capital" (Vukina, 2001). Thus, the coordination of egg production, marketing, and distribution differs between emerging economies and developed economies around the world (Mcleod *et al.*, 2009). The poultry sector, in general, "has been quick to take advantage of economies of scale and has rapidly become consolidated and integrated" (Mcleod *et al.*, 2009). This change has been quite rapid in countries that are developed and that trade internationally.

3.4.1. Coordination strategies in the egg industries of the top egg-producing countries

The top egg-producing countries in the world are China (with a market share of 37%), the US (with a share of 9%), and India (with a share of 5%) (Ahmad *et al.*, 2016; Windhorst *et al.*, 2015). The egg production and marketing systems in these countries are driven by intensified vertical or horizontal coordination. China's egg industry is the largest one globally (Fu *et al.*, 2019; Magdelaine, 2011; Windhorst *et al.*, 2015), and is dominated by the top six egg producers, which of each possess an average of five million laying hens (Yang *et al.*, 2018). These massive egg producers are vertically integrated and can use both backward and forward integration systems (Yang, 2011). Yang *et al.* (2018) mention that there is an increasing expectation that Chinese egg producers will adopt more intense vertical coordination in the future. Chinese egg production displays similar coordination strategies to those in the US (Mench *et al.*, 2011).

The US egg industry is the second-largest egg producer after China (Ahmad *et al.*, 2016; Windhorst *et al.*, 2015). This egg industry is dominated by increased vertical coordination strategies that exist due to the influence of the following incentives (Martinez (2002b):

- First, "the emergence of new specialised large-scale technologies that place prominence on the quality control and efficient use of information".
- Second, "the heightened speed of production, the perishability of the products and significance of measuring and sorting costs".

These incentives increase the costs of economic exchange and increase the difficulty of obtaining accurate economic information (Martinez, 2002b). The US egg industry thus uses tighter vertical coordination strategies (Lo, 2010; Martinez, 2002a, 2002b; Thompson *et al.*, 2019; Vukina, 2001).

The increased vertical coordination in the US egg industry is mostly done through long-term production contracts (Martinez, 2002a, 2002b) and vertical integration (Lo, 2010; Martinez, 2002a, 2002b). These strategies of coordination enable most of the US egg-producing firms to be highly integrated, and so they can deal directly with breeders and obtain parent stock and produce their hatching eggs, chicks, and pullets (Hayenga *et al.*, 2000; Rogers, 1979). As a result, the integrated companies maintain their egg marketing and distribution operations (Martinez, 2002b; Oberholtzer *et al.*, 2006). The leading egg-producing firms in the US own egg brands in the country's retail sector (Dive & Ambade, 2016; Scrinis *et al.*, 2017). The branding of agri-products helps to reduce measuring and sorting costs and acts as a quality assurance method (Dive & Ambade, 2016; Martinez, 2002a).

The vertical coordination assists with regional integration and industry expansion (Hayenga *et al.*, 2000; Ncube, 2018; Ncube *et al.*, 2017), and so requires massive investments (Hayenga *et al.*, 2000). This is shown by egg-producing countries that dominate, practise, and can manage high vertical coordination strategies in their regions, such as China's dominance in Asia (Hellin *et al.*, 2015) and US dominance in North America (Windhorst *et al.*, 2015). This is probably the reason for the significant amount of increased vertical coordination in the egg industries of developed economies. However, in many emerging economies, egg production and marketing are done by independent smallholder producers that use less intense coordination strategies (Mcleod *et al.*, 2009).

3.4.2. Coordination strategies in the egg-producing industries of developing countries

The developing egg-producing countries behind the top two are India, Japan, Mexico, Brazil, and Indonesia (Windhorst *et al.*, 2015). In contrast to the top two egg industries, the developing egg-producing countries have similar coordination strategies that differ from the two developed countries. The existence of vertical integration in the egg industries of developing countries is minimal, which may be due to a lack of investment. For instance, in the Indian egg industry,

the commonly practised coordination mechanism is a hybrid, which involves several egg cooperatives (Mehta & Nambiar, 2007) and joint venture business strategies (Karthikeyan & Nedunchezhian, 2013) in which the chain players of the country's egg industry form partnerships that are based on either equity or trust (Reddy, 2010).

Horizontal coordination seems to dominate the Indian egg industry. This integration acts as a measure to ensure a consistent supply of high-quality eggs (Hellin *et al.*, 2015). The integration has resulted in more take-overs by retailers to standardise quality, "improve bargaining power and achieve economies of scale" (Hellin *et al.*, 2015). Also, the existence of such integration and the retail boom in India paved the way to organised retailing (Karthikeyan & Nedunchezhian, 2013). The practice of vertical integration in the Indian egg industry is rarely seen, unlike in its broiler industry (Reddy, 2010). Therefore, very few leading Indian egg producers own their egg value chain fully or partially, from parent breeding to hatcheries, and the retail chain outlets (Karthikeyan & Nedunchezhian, 2013).

Coordination in the Brazilian egg industry has similar features of a developing country in egg production. The Brazilian egg production system involves independent egg producers that are members of different egg cooperatives (Mizumoto & Zylbersztajn, 2004). The wholesalers and retailers are the main distribution channels, which several egg producers produce under their brands (Mizumoto & Zylbersztajn, 2004; Similä, 2013).

The coordination strategies in the egg industries of Mexico and Indonesia are the same as those of India and Brazil. For instance, the Indonesian egg production system also involves the distribution of eggs through egg branding channels of wholesalers and retailers (Ahmad *et al.*, 2016). There are also independent egg producers who are contracted to these retailers, and some of the independent producers are producing for certain egg brands that belong to certain cooperatives (Ahmad *et al.*, 2016).

3.5. STRATEGIES OF COORDINATING IN THE SOUTH AFRICAN EGG INDUSTRY

The South African egg industry is ranked number 26 among egg-producing countries, with an annual production volume of 467,100 tonnes (Windhorst *et al.*, 2015). Its coordination strategies are indistinguishable from the strategies of other egg-producing developing

countries. The procurement of eggs is organised, managed, and coordinated by a small number of firms. These firms form a large production system, and multiple independent egg producers operate either on contracts (DAFF, 2018; Nkukwana, 2018; SAPA, 2017; Vermeulen *et al.*, 2008) or produce for similar egg brands that are owned by retailers and cooperatives (DAFF, 2018; Louw *et al.*, 2007). Table 3-1 below shows some of the South African egg chain players and their chosen coordination strategies for each stage of the egg chain.

There are only a few breeders in the South African egg industry, and they operate on contract to supply day-old chicks to the different independent egg producers. However, some day-old chick suppliers breed for their own vertically integrated organisations. There are several independent egg producers in the South African egg industry that rear and raise their pullets for their chicken layer farms, and produce different types of eggs that are pasteurised, free-range, barn. Many of these producers distribute their products by producing for egg cooperatives' brands or for retailers' brands (DAFF, 2018) such as Highveld's Topley, Pick n Pay's No Name, or Shoprite's Rebrand (Louw *et al.*, 2007). These egg producers practise vertical integration, contracting alliances based on either equity or trust to achieve their chain objectives (Karwat-Woźniak, 2013; Peterson *et al.*, 2001; Sjauw-Koen-Fa *et al.*, 2016).

Table 3-1: Different coordination stages of South African egg producers

Direction of Coordination (starting from breeders to retailers) is either through Vertical integration, Partnerships, Contracts or Cooperation →		Coordination Stages				
		Breeders (Day-old-age chicks' suppliers)	**Pullets** (Rearing)	**Layers** (Chicken layers farms)	**Eggs** (Shell, Pasteurised, Free range, Barn, etc)	**Market** (Retailers, Wholesalers, Processors, Restaurants)
South African egg chain players	Fair Acres	X	X	X	X	X
	Rossgro Poultry		X	X	X	X
	Moreson Poultry Farm		X	X	X	X
	Kiepersol Eggs		X	X	X	X
	Avichicks	X				
	Nulaid (Bergvlei Chicks)	X	X	X	X	X
	Highveld Eggs Co-op (TopLay)				X	X
	Alzu Layer Farms			X	X	X
	Eikenhof Poultry Farms (Pty)Ltd		X	X	X	X
	Grendon (Pty) Ltd	X	X	X	X	X
	Eggbert			X	X	X
	Hyline	X				
	Heidel Eggs			X	X	X
	Wolfhart Poultry		X	X	X	X
	Bartlet Poultry Farm			X	X	X
	Almur Smit Poultry Farms		X			
	Windmeul Eierboere (PTY) Ltd			X	X	X
	El-Azaar Poultry Farm CC.			X	X	X
	Golden Lay		X	X		
	Inverness rearers		X	X		
	Kuipers Group				X	X
	Wilco van der Schyff Boerdery		X			
	JJ van der Schyff Boerdery			X	X	

Sources: Compiled from DAFF (2018), SAPA (2017), and from the profiles of the listed companies

Table 3-1 displays the different forms of coordination strategy most commonly used by the chain players in the South African egg industry. Some producers are vertically integrated, from breeding stock to rearing and raising pullets, owning chicken layer farms, producing eggs, and owning their retail outlets or contracting with egg processing companies that transform shell eggs to liquid or powdered eggs (Oliveira *et al.*, 2013). Other producers use joint venture business strategies by being in relationship-based or capital-based partnerships (Williams, 2019) with retailers, or they operate in contract conditions with retail outlets (Louw *et al.*, 2008).

Vermeulen *et al.* (2008) highlight that "the incorporation of emerging farmers is usually done through the distribution of empowerment shares to farmworkers in the egg industry". The authors add that independent emerging producer operates on specified contracts that state the volume, quality, and delivery date requirements, and the range of egg prices. In essence, the South African egg industry under commercial production excludes the open market and that's the focus for this study. Since commercial production includes mainly a token number of big firms that pursue lean and highly integrated strategies and some independent producers that operate on long-term production contracts (DAFF, 2018; Nkukwana, 2018; SAPA, 2017; Vermeulen *et al.*, 2008).

3.5.1. Strategic choices along the vertical coordination continuum in the South African egg chain

Based on the information in Table 3-1, the dominant coordination strategy seems to be a hybrid one, consisting of contract specifications, an alliance based on equity or relationships, joint business ventures, and cooperatives (Peterson *et al.*, 2001), while vertical integration is minimally represented. The decision of the coordination stage taken by these chain players is indicated by label (x) under each stage. The more label (x) appears as the direction of coordination shifts from left to right, imply that many players operate using coordination strategies such as cooperation membership, partnership formation based on either trust of equity or contract basis. This means that the most dominant strategy is hybrid in the south African egg industry as the about mentioned strategies of coordination all fall under hybrid. Figure 3-2 below displays different strategic choices for vertical coordination that are taken to enhance business chain performance (Anand & Grover, 2015; Schiefer *et al.*, 2009; Van der Merwe, 2017).

The strategic choices have different characteristics of coordination shown in Figure 3-2 (Peterson *et al.*, 2001; Wognum & Wever, 2008; Zhong *et al.*, 2018). The interdependency (intensity of control) is one of the main arguments built into this study. The figure shows that intensity of control increases from the spot market to the vertical integration along the horizontal axis denoting an increase in vertical coordination. South Africa egg chain players have a high intensity of control in their value chain as they pursue either hybrid (contractual relationship, relation, or equity-based alliance) or vertical integration for strategic coordination.

	Spot market (market)	Non-contractual relationship		Contractual relationship	Relation-based alliance	Equity-based alliance	Vertical integration (hierarchy)
		with a non-qualified partner	with a qualified partner				
	S	S+	S++	C	RB	JV	VI
Irrelevance of identity	Yes	No	No	No	No	No	No
Length	Short	Medium	Long	Long	Long	Long	Long
Restriction on the choice of partner	No	No	Yes	No	No	Yes	Yes
Written contract	No/Yes	No	No	Yes	No/Yes	Yes	Yes
Contract specifications	Price	General terms and relational objectives	General terms and relational objectives	All or part of each party's obligation	All or part of each party's obligation	Alliance agreement	Governance structure
Resource sharing	Owns own resources	Owns own resources	Owns own resources	Owns own resources	Owns own resources	Each party put resources into new entity	Common ownership
Joint forces for mutual benefit	No	No	No	No	Yes	Yes	Yes
Intensity of control	Low	Low	Low	Moderately Low	Moderate	Moderately high	High
Focus of control	Immediate transaction	Relationship	Relationship	Contract terms	Relationship	Property rights of stakeholders in limited joint entity	Property rights of stakeholders in full entity

Figure 3-2: Strategic choices for vertical coordination and their determining variables

Source: (Schiefer *et al.*, 2009; Van der Merwe, 2017)

As a result, the interdependencies between the chain players in the South African egg industry act as catalysts for its chain fragility. This is because they expose the chain to risks and uncertainties that seem to be disruptive and detrimental.

3.6. RISK AND UNCERTAINTY IN THE SOUTH AFRICAN EGG INDUSTRY

Coordination in the egg chain is arranged in different ways to deal with the operational risks (Kleindorfer & Saad, 2005; Sodhi *et al.*, 2012; Tang, 2006) shown earlier; these risks are associated with the coordination of supply and demand together with the uncertainties within such strategies. This dissertation does not particularly focus on such risks, but rather on the disruptive risks that result in catastrophic impacts such as the closure of businesses (Bailey, 2016; Jordaan, 2017; Kleindorfer & Saad, 2005; Sodhi *et al.*, 2012; Tang, 2006). The disruptive risks deal with events that occur due to crises (Bailey, 2016; Jordaan, 2017; Kleindorfer & Saad, 2005). These events result in risks that are categorised as having a low likelihood but a high consequential impact (Bailey, 2016; Jordaan, 2017; Kleindorfer & Saad, 2005).

Inevitably, unforeseen events serve to underline that agri-food chains, such as the South African egg chain, are vulnerable to variables in the fragility that emanate from internal, external, or chain factors (Bailey, 2016; Jordaan, 2017; Stonebraker *et al.*, 2009). The events can also result in escalating susceptibility throughout the entire chain (Bailey, 2016; Jordaan, 2017; Peck, 2005). This dissertation focuses on these disruptively risky events that occur in the South African egg industry.

3.6.1. The outbreak of highly pathogenic avian influenza

The most recent and deadliest event was the 2017 outbreak of HPAI, which occurred first in the broiler industry on 19th June 2017 (Abolnik *et al.*, 2018; BFAP, 2018). The outbreak occurred in the egg industry in Standerton in Mpumalanga province (SAPA, 2017). The report by SAPA (2017) highlights that control measures were put in place to contain and prevent further outbreaks. However, more outbreaks occurred in other provinces, such as Gauteng, North West, Western and Eastern Cape, Free State, and KwaZulu-Natal; and these outbreaks hit the commercial layer sector the worst (SAPA, 2017).

Seventy-eight outbreaks were reported in 2017, which included commercial ostrich farms (SAPA, 2017). The consequences were that 4.69 million laying hens died, some of which were

selectively slaughtered; and millions of eggs that were produced daily by hens that were put under quarantine were reported to have been destroyed (SAPA, 2017). About 25 South African egg farms went out of production (Davids *et al.*, 2018; SAPA, 2017). Furthermore, product recalls were made, which resulted in about 3.7 million eggs per day being removed from the market (SAPA, 2017). The consequences of the outbreak, the product recalls, and the decline in egg production caused an increase in egg retail prices and a decline in egg consumption (Davids *et al.*, 2018; BFAP, 2018; SAPA, 2017).

The control measure that was taken to contain the outbreak was to cull affected birds while a possible vaccination strategy was being considered (Davids *et al.*, 2018; BFAP, 2018). The culling of birds – the strategy used – came with compensation for the affected producers (Davids *et al.*, 2018; BFAP, 2018; SAPA, 2017). Nevertheless, some major financial losses were reported by the Bureau for Food and Agricultural Policy (BFAP), including biological and income losses and direct costs which all amounted to R1.87 billion (BFAP, 2018; Davids *et al.*, 2018; BFAP, 2018; SAPA, 2017). These financial losses represented about 18% of the gross value of egg production, and the egg industry suffered 76% of the income lost due to the outbreak in 2017 (SAPA, 2017).

Fundamentally, detrimental events such as this outbreak disrupt the normal functioning of a chain, expose its vulnerability, and contribute to the closure of businesses (Christopher *et al.*, 2002; Engber, 2012; Jordaan, 2017; Kleindorfer & Saad, 2005). Disease outbreaks such as an HPAI outbreak are factors that are that contribute to chain fragility (Jordaan, 2017; Stonebraker *et al.*, 2009).

3.6.2. Regulatory and compliance issues

Regulatory and compliance changes disrupt the normal functioning of a chain (Jordaan, 2017; Stonebraker *et al.*, 2009). The South African *Government Gazette* published on 15th April 2016 contains information about the Agricultural Product Standards Act (Act 119 of 1990) (DAFF, 2019). According to SAPA (2017), DAFF has appointed an agency, Food Safety and Quality Assurance (FSQA), to deal with the regulation of agri-food products in respect of marking, grading, and packing eggs destined for sale in South Africa. The FSQA was appointed as an independent agency that has to make sure that food safety and the quality of agri-food products that are either imported or produced in the country meet the required standards (DAFF, 2019;

SAPA, 2017). The agency has also defined the methods of producing eggs – barn eggs, organic eggs, free-range eggs, and caged eggs – that should be followed.

All these regulations came into effect on 15th April 2017 (SAPA, 2017). This affected egg producers, as the gazetted fee of R1.8 per dozen, had to be paid by the producers to fulfil the regulations. The producers also have to incur the costs of travelling and laboratory fees (SAPA, 2017). However, after several objections were lodged, the fee was decreased to R0.72 per dozen (SAPA, 2017).

The literature has shown that compliance and regulatory issues disrupt the normal functioning of a chain and that they are regarded as external factors that contribute to the fragility of a chain (Jordaan, 2017; Stonebraker *et al.*, 2009; Vlajic *et al.*, 2012). These regulatory issues faced by the egg value chain are regarded as one of the many disruptive events that can contribute to the fragility of the egg chain.

3.6.3. Lingering drought

South Africa has experienced a crippling drought in recent years that has had a severe impact on agriculture as a whole, with the Western Cape province being the most severely affected (Archer *et al.*, 2019; SAPA, 2017). Weather-SA (2018) stated that South Africa is susceptible to continual droughts, with the long-term annual rainfall estimated at 600mm. Most egg producers in the provinces that were worst affected due to lack of water for operations at their farms – the Western Cape, the Eastern Cape, and KwaZulu-Natal – are still dealing with the consequences of that lingering drought (SAPA, 2017). The dam levels in those provinces are recovering, but at a slower rate (SAPA, 2017). The drought elevates the prices of products such as maize (Moobi, 2019), which in turn become a high input cost to the egg industry.

The drought is thus an environmental issue that disrupts the normal functioning of a chain and exposes its vulnerability (Christopher & Peck, 2004; Vlajic *et al.*, 2012). It is thus regarded as an external factor that contributes to the fragility of a value chain (Jordaan, 2017; Stonebraker *et al.*, 2009; Vlajic *et al.*, 2012).

3.6.4. A decline in the consumption of eggs

The consumption of eggs has dropped recently for the reasons stated by Davids *et al.* (2018) and SAPA (2017): retail price increases, and the outbreak of HPAI. The decline of egg consumption is a negative spillover effect caused by few issues raised by SAPA (2017) below and this spillover disrupt the normal functioning of the egg chain, hence, it is regarded as a disruptive event[8]:

- The latest studies of cholesterol and high egg protein and fat contribute significantly to the decline in egg consumption.
- Concerns about food safety (eggs are associated with bacterial diseases such as salmonella) are assumed to have contributed to the decline.
- Constrained consumer spending is assumed to be a third contributor to the decline.

These are assumed to be the main contributors to the decline in the demand for eggs in South Africa (SAPA, 2017). The figure below displays annual egg consumption per capita, revealing a massive drop in egg consumption in South Africa in 2017.

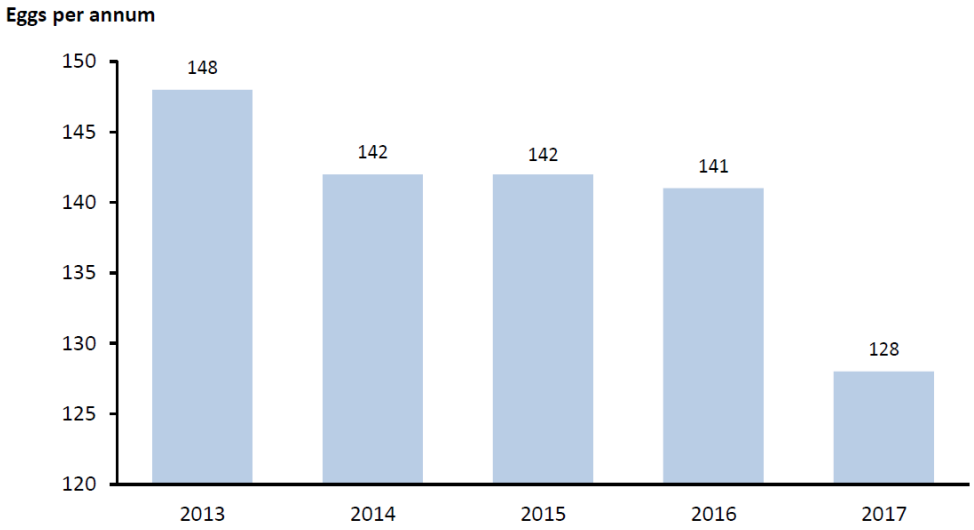


Figure 3-3: Declining annual consumption of eggs per capita in the South African market

Source: SAPA (2017)

[8] The negative spill overs effects are regarded as consequences of disturbances and these effects fall under disruptive events because their disruptions on a normal functioning of a chain.

The drop in the egg consumption rate in South Africa left most firms with poor cash flow, as eggs are their main product. The cash flow is regarded as an internal fragility factor of the agri-food value chain (Jordaan, 2017; Jordaan & Kirsten, 2019), and can result in the closure of businesses if the firm has a very poor cash flow, as the incoming cashflow would be insufficient to meet the outgoing cash flow needs of the business.

2.3. SUMMARY

Coordination strategies – such as long-term contracts, lean operations, outsourcing, vertical integration, horizontal integration, and alliance partnerships based on either equity or relationships – are commonly used in the South African egg industry (Vermeulen *et al.*, 2008). Most retailers, big commercial egg producers, and cooperatives use channels such as grouping producers under the same quality management schemes, or producing for the same egg brand, as their way of enhancing their chain performance (Louw *et al.*, 2007; Vermeulen *et al.*, 2008). All these strategies and channels lead to increased coordination, which creates the interdependencies and interconnectedness between chain players (Jordaan, 2017; Wever *et al.*, 2012a). In return, the interdependencies expose the vulnerability of the chain to the detrimentally disruptive events that were mentioned above, and many more (Christopher *et al.*, 2002; Jordaan, 2017; Stonebraker *et al.*, 2009; Wagner & Bode, 2006).

The more often that such disruptive events occur, the more vulnerable the chain becomes. That is, if a single chain player is affected or disrupted, that disruption can spread rapidly throughout the entire chain because of the existing interdependencies between chain players (Jordaan, 2017) – hence the emphasis that Jordaan (2017) places on the fragility of a chain. The focus of this dissertation is therefore on coordination strategies in the South African egg industry, and the interdependencies they create between chain players, to highlight the fragility concept. Fragility is detrimental to business continuity and leads to the collapse of a value chain.

The South African egg value chain is considered for empirical analysis in this study. This empirical analysis takes into account the notable popularity of fragility as a concept and justifies the fragility measure framework developed for agri-food chains by Jordaan (2017). Thus, this chapter leads into the next chapter, which describes the methodology of this study.

CHAPTER 4
METHODOLOGY

4.1 INTRODUCTION

This chapter discusses the measurement of the fragility of the South African egg value chain, considering the different arrangements of the chain's coordination strategies. The measurement is carried out using an approach called heuristic stress-testing, which was developed by Taleb *et al*. (2012); its first application in the value chain context was done by Jordaan (2017). The approach is used to assess whether systems such as value chains (Jordaan, 2017) can withstand the consequences of adversely disruptive events.

The chapter also describes the methods used to collect and analyse data and provides the details about the unequal variance t-test on the comparative fragility analysis of two egg chains' configurations to provide accurate results and a justification of the fragility analysis. It then outlines the descriptive overview of the respondents and the accuracy of the sample size are provided.

4.2 MEASURING VALUE CHAIN FRAGILITY

This study adopted the tool to measure value chain fragility by Jordaan (2017) and Jordaan and Kirsten (2019), which presents each of the 17 value chain fragility factors explained in the second chapter of this dissertation. The same procedure with the respondents is followed as that used by Jordaan and Kirsten (2019):

> "…the respondents' reactions were elicited in response to a progressively worsening adverse event, concerning the specific factor. 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%."

For more details refer to the questionnaire in the appendix on page 92 of this dissertation.

As already stated, the measurement of fragility in the South African egg value chain was carried out using heuristic stress testing. This approach sought to evaluate the value chain's fragility

rather than a specific incident that would reveal its fragility. Also, this approach did not give a single measure that confines all fragility factors for agri-food chain (Jordaan, 2017). Thus a procedure is used to put in place a composite index for each value chain player, and then combine the composite indices of the respective chain players to come up with an outcome that indicates the chain's fragility (Jordaan, 2017).

For more details, Taleb *et al*. (2012), Jordaan (2017), and Jordaan and Kirsten (2019) provide information on the application of a heuristic for fragility detection in the context of stress testing in the banking sector. Their perspective on heuristic stress-testing entails:

> "... 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 H, where:
>
> Equation 4-1: $$H = \frac{\mathbf{f}(\boldsymbol{\alpha}-\Delta)+\mathbf{f}(\boldsymbol{\alpha}+\Delta)}{\mathbf{2}} - f(\alpha)$$
>
> **f(x)** 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. Δ is a change in **α**, a certain multiple of the mean deviation of the variable. The severity of the convexity expressed by **H** should be interpreted concerning 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 **H=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 Δ) **x** is equal to the potential loss from an equivalently sized larger **x**. When **H<0**, and significantly so concerning capital, the outcome is fragile, in the sense that the additional losses with a small unfavourable shock (that is, compared to a given tail outcome) will be much larger than the additional gains with a small favourable shock. Thus, volatility is bad in such a situation; that is, we can say that an institution for which **H** is negative is 'fragile' to higher volatility. When **H>0** the output is anti-fragile, with the sense that additional losses with the unforeseen event will be much lower than additional gains as a shock would be a favourable one."

Figure 4-1 below shows the concept explained above.

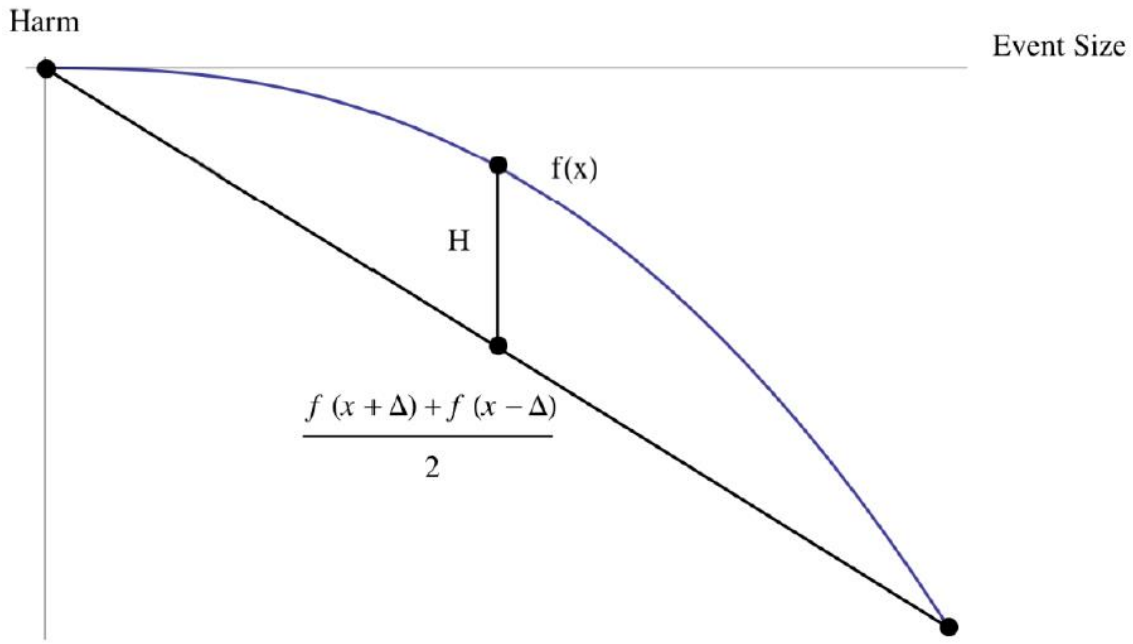


Figure 4-1: Fragile results of heuristic stress test

Source: Adopted from Taleb *et al*. (2012), Jordaan (2017), and Jordaan and Kirsten (2019)

The action plan to measure the South African egg value chain's fragility is represented by most of the value chain fragility factors – internal and external – as stated in the literature review. The above procedure is put in place to assist with assessing the comparative fragility analysis of two different egg value chains' coordination strategies.

4.3 COMPARATIVE VALUE CHAIN FRAGILITY ANALYSIS

The specific reason for choosing the heuristic stress testing approach was because of Jordaan and Kirsten (2019) state that the approach gives the techniques to cross-examine the concept that there is some sort of relationship between the strength of a value chain's coordination strategy and its fragility. Therefore, as stated before, the approach does not give a single measure that confines all fragility factors for agri-food chain (Jordaan, 2017). To come up with a measure of fragility, Jordaan (2017) and Jordaan and Kirsten (2019) state that there is a development of "a composite index per chain player and final score denoting 'value chain fragility', comprised of all the composite indices of each value chain player in the chain being analysed".

As a result, to complete a single measure of fragility, a polygon is developed with final sub-index values, which entails the fragility of a particular chain that is being analysed (Jordaan & Kirsten, 2019; Jordaan, 2017; Gopal & Thakkar, 2015). For comprehensive details on this approach, Jordaan (2017) and Jordaan and Kirsten (2019) state their perspective as follows:

> "… 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 chain player 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."

Jordaan and Kirsten (2019) emphasise that the above-explained procedure is then used to combine the individual fragility scores per chain player into a composite index that represents the measure of fragility for the whole chain. For simplicity, Jordaan and Kirsten (2019) summarise the steps required to accomplish a measurement of a value chain's fragility:

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

Step 2 – combine each of the fragility outcomes per fragility factor into a composite index of fragility for each chain player.

Step 3 – combine each of the fragility outcomes per chain player into a composite index of fragility for each chain.

This means that there is a specific trade-off between chain performance and chain fragility (Jordaan, 2017). Thus, the South African egg value chain is considered in two different configurations to compare its coordination strategies for a comparative analysis of its fragility.

1. The first configuration of the chain incorporates the lower levels of the vertical linkages (low levels of interconnectedness and interdependency).

2. The second configuration of the chain incorporates the higher levels of the vertical linkages (high levels of interconnectedness and interdependency).

Then the unequal variance t-test is used to test whether the average fragility of the two different egg value chains, which possess different levels of interdependency among their chain players, are significantly different from each other. Below are two hypotheses for the activity.

1. The null hypothesis: There is no statistically significant difference in the average chain fragility of the two different South African egg chain coordination strategies.

2. The alternative hypothesis: There is a statistically significant difference in the average chain fragility of the two different South African egg chain coordination strategies.

The data collection was carried out through an emailed questionnaire and arranged interviews. A stratified and random sampling selection of the South African egg value chain players was conducted. The different activities in the chain were the strata, and within these strata, respondents were randomly selected sources. The data analysis was carried out using Microsoft Excel.

4.4. OVERVIEW OF THE RESPONDENTS AND ACCURACY OF THE SAMPLE SIZE

A stratified and random sampling selection of the South African egg value chain players was conducted. The 195 randomly selected members from South African commercial egg chains were invited to participate in the study; the questionnaire was then presented and distributed to them. The response rate was 37.4% (73 complete questionnaires). The respondents were distributed across the egg chain configurations, as shown in Figure 4-2 below, but mainly in vertical integration, specified contracts, equity-based alliances, and relationship-based alliances.

The sample size of 73 respondents offered a marginal error of 10% and a confidence level of 90% for the adequacy of the sample, given that the total population size was 1,216 egg

producers, 43 pullets rearers, and 29 retailers (SAPA, 2017; DAFF, 2018; Igumbor *et al.*, 2012).

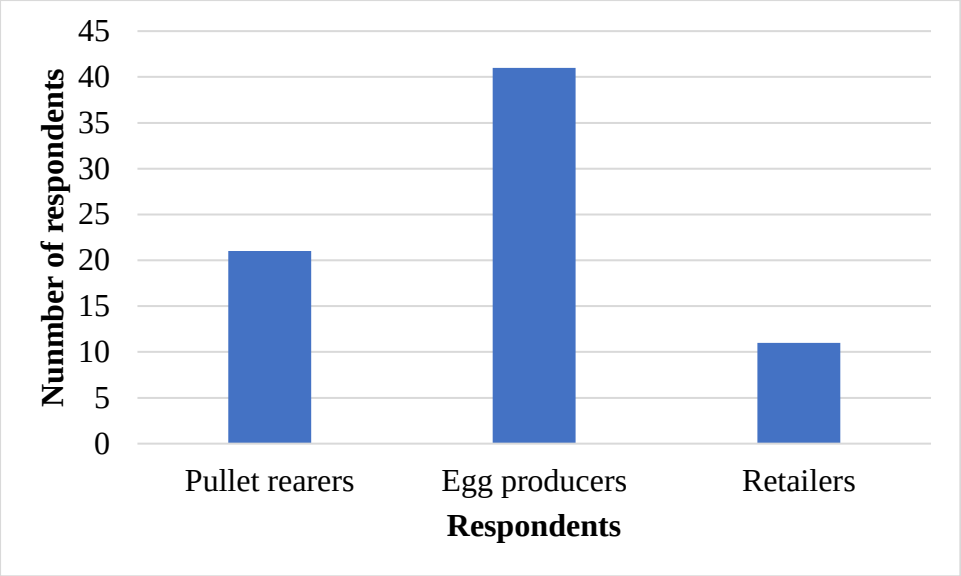


Figure 4-2: Distribution of respondents from South African egg chain

4.5. SUMMARY

This chapter described the methodology used to attain two specific objectives of the study: to measure the fragility of the South African egg value chain, and to carry out a comparative fragility analysis of the South African egg value chain by a comparison of two egg chains. Both objectives were achieved using heuristics stress testing. Then a comparative fragility analysis was done using the unequal variance t-test to compare two egg chains with different coordination strategies (high and low interconnectedness and interdependencies). This was done to simulate the variation of possible results for the fragility of the two chains.

This chapter leads into chapter 5, which addresses the results and discusses them.

CHAPTER 5
RESULTS AND DISCUSSION

5.1. INTRODUCTION

The previous chapters provided an overview of the study's problem statement, its objectives, its conceptual framework, and details about the methods and procedures used in the study. This chapter presents the fragility analysis and fragility results and discusses them. The fragility results are presented based on fragility factors, fragility scores per chain player, and fragility scores of specific individual chain structures. Then the fragility analysis compares the two South African egg chain configurations, which involve levels of interdependencies between chain players as the study hypotheses have highlighted.

This chapter outlines the findings of the heuristic stress testing are presented; and last, the reports of the fragility results are followed by a discussion of the results.

5.2. FRAGILITY SCORES PER FACTOR

The results of the fragility analysis showcase a notable outcome of the average fragility scores of the fragility factors and this is the first step of measuring fragility as stated in chapter 4, which is to determine the fragility of each of the fragility factors for each player. The fragility scores result from two South African egg chain configurations representing two chains: one with higher levels of interdependency between its chain players (Figure 5-1 below), and the other with lower levels of interdependency between its chain players (Figure 5-2 below).

These scores confirm what Jordaan (2017) and Jordaan and Kirsten (2019) say about "non-linear effects" that are in correlation with the fragility of any particular factor. These effects ultimately indicate the susceptibility of a factor to unforeseen and highly detrimental events. Both Figure 5-1 and Figure 5-2 show the fragility scores per factor for each of the egg chain configurations and its chain players. The negative scores, which are known as the negative convexity effect, specify fragility, while the positive scores, known as the positive convexity effect, specify anti-fragility (Jordaan, 2017; Jordaan & Kirsten, 2019).

Based on the results presented in Figures 5-1 and 5-2, the fragility factors such as business operational reliability, products' quality, and safety performance, supporting infrastructure, business's cash-flow position, and buyer and supplier reliabilities have high fragility scores.

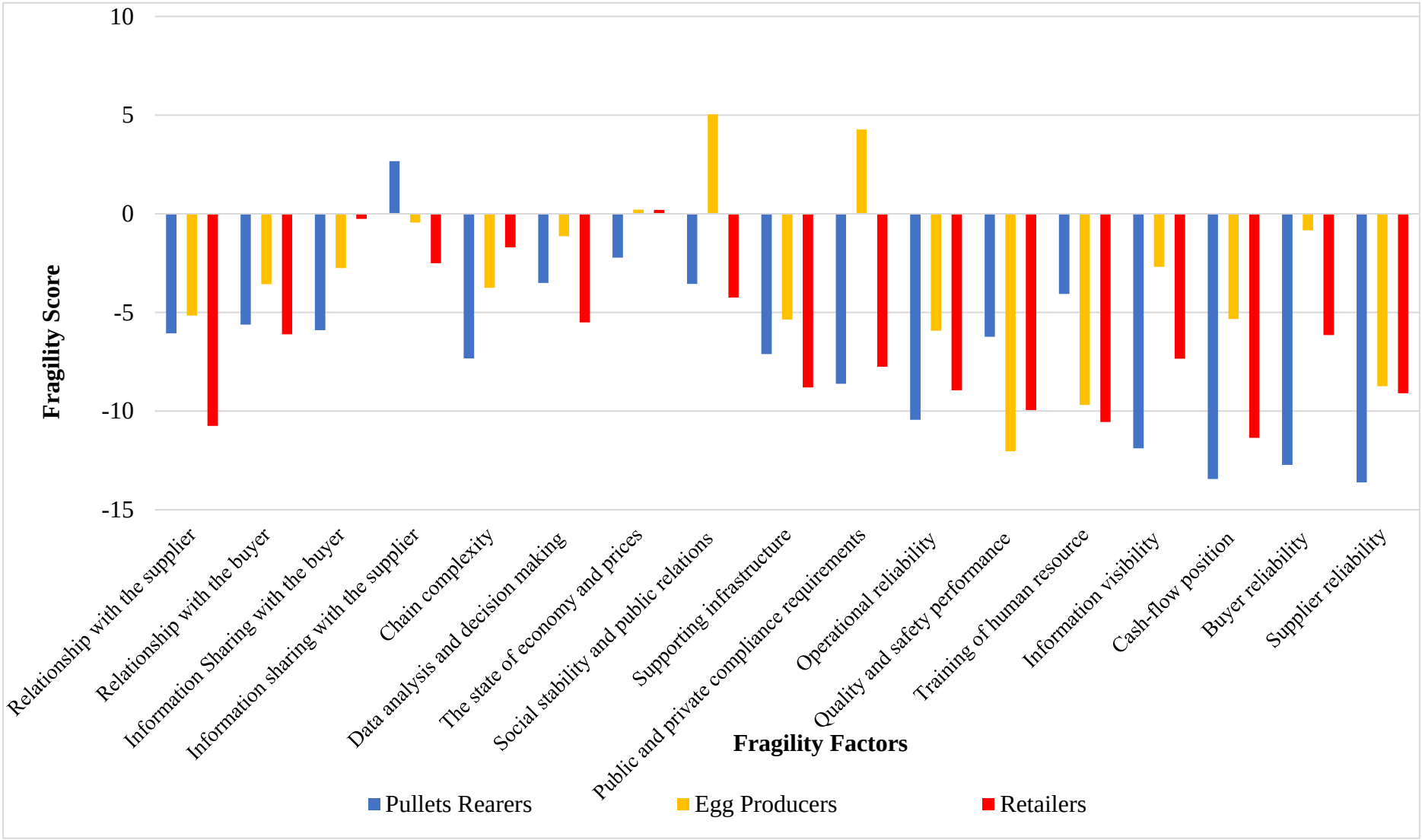


Figure 5-1: Average fragility per factor in South African egg chain with higher levels of interdependency

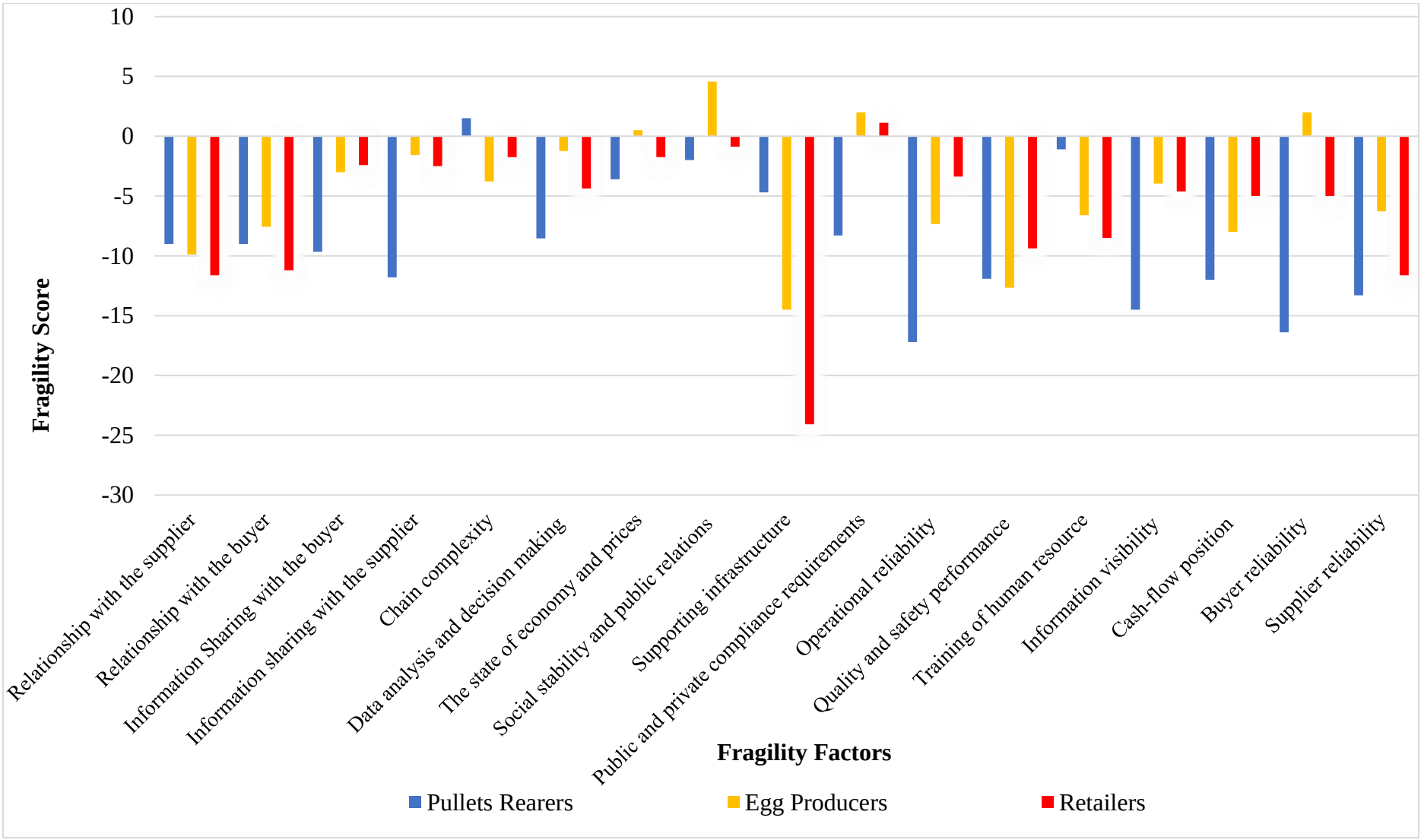


Figure 5-2: Average fragility per factor in South African egg chain with lower levels of interdependency

Figures 5-1 and 5-2 also show the factors that display anti-fragility, because they possess positive convexity effects across both chains and for their chain players. These factors are the state of the economy and prices, social stability and public relations, information sharing with the buyer, and private and public compliance requirements. These positive convexity effects differ across the chain players in both configurations. The only two factors that display the effects for egg producers in both chains are social stability and public relations, together with private and public compliance requirements, while information sharing with the buyer is the only factor that displays the effects for pullet rearers that are in the chain configuration with lower levels of interdependencies. Last, the state of the economy and prices displays minimal effects for the retailers in both chains' configurations.

Although it is important to consider fragility scores per factor, it is also important to consider the fragility factor across the chain players in the same chain configuration. Also, the consideration ranks the most important factors per player to determine whether there is any convergence across the chain of the same factors. This determination provides important information and knowledge about which chain player is more exposed to uncertainty under that factor.

Therefore, in the chain configuration with higher levels of interdependencies, it is notable that the following factors are important to all chain players due to their higher fragility scores: supplier reliability, buyer reliability, cash flow position, and operational reliability. The following factors such as information visibility and relationship with the supplier are key for retailers, while the training of human resources and chain complexity is key for pullet rearers, and egg producers most face quality and safety performance requirements. Furthermore, all these factors are vital for chain players in the chain configuration with lower levels of interdependencies.

In other words, quite a few factors – such as like operational reliability, quality and safety performance, and the training of human resources – are vital to pullet rearers and egg producers in the chain with lower interdependencies; supporting infrastructure is an important factor for retailers and egg producers, and the cash flow position is the only fragility factor that is key for all chain players in both egg chain configurations. Consequently, the chain players are exposed

to uncertainty in different ways, even though they are in the same chain configuration. The figures below (Figures 5-3, 5-4 and 5-5) show the fragility of each chain player in both chain configurations.

5.3. FRAGILITY PER CHAIN PLAYER

The results of the fragility per chain player (from Figures 5-3 to 5-5) show that pullet rearers and retailers have a higher exposure to fragility than do egg producers under both chain configurations, this is seen by larger areas of their polygons. The results support the observations of Jordaan (2017) and Jordaan and Kirsten (2019) that there is a connection between the differences in the fragility factor per chain player and the equal size of the total fragility per chain player. As stated in Chapter 4, "the larger the area of the polygon is, the greater the fragility of the chain player under analysis is" (Jordaan & Kirsten, 2019). Thus, the observation supports the finding of Jordaan (2017) and Jordaan and Kirsten (2019) that the massive impact but infrequent incidence for a particular chain player could predictably have an indistinguishable impact on the other chain player.

A fascinating observation drawn from the results is that all the chain players in both chain configurations are differently exposed to fragility. That is, the chain players in one configuration with similar levels of interdependencies possess differences in the fragility they face. This means that the chain players are exposed to uncertainty differently. This suggests that, even though players have the same levels of interdependencies, their fragility scores differ due to their distinctive features. For instance, the pullet rearers are exposed to more uncertainty than are the egg producers and retailers in both configurations as shown by Figure 5-6. That is, in whatever chain configuration they operate, that does not change anything, as they have sequential interdependencies in both chains. However, further reasons were not assessed, as that would have required further analyses that were beyond the scope of the study.

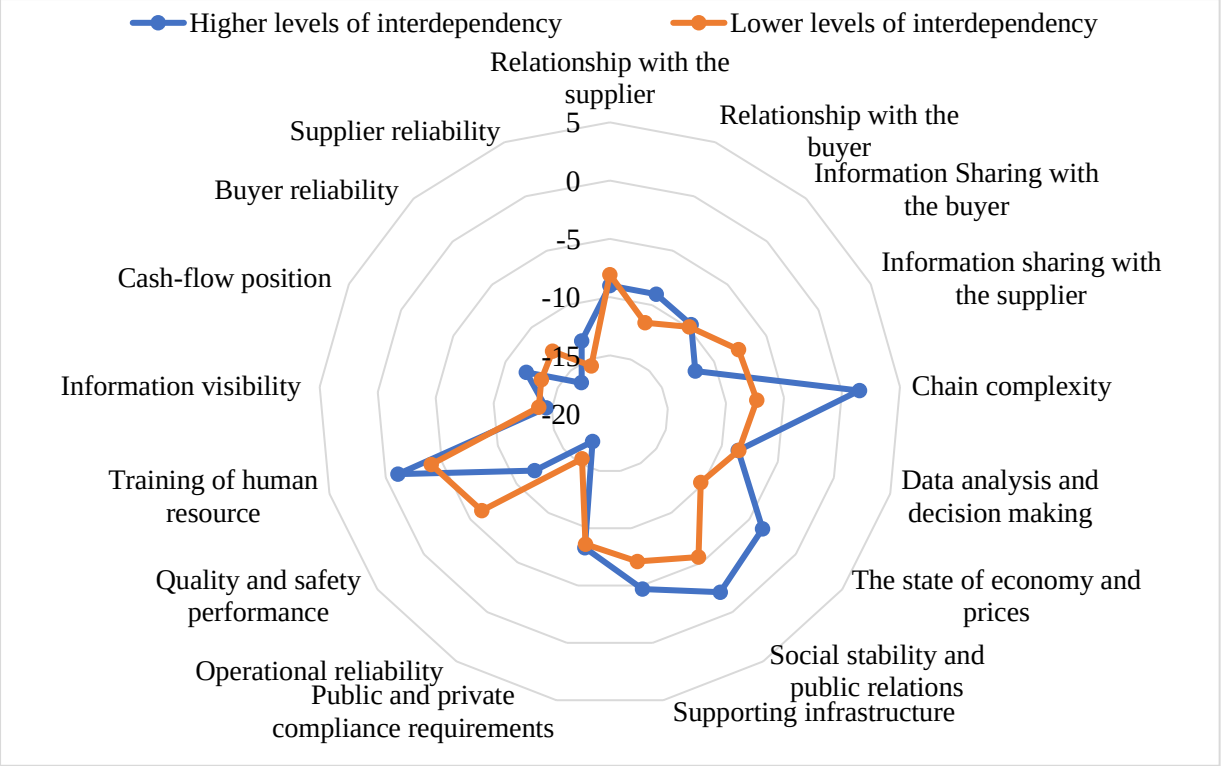


Figure 5-3: Fragility of pullet rearers in South African egg chain with lower levels of interdependency and with lower levels of interdependency

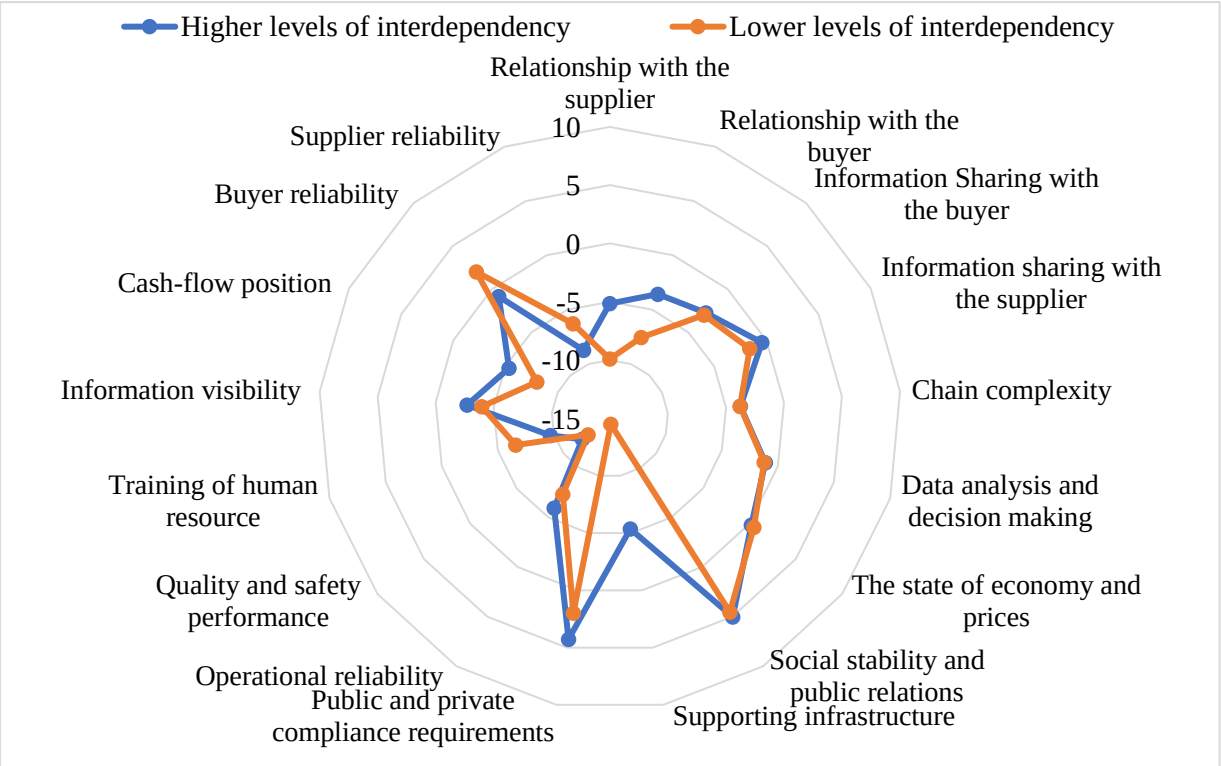


Figure 5-4: Fragility of egg producers in South African egg chain with lower levels of interdependency and with lower levels of interdependency

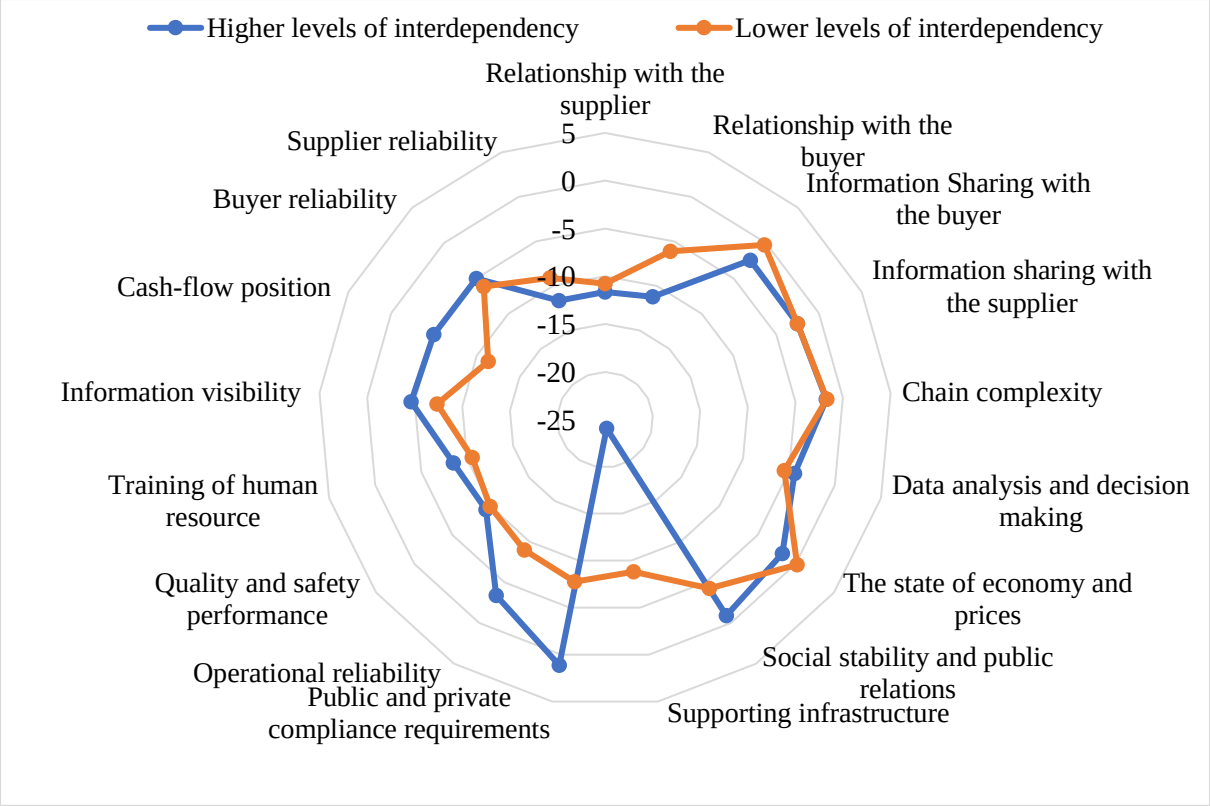


Figure 5-5: Fragility of retailers in South African egg chain with lower levels of interdependency and with lower levels of interdependency

The differences in the fragility of any chain player under two chain configurations are what was expected, solely because the two chains have different levels of interdependency and interconnectedness between their chain players. Thus, the chain players of a chain that presents higher levels of interdependency between its members are exposed to more uncertainty than those in a chain that presents lower levels of interdependency between its members. Figure 5-6 below shows comparisons of the fragility per chain player in the South African egg chain. The figure also supports the previous statement about the differences in fragility per chain player.

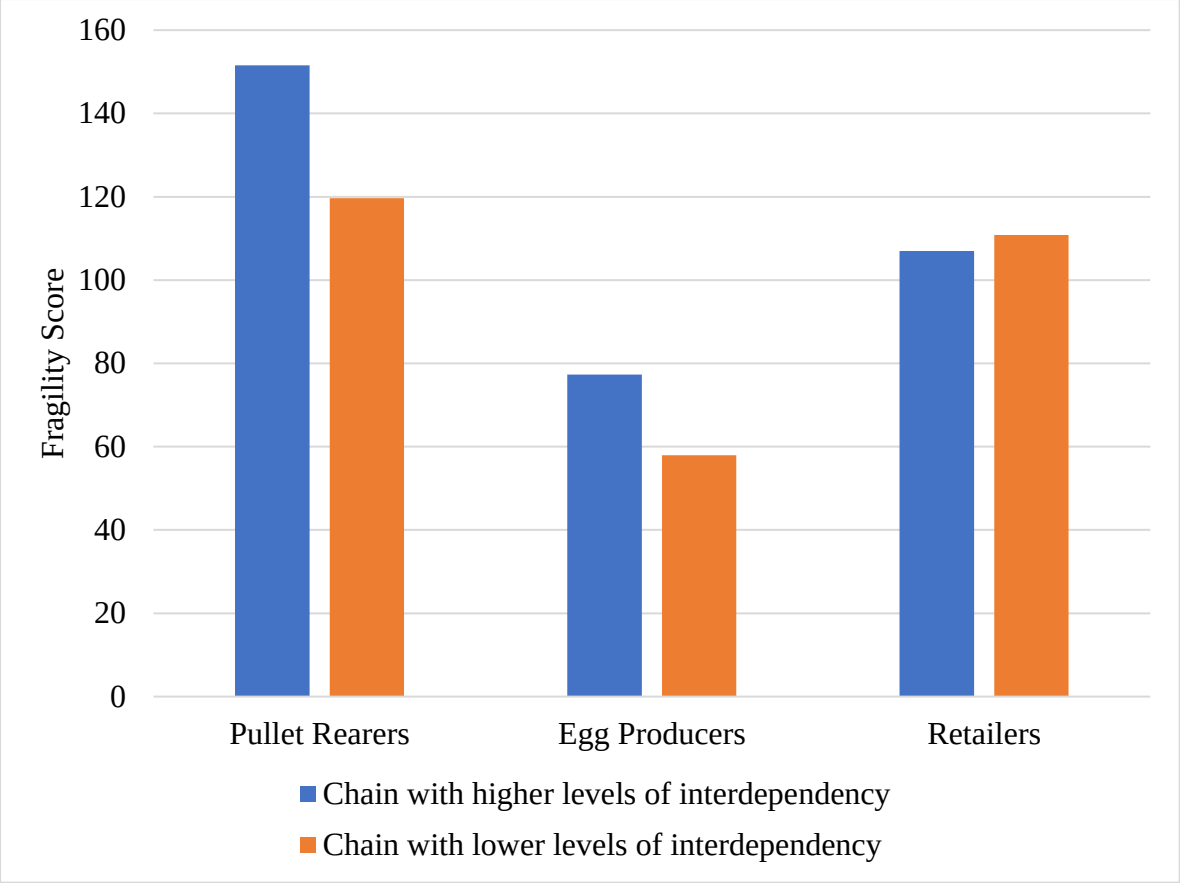


Figure 5-6: Comparison of fragility per chain player in two specified South African egg chains

5.4. COMPARING THE FRAGILITY OF TWO EGG CHAIN CONFIGURATIONS

The second objective of the dissertation was to measure the fragility of the South African egg industry's value chain. The third objective was to examine the comparative fragility analysis between the two egg chain configurations. The second objective was achieved by quantifying the fragility per factor and per chain player into chain fragility. Consequently, each of the two egg chain configurations has its own nondescript value, which is proportional to the polygon's area (Figure 5-7). As illustrated in Chapter 4, the area of the polygon is calculated by dividing the total area of each polygon of the chain players (Figure 5-3 to Figure 5-5) 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, and that represents a value chain's fragility (Jordaan & Kirsten, 2019).

Thus, the polygon's area in the egg chain with higher levels of interdependency between chain players is 225 815, while the polygon's area in the egg chain with lower levels of interdependency between chain players is 114 624. Both of these values that represent chain fragility indicate that South African egg chain fragility was attainable using Jordaan (2017) framework. Then, Figure 5-7 below shows the overall fragility of the South African egg value chain's two chain configurations.

To achieve the dissertation's third objective, a comparative analysis of the two chain configurations was performed. This found that the egg chain with higher levels of interdependency was significantly more fragile than the one with lower levels of interdependency. Also, an unequal variance t-test was performed to justify the significance of the difference between the two chain configurations.

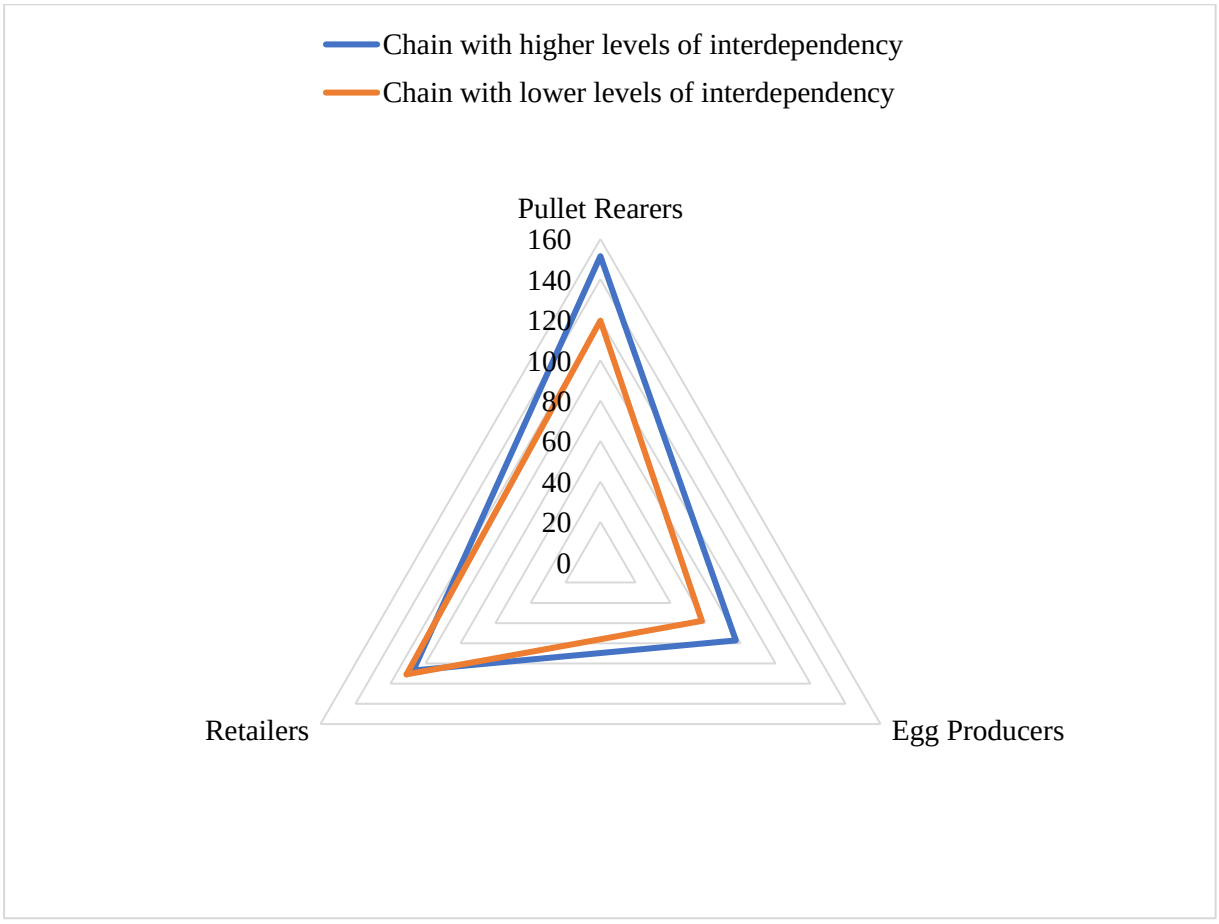


Figure 5-7: Comparison of overall chain fragility of two specified South African egg chains

To justify the significant differences, the hypotheses of the study were tested as to whether the fragility averages of the two South African chain configurations were statistically and significantly different. Using a 5% level of significance and a degree of freedom of 30, the critical value of 2.042 under two tails was less than the calculated t-value of 2.364. This indicated that the calculated t-value was greater than the critical value at a significance level of 5%. Thus, the null hypothesis – that there is no statistically significant difference in the chain fragility means of the two South African egg value chain strategies – was rejected. The alternative hypothesis – that there is a statistically significant difference in the chain fragility means of the two South African egg value chain strategies – was therefore not rejected.

In this specific instance, the difference between the chains' configurations is associated with a variety of differences at the level of the factor and the chain player (Figure 5-6) led to a 21% higher overall chain fragility (Figure 5-7) of the chain with higher levels of interdependency. That is the chain's higher fragility results from the extensive fragility at the levels of pullet rearers and retailers. Interestingly, this implies that the increased coordination intensity of South African egg value chains results in increased levels of interdependency between their chain players, which increases the fragility of the chain.

5.5. DISCUSSION

This chapter aimed to measure the fragility of the South African egg value chain and to perform a comparative analysis of the chain's two configurations. This aim was attained by following the steps that are explained in Chapter 4: first, determining the fragility of each of the fragility factors per chain player (Figure 5-1 and Figure 5-2); second, combining each of the fragility outcomes per fragility factor into a composite index of fragility for each chain player (Figure 5-3 to Figure 5-5); and third, combining each fragility's outcomes per chain player into a composite index of fragility for each chain (Figure 5-7).

These steps of measuring the fragility of the chain are equally essential, as they enable a supply chain manager or an analyst to identify the causes or catalysts of the fragility at a specific level of analysis, which can be at factor level, chain player level, or chain level (Jordaan & Kirsten, 2019). Such comparative analysis can be done at any of those levels and is essential to trace and recognise the magnitude of such fragility. This measure of fragility for the South African egg value chain supports the finding of Jordaan and Kirsten (2019) that "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". Thus, the results of the analysis show that, at factor level, a higher priority should be given to those fragility factors that have high fragility scores. These factors are a business's operational reliability, product quality and safety performance, the supporting infrastructure, a business's cash flow position, and supplier and buyer reliabilities (Jordaan & Kirsten, 2019; Jordaan, 2017; Stonebraker *et al*., 2009). However, the results have shown that these factors did not occur across all of the chain players.

Ultimately it is imperative to consider the fragility factor across chain players in the same chain configuration. Also, that consideration should rank the most important factors per player to determine whether there is any convergence of the same factors across the chain. In return, that determination should provide important information and knowledge that shows which chain player is more exposed to uncertainty for each factor. Thus, supplier reliability, buyer reliability, cash flow position, and operational reliability rank high in the chain configuration with higher levels of interdependencies (Wever *et al*., 2012b; Jordaan & Kirsten, 2019), while training of human resources and supporting infrastructure rank high in the chain configuration with lower levels of interdependencies (Jordaan, 2017; Stonebraker *et al*., 2009).

Some factors display anti-fragility because they possess positive convexity effects across both chains and for their chain players. These factors are the state of the economy and prices, social stability and public relations, information sharing with the buyer, and private and public compliance requirements (Jordaan, 2017; Jordaan & Kirsten, 2019). Their convexity effects differ from chain to chain. However, information sharing with the buyer is the factor that displays the positive effects in chain configuration with lower levels of interdependencies, while private and public compliance requirements rank high in the chain configuration with higher levels of interdependencies. However, the only two factors that rank high under both chains are social stability and public relations and the state of the economy and prices.

The results show that, at chain player level, pullet rearers and retailers are exposed to higher uncertainty than egg producers because of their higher fragility scores (Figure 5-6). Therefore, the chain players are equally responsible for the task of fragility management for the entire South African egg value chain. Their responsibility mainly includes the discussion and restructuring of strategies that could assist with the reduction of fragility through the whole chain due to the existing interdependencies among themselves.

The comparative analysis of the two configurations of the South African egg value chain raised the relationship between strategies of coordinating and fragility. The results of the analysis show that increased coordination in strategies such as vertical integration and contracting results in sequential interdependencies (Wever *et al*., 2012a; Lazzarini *et al*., 2001; Jordaan, 2017), which result in the increased fragility of a chain (Jordaan, 2017). These findings concur with those of Jordaan and Kirsten (2019) on the South African lamb value chain: that there is a relationship between increasing coordination intensity and increasing fragility. The findings also support an argument of Jordaan (2017) that "increasing fragility is due to the increasing vertical coordination intensity and not that the coordination intensity is due to this fragility".

Furthermore, the results also concur with the literature that suggests that leaner and highly integrated strategies – such as contracting and vertical integration – are due to increased coordination as major ways to reduce costs and risks within supply chains (Maslaric *et al*., 2013; Jordaan, 2017; Cadot, 2015; Watabaji *et al*., 2016; Weseen *et al*., 2014; Martinez, 2002a, 2002b). These coordinating strategies produce the interdependencies between chain players (Jordaan, 2017; Lazzarini *et al*., 2001; Wever *et al*., 2012a) and these interdependencies, in turn, expose the vulnerability of chains that pursue such lean and highly integrated strategies due to disruptive and detrimental events with very low likelihoods but huge impacts (Bailey, 2016; Simba *et al*., 2017; Kleindorfer & Saad, 2005; Jüttner, 2005; Wagner & Bode, 2009; Vlajic *et al*., 2013; Christopher *et al*., 2002; Wagner & Neshat, 2012). Also, increased chain vulnerability as a harmful stressor relates to chain fragility (Jordaan, 2017).

5.6. SUMMARY

This chapter has shown the results of measuring the fragility of the South African egg value chain. The measurement has revealed the quantification and the magnitude of both negative and positive convexity effects (Jordaan, 2017; Jordaan & Kirsten, 2019) at the factor, chain player, and chain levels. The fragility measurement of the egg chain is akin to heuristics stress-testing, in that the responses at the three levels were tested against fragility factors that were continually deteriorating (Jordaan & Kirsten, 2019). On both factor levels, the following fragility factors ranked high: a business's operational reliability, product quality and safety performance, a supporting infrastructure, a business's cash flow position, and supplier and buyer reliabilities.

Then, on the chain player level, the chain players of a chain with higher levels of interdependency between its members are exposed to more uncertainty than those of a chain with lower levels. Chain players in the same chain also have different fragility scores, meaning that they are exposed to uncertainty differently (Jordaan, 2017). This supports points made by Jordaan and Kirsten (2019), Sporleder and Boland (2011), and Jordaan (2017) that chain players in the same chain have different fragility scores due to their uniquely different features.

On the chain level, the comparative analysis was performed on the South African egg chain. The analysis proves the study's alternative hypothesis, that statistically there is a significant difference in the chain fragility means of the two South African egg chain strategies. This concurs with the literature that states that the adoption of leaner and highly integrated strategies to reduce costs and risks in supply chains as a result of increased coordination results in increased fragility (Jordaan, 2017; Maslaric *et al*., 2013; Jordaan & Kirsten, 2019; Vlajic *et al*., 2013). Also, the affirmation that the results of the analysis are in line with the literature confirms the central point of this dissertation, that there is a trade-off between chain performance and fragility.

The practical implication of the trade-off is that highly integrated and lean strategies improve chain performance by reducing transaction costs and risks in agri-food chains. However, these strategies increase the fragility of the chains (Maslaric *et al*., 2013; Jordaan, 2017; Wagner & Neshat, 2010; Wagner & Neshat, 2012). Thus, the important strategic choice for chain players in the South African egg industry and their value chains is to find a suitable coordination strategy that locates chain performance and fragility at the point of equilibrium (Nooraie & Parast, 2016). However, the concept of a trade-off between chain performance and fragility is only slightly discussed in the literature. For instance, Brede and de Vries (2009) highlight that efficient systems (chains with improved chain performances) are not robust (are fragile), while robust systems are inefficient.

Also, the argument is that both chain performance and fragile chain structures are essential requirements in the design of agri-food chains (Brede & de Vries, 2009; Jordaan, 2017). Thus, the trade-off is essential in the coordination of agri-food chains, signalling that there is an equilibrium between chain performance and fragility (Jordaan, 2017). The conceptual framework of the dissertation is a central argument for such as trade-off.

This chapter leads to the sixth and final chapter of the dissertation, which presents its conclusions and recommendations.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1. INTRODUCTION

This chapter first provides the conclusions that are based on the insights obtained from the results of the analysis, the study's contribution to the existing literature, and its limitations. Second, the recommendations are presented into two parts. The first part involves recommendations for chain players in the South African egg industry, and the second offers recommendations to scholars for pursuing further research in the field.

6.2. CONCLUSIONS OF THE STUDY

The study had several objectives. The first was to map the South African egg value chain and to showcase the coordination strategies that are mostly adopted in the egg industry. The second was to measure the fragility of the South African egg chain. The third and final purpose was to perform a comparative fragility analysis of the two egg chain configurations, which reflect two strategies of coordinating: a chain with higher levels of interdependency between its members, and a chain with lower levels of interdependency between its members.

The first objective of the study revealed the strategies of coordination that are mostly used in the South African egg industry:

- The use of contracts between several egg producers, pullets rearers, feed providers, breeders, and retailers.
- Retailers' use of their egg brands channels to organise their procurement vertically, bringing many producers and marketers of eggs under their brands.
- Very few large companies that produce eggs that are fully or partially vertically integrated.
- Few cooperatives with their egg brands, under which their members produce and market their produce.

The main goals of these strategies are to enhance their egg chains. Also, the goals are attainable via reduced transaction costs and risks associated with outputs and inputs, products' quality, traceability of products from their origin, and safety of performance as a result of food safety

scandals (Canavari *et al.*, 2010; Hernández-Espallardo *et al.*, 2010; Hobbs, 1996; Hobbs & Young, 1999; Andre Louw *et al.*, 2008; Andre Louw *et al.*, 2007).

However, as was repeatedly emphasised in Chapter 3 and Chapter 5, although increasing coordination into strategies that are leaner and highly integrated reduces costs and risks in supply chains, it also creates interdependencies between chain players (Lazzarini *et al*., 2001; Jordaan, 2017; Wever *et al*., 2012b; Wever *et al*., 2010). Eventually, the interdependencies make the chain and its players vulnerable to disruptive and detrimental events with low likelihoods but huge impacts (Jordaan, 2017; Bailey, 2016; Kleindorfer & Saad, 2005; Christopher *et al*., 2002). Thus, the vulnerability escalates throughout the chain due to the linkages between chain players, contributing to the fragility of the chain (Jordaan, 2017; Stonebraker *et al*., 2009).

The fragility measurement of the South African egg chain at the levels of the factor, chain player, and chain provides useful information about the causes and catalysts of fragility at each level (Jordaan & Kirsten, 2019; Jordaan, 2017). At the factor level, it was concluded that a higher priority should be placed on the fragility factors that have high fragility scores. These factors are a business's operational reliability, product quality and safety performance, a supporting infrastructure, a business's cash flow position, and supplier and buyer reliabilities.

At the chain level, performing a comparative fragility analysis of the chain's two strategies showcased which coordination strategy is fragile. It was also concluded that the increased coordination in the South African egg industry not only enhances the industry's chain performance, but it also contributes to the fragility of the chain and its players. In this specific instance, the difference between the chains' configurations was associated with a variety of differences at the factor and chain player level that led to 21% greater overall chain fragility of the chain with higher levels of interdependency. More specifically, the chain's greater fragility evolves from the extensive fragility at the pullet rearers' and retailers' levels. Interestingly, this implies that the increased coordination intensity of the South African egg value chain results in increased levels of interdependency between its chain players, which in turn increases the fragility of the chain (Jordaan, 2017; Jordaan & Kirsten, 2019). This conclusion agrees with the conceptual framework of the study.

6.3. CONTRIBUTION OF THE STUDY TO THE LITERATURE

The contribution of the dissertation to the literature is on the concepts in agri-food chains regarding uncertainty, risk, vulnerability, fragility, interdependencies, and sustainability. In this regard, agri-food chains – particularly the South African egg chain – have demonstrated the tension between their chain performance and their fragility. Thus, this dissertation has practically explored the difference between the strategies of coordination that are most often used in the egg industry. The strategies are influenced by the TCE framework, which is concerned with the coordinating of supply and demand in value chains to economise on the costs of transacting (Hobbs, 1996; Hobbs & Young, 1999). The conceptual framework of the study has presented its central thesis: that there is a trade-off between chain performance and fragility (Jordaan, 2017).

The practical implication of the trade-off is that highly integrated and lean strategies improve chain performance by reducing transaction costs and risks in agri-food chains. However, the strategies also increase the fragility of the chains (Maslaric *et al*., 2013; Jordaan, 2017; Wagner & Neshat, 2010; Wagner & Neshat, 2012). Thus, the important strategic choice for chain players in the South African egg industry and their value chains is to develop a suitable coordination strategy that positions chain performance and fragility at the point of equilibrium (Nooraie & Parast, 2016). The need for a trade-off is noted in the literature. For instance, Brede and de Vries (2009) highlight that efficient systems (chains with improved chain performances) are not robust (are fragile), while robust systems are inefficient.

Also, the argument is that both chain performance and fragile chain structures are essential requirements in the design of agri-food chains (Brede & de Vries, 2009; Jordaan, 2017). As a result, the trade-off is essential to the coordination of agri-food chains – that is, that there is an equilibrium between chain performance and fragility (Jordaan, 2017). The conceptual framework of the dissertation presents a central argument for the trade-off.

Moreover, consideration of this trade-off shows that it is urgently necessary to reassess the TCE framework as it has been commonly applied in agribusiness research (Jordaan, 2017), and to address the question of coordination (Peterson *et al*., 2001) as agri-food chains develop a new framework (Vlajic *et al*., 2012; Jordaan, 2017). The new framework would position the impacts of chain performance and fragility at a strategic equilibrium in the design of agri-food chains and their management (Maslaric *et al*., 2013; Jordaan, 2017).

It is a priority for chain players in the South African egg industry to manage fragility for the sake of the sustainability of their chains. As Taleb (2012) says, “what is missed is the strong logical precedence of survival over success”. A fragile system or chain will surely break as time goes by (Taleb, 2012).

6.5. LIMITATIONS OF THE STUDY

Just as most research has some limitations, so too does this research; to some extent, this has affected the applicability and generalisation of its findings. The first limitation involves the concept of heuristic stress-testing as a measure of fragility in the South African egg chain. This method of measurement can lead to flaws in the fragility analysis: the respondents were asked to gauge the fragility factors used in the study as they were continuously deteriorating. Therefore, because the fragility of these factors depended on the respondents, there was a probability that they gauged some factors equally, even though this might not be the true picture. Thus, this would limit the quality of the results as relevant and appropriate.

The second limitation involves the comparative fragility analysis of both the South African egg chain’s configurations. The results of the analysis might or might not have favoured certain chain configurations, as the number of chain players in the chain with lower levels of interdependencies was higher than the number of chain players in the other chain configuration. However, this could not be avoided: the South African egg industry is dominated by chain players that are involved in coordination strategies that result in low interdependencies. This too would limit the quality of the results as relevant and appropriate.

The third limitation involves the respondents to the study questionnaire, whom all participate in the commercial production of eggs in South Africa. Therefore, this limits the study to appropriately generalise its findings as small egg producers were not involved in the study. Their exclusion is mainly because the South African egg industry is mainly commercial and small-scale egg production amounts to a very small percentage.

6.5. RECOMMENDATIONS OF THE STUDY

6.5.1. Recommendations to the egg industry

This dissertation recommends several approaches that the management of individual egg firms and other role players in the South African egg industry could adopt. However, first, to put them in context, there are explanations in the first and second chapters of the dissertation of the uncertainties and risks in the egg industry and their consequences. For instance, the 2017 HPAI outbreak forced several egg firms to shut down their operations. That is why the whole industry and its role players must consider strategies of coordination to limit its fragility and still improve chain performance.

The coordination strategies explored in the second chapter of the dissertation show that role players in the South African egg industry prefer increased coordination because it results in leaner and highly integrated strategies for improved chain performance. Although these strategies improve chain performance, the results of the analysis show that strategies of increased coordination eventually result in increased fragility.

Consequently, the recommendation to egg firms is that it is important to contain fragility when worrying about the performance of a business or the chain. Relevantly, Taleb (2012) point out that "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". For instance, a value chain with higher levels of interdependency due to its leaner and highly integrated strategies of coordination is more vulnerable to unforeseen, disruptive, and detrimental events such as HPAI outbreak. Also, that vulnerability escalating throughout the entire chain contributes towards its fragility.

Ultimately, a chain's fragility contributes to the closure of businesses as most South African egg firms shut down their operations. Therefore, the recommendations to the South African egg industry and its role players are as follows:

- The first recommendation is that a chain structure and its coordination strategies be decentralised in an organisation's value chain management. This is because a decentralised system allows for the containment of adverse impacts.

- The second recommendation is about developing a 'layered organisational' structure, which allows for containment of adverse impacts within the system and facilitates learning within and across different layers to drive survivorship.
- The third recommendation is about planning for spare capacity (redundancy). This is argued to be at the heart of managing fragility and it is essential in dealing with unanticipated events.
- The fourth recommendation is about considering which value chain strategy an organisation should pursue. This is because [an] organisation needs to strike a balance between reducing transaction costs to increase efficiency and enduring some transaction costs to contain fragility (Jordaan, 2017).

6.5.2. Recommendation for further research

The conclusion of this dissertation highlights further possible research into the fragility of the South African egg chain and agri-food chains in general. To popularise the concept of fragility in agri-food chains, there is a need for more research on this concept. Therefore, the recommendations below are made for further research.

First, a more rigorous fragility analysis of the value chain players' features in similar chain configurations needs to be explored. This is because the chain players in the same chain seem to display different levels of fragility – although one could ask why, since they are exposed to similar uncertainties, and the interdependencies between them are the same most of the time. Therefore, the interesting point is why chain players in a chain with similar interdependencies seem to have different levels of fragility.

Second, since the sequential interdependencies between chain players cause fragility to shift from player to player, and eventually throughout the entire chain, the point to note is whether the egg chain's fragility could influence the fragility of chains in other industry such as feeds, financial services, and veterinary services, due to the dependence of the egg chain on such industries.

Last, the concept of fragility was discussed in more depth in this dissertation than the concept of anti-fragility. Therefore, in further research, the researcher could analyse whether pursuing anti-fragility decreases a chain's performance. As repeatedly discussed in the various chapters

of the dissertation, pursuing chain performance increases fragility. Thus, it is important to find the point of equilibrium when pursuing both goals in value chain management.

REFERENCES

Abolnik, C., Pieterse, R., Peyrot, B. M., Choma, P., Phiri, T. P., Ebersohn, K., . . . Geertsma, P. J. (2018). The incursion and spread of highly pathogenic avian influenza H5N8 Clade 2.3. 4.4 within South Africa. *Avian Diseases, 63*(1s), 149-156.

Ahmad, A. A., Arifin, A., & Chew, B. C. (2016). Market structure and price transmission of eggs commodity. *JEJAK: Jurnal Ekonomi dan Kebijakan, 9*(2), 200-221.

Akerlof, G. A. (1970). The market for "lemons": Quality uncertainty and the market mechanism, 84Q. *J. ECON, 488*, 489-490.

Altay, N., & Green III, W. G. (2006). OR/MS research in disaster operations management. *European Journal of Operational Research, 175*(1), 475-493.

Anand, N., & Grover, N. (2015). Measuring retail supply chain performance: Theoretical model using key performance indicators (KPIs). *Benchmarking: An International Journal, 22*(1), 135-166.

Ang, J. S., Cole, R. A., & Lin, J. W. (2000). Agency costs and ownership structure. *the Journal of Finance, 55*(1), 81-106.

Archer, E., Landman, W., Malherbe, J., Tadross, M., & Pretorius, S. (2019). South Africa's winter rainfall region drought: A region in transition? *Climate Risk Management, 25*, 100188.

Assefa, T. T., Meuwissen, M. P., & Oude Lansink, A. G. (2015). Price volatility transmission in food supply chains: A literature review. *Agribusiness, 31*(1), 3-13.

Aven, T. (2015). The concept of antifragility and its implications for the practice of risk analysis. *Risk Analysis, 35*(3), 476-483.

Bagopi, E., Chokwe, E., Halse, P., Hausiku, J., Humavindu, M., Kalapula, W., & Roberts, S. (2014). *Competition dynamics and regional trade flows in the poultry sector: The case of South Africa, Botswana, Namibia, and Zambia.* Paper presented at the Pre-ICN Forum.

Bagopi, E., Chokwe, E., Halse, P., Hausiku, J., Humavindu, M., Kalapula, W., & Roberts, S. (2016). Competition, agro-processing and regional development: The case of the poultry section in South Africa, Botswana, Namibia and Zambia. *Competition in Africa: Insights from Key Industries,* 66-101.

Bailey, K. (2016). *An investigation into risk and vulnerability in the UK food supply network.* Cardiff University.

Barbarosoglu, G. (2000). An integrated supplier-buyer model for improving supply chain coordination. *Production Planning & Control, 11*(8), 732-741.

Behzadi, G., O'Sullivan, M. J., Olsen, T. L., Scrimgeour, F., & Zhang, A. (2017). Robust and resilient strategies for managing supply disruptions in an agribusiness supply chain. *International Journal of Production Economics, 191*, 207-220.

Behzadi, G., O'Sullivan, M. J., Olsen, T. L., & Zhang, A. (2018). Agribusiness supply chain risk management: A review of quantitative decision models. *Omega, 79*, 21-42.

BFAP. (2018). *Economic impact of the 2017 highly pathogenic avian influenza outbreak in South Africa*. Retrieved from http://www.bfap.co.za/wp-content/uploads/2018/08/AI-Report-final.pdf [Accessed: 02 April 2019].

Bijman, J., Muradian, R., & Cechin, A. (2011). Agricultural cooperatives and value chain coordination. *Value chains, social inclusion and economic development: Contrasting theories and realities*, 82-101.

Boehlje, M., Roucan-Kane, M., & Bröring, S. (2011). Future agribusiness challenges: Strategic uncertainty, innovation and structural change. *International Food and Agribusiness Management Review, 14*(5), 53-82.

Bontems, P., & Fulton, M. (2009). Organizational structure, redistribution and the endogeneity of cost: Cooperatives, investor-owned firms and the cost of procurement. *Journal of Economic Behavior & Organization, 72*(1), 322-343.

Borgatti, S. P., & Li, X. (2009). On social network analysis in a supply chain context. *Journal of Supply Chain Management, 45*(2), 5-22.

Bosman, R. (2006). The new supply chain challenge: Risk management in a global economy. *FM Global, 4*(6), 1-10.

Brede, M., & de Vries, B. J. (2009). Networks that optimize a trade-off between efficiency and dynamical resilience. *Physics Letters A, 373*(43), 3910-3914.

Cadot, J. (2015). Agency costs of vertical integration: The case of family firms, investor-owned firms and cooperatives in the French wine industry. *Agricultural Economics, 46*(2), 187-194.

Canavari, M., Centonze, R., Hingley, M., & Spadoni, R. (2010). Traceability as part of competitive strategy in the fruit supply chain. *British Food Journal*, ISSN: 0007-070X

Capaldo, A., & Giannoccaro, I. (2015). Interdependence and network-level trust in supply chain networks: A computational study. *Industrial Marketing Management, 44*, 180-195.

Cembalo, L., Pascucci, S., Tagliafierro, C., & Caracciolo, F. (2014). Development and management of a bio-energy supply chain through contract farming. *International Food and Agribusiness Management Review, 17*(1030-2016-83019), 33.

Che, Y.-K., & Sákovics, J. (2006). *The hold-up problem*. Retrieved from https://www.research.ed.ac.uk/portal/en/publications/the-holdup-problem(79700cc7-1ecd-494d-bee3-6d0b8b8cb6fc).html [Accessed: 04 July 2020].

Chopra, S., & Sodhi, M. (2004). Supply-chain breakdown. *MIT Sloan Management Review, 46*(1), 53-61.

Christopher, M. (2000). The agile supply chain: Competing in volatile markets. *Industrial Marketing Management, 29*(1), 37-44.

Christopher, M. (2016). *Logistics & supply chain management*.

Christopher, M., McKinnon, A., Sharp, J., Wilding, R., Peck, H., Chapman, P., . . . Bolumole, Y. (2002). *Supply chain vulnerability*. Cranfield University, Cranfield.

Christopher, M., & Peck, H. (2004). Building the resilient supply chain. *The International Journal of Logistics Management, 15*(2), 1-14.

Clay, P. M., & Feeney, R. (2019). Analyzing agribusiness value chains: A literature review. *International Food and Agribusiness Management Review, 22*(1), 31-46.

Coleman, L. (2006). Frequency of man-made disasters in the 20th century. *Journal of Contingencies and Crisis Management, 14*(1), 3-11.

Contò, F., Fiore, M., & La Sala, P. (2013). The role of innovation in the integration processes of integrated projects of food chain: The case of the cherry cultivation chain in Apulia region. *Intellectual Economics, 7*(4), 467-485.

Crook, T. R., Combs, J. G., Ketchen Jr, D. J., & Aguinis, H. (2013). Organizing around transaction costs: What have we learned and where do we go from here? *Academy of Management Perspectives, 27*(1), 63-79.

DAFF. (2018). *A profile of the South African egg market value chain*. Retrieved from https://www.nda.agric.za/doaDev/sideMenu/Marketing/Annual%20Publications/Commodity%20Profiles/Egg%20Market%20Value%20Chain%20Profile%202018 [Accessed: 09 May 2019].

DAFF. (2019). *Food safety and quality assurance*. Retrieved from https://www.daff.gov.za/daffweb3/Branches/Agricultural-Production-Health-Food-Safety/Food-Safety-Quality-Assurance [Accessed: 21 September 2019].

Davids, P., & Meyer, F. (2017). Price formation and competitiveness of the South African broiler industry in the global context. *Agrekon, 56*(2), 123-138.

Davids, T., Louw, M., Smit, A., & Meyer, F. (2018). Economic impact of the 2017 outbreak of HPAI in South Africa. *Oilseeds Focus, 4*(2), 38-39.

De Keizer, M., Akkerman, R., Grunow, M., Bloemhof, J. M., Haijema, R., & van der Vorst, J. G. (2017). Logistics network design for perishable products with heterogeneous quality decay. *European Journal of Operational Research, 262*(2), 535-549.

Dive, S. N., & Ambade, V. (2016). Increasing influence of private label brands in organized retail. *CLEAR International Journal of Research in Commerce & Management, 7*(12).

Dosi, G., & Egidi, M. (1991). Substantive and procedural uncertainty. *Journal of Evolutionary Economics, 1*(2), 145-168.

Dubois, A., Hulthén, K., & Pedersen, A.-C. (2004). Supply chains and interdependence: A theoretical analysis. *Journal of Purchasing and Supply Management, 10*(1), 3-9.

Duclos, L. K., Vokurka, R. J., & Lummus, R. R. (2003). A conceptual model of supply chain flexibility. *Industrial Management & Data Systems, 103*(6), 446-456.

OECD. (2013). *Interconnected economies: Benefiting from global value chains*. *Synthesis Report.* OECD.

Elms, D. K., & Low, P. (2013). *Global value chains in a changing world*: World Trade Organisation Geneva.

Engber, D. (2012). The sliming: How processed beef trimmings got rebranded, again, and again and again. *Slate* [Online] Available from: http://www.slate.com/articles/news_and_politics/food/2012/10/history_of_pink_slime_how_partially_defatted_chopped_beef_got_rebranded.htm [Accessed: 25 May 2019].

Enyinda, C. I. (2009). *Modeling risk management in the pharmaceutical industry global supply chain logistics using analytic hierarchy process model*: North Dakota State University.

Fan, J. P. (2000). Price uncertainty and vertical integration: An examination of petrochemical firms. *Journal of Corporate Finance, 6*(4), 345-376.

Fawcett, S. E., & Magnan, G. M. (2002). The rhetoric and reality of supply chain integration. *International Journal of Physical Distribution & Logistics Management, 32*(5), 339-361.

Fischer, C., Hartmann, M., Reynolds, N., Leat, P., Revoredo-Giha, C., Henchion, M., . . . Gracia, A. (2009). Factors influencing contractual choice and sustainable relationships in European agri-food supply chains. *European Review of Agricultural Economics, 36*(4), 541-569.

Fu, J., Luo, Z., Chen, P., & Shen, X. (2019). *Cooperative game of income allocation of shell-egg industry supply chain.* Paper presented at the 2019 International Conference on Electronical, Mechanical and Materials Engineering (ICE2ME 2019).

Garvey, M. D., Carnovale, S., & Yeniyurt, S. (2015). An analytical framework for supply network risk propagation: A Bayesian network approach. *European Journal of Operational Research, 243*(2), 618-627.

Gereffi, G. (2014). Global value chains in a post-Washington Consensus world. *Review of International Political Economy, 21*(1), 9-37.

Goncharuk, A. G., & Gamma, T. (2013). Integration processes in the dairy industry: Ukrainian experience. *Economia. Seria Management, 16*(1), 146-160.

Gopal, P., & Thakkar, J. (2015). Development of composite sustainable supply chain performance index for the automobile industry. *International Journal of Sustainable Engineering, 8*(6), 366-385.

Gray, A. W., & Boehlje, M. D. (2005). Risk sharing and transactions costs in producer-processor supply chains. *Choices, 20*(4), 281-286.

Gulati, R. (1995). Does familiarity breed trust? The implications of repeated ties for contractual choice in alliances. *Academy of Management Journal, 38*(1), 85-112.

Håkansson, H., & Persson, G. (2004). Supply chain management: The logic of supply chains and networks. *The International Journal of Logistics Management, 15*(1), 11-26.

Handayati, Y., Simatupang, T. M., & Perdana, T. (2015). Agri-food supply chain coordination: The state-of-the-art and recent developments. *Logistics Research, 8*(1), 5.

Hardaker, J. B., Lien, G., Anderson, J. R., & Huirne, R. B. (2015). *Coping with risk in agriculture: Applied decision analysis* 3rd edition. CABI.

Hashemi, A., Butcher, T., & Chhetri, P. (2013). A modeling framework for the analysis of supply chain complexity using product design and demand characteristics. *International Journal of Engineering, Science and Technology, 5*(2), 150-164.

Hayenga, M., Schroeder, T., Lawrence, J., Hayes, D., Vukina, T., Ward, C., & Purcell, W. (2000). *Meat packer vertical integration and contract linkages in the beef and pork industries: An economic perspective*. American Meat Institute.

Hellin, J., Krishna, V., Erenstein, O., & Boeber, C. (2015). India's poultry revolution: Implications for its sustenance and the global poultry trade. *International Food and Agribusiness Management Review, 18*(1030-2016-83092), 151-164.

Hernández-Espallardo, M., Rodríguez-Orejuela, A., & Sánchez-Pérez, M. (2010). Inter-organizational governance, learning and performance in supply chains. *Supply Chain Management: An International Journal*, ISSN: 1359-8546.

Hobbs, J. E. (1996). A transaction cost approach to supply chain management. *Supply Chain Management: An International Journal, 1*(2), 15-27.

Hobbs, J. E., & Young, L. M. (1999). *Increasing vertical linkages in agrifood supply chains: A conceptual model and some preliminary evidence*, (No. 1120-2016-91891).

Holton, G. A. (2004). Defining risk. *Financial Analysts Journal, 60*(6), 19-25.

Hugos, M. H. (2018). *Essentials of supply chain management*. John Wiley & Sons.

Igumbor, E. U., Sanders, D., Puoane, T. R., Tsolekile, L., Schwarz, C., Purdy, C., . . . Hawkes, C. (2012). "Big food," the consumer food environment, health, and the policy response in South Africa. *PLoS medicine, 9*(7), DOI: 10.1371/journal.pmed.1001253

Jordaan, D. du P. S. (2017). *Agribusiness value-chain risk, fragility and coordination strategies: Case studies of South African value chains*. PhD, Department of Agricultural Economics, Extension and Rural Development, University of Pretoria, Pretoria, South Africa.

Jordaan, D. du P. S., & Kirsten, J. F. (2019). Measuring the fragility of agribusiness value chains: A case study of the South African lamb chain. *International Food and Agribusiness Management Review, 22*(1), 137-154.

Jüttner, U. (2005). Supply chain risk management: Understanding the business requirements from a practitioner perspective. *The International Journal of Logistics Management, 16*(1), 120-141.

Jüttner, U., Peck, H., & Christopher, M. (2003). Supply chain risk management: Outlining an agenda for future research. *International Journal of Logistics: Research and Applications, 6*(4), 197-210.

Karthikeyan, R., & Nedunchezhian, V. (2013). Vertical integration paving way to organised retailing in Indian poultry industry. *International Journal of Business and Management Invention, 2*(1), 39-46.

Karwat-Woźniak, B. (2013). Horizontal integration processes in agriculture and the benefits of management within a group of agricultural producers. *Agraren Universitet Plovdiv-Nauchni Trudove/Scientific Works of the Agrarian University-Plovdiv, 57*, 29-37.

Kembro, J. (2015). Exploring information sharing in the extended supply chain: An interdependence perspective. *Supply Chain Management: An International Journal, 20*(4), 455-470. doi:10.1108/SCM-07-2014-0252

Kembro, J., Selviaridis, K., & Näslund, D. (2014). Theoretical perspectives on information sharing in supply chains: A systematic literature review and conceptual framework. *Supply Chain Management: An International Journal, 19*(5/6), 609-625.

King, R. P., Boehlje, M., Cook, M. L., & Sonka, S. T. (2010). Agribusiness economics and management. *American Journal of Agricultural Economics, 92*(2), 554-570.

Kirsten, J. F., Karaan, A. M., & Dorward, A. R. (2009). Introduction to the economics of institutions. *Institutional Economics Perspectives on African Agricultural Development*, 35-74.

Klein, B., Crawford, R. G., & Alchian, A. A. (1978). Vertical integration, appropriable rents, and the competitive contracting process. *The Journal of Law and Economics, 21*(2), 297-326.

Kleindorfer, P. R., & Saad, G. H. (2005). Managing disruption risks in supply chains. *Production and Operations Management, 14*(1), 53-68.

Knight, F. H. (2012). *Risk, uncertainty and profit*. Courier Corporation.

Kwon, I.-W. G., Hamilton, J. H., & Hong, S.-J. (2012). Trust and transaction cost in supply chain cost optimization: An exploratory study. *Inter-Organizational Information Systems and Business Management: Theories for Researchers*, 70-82, IGI Global, DOI: 10.4018/978-1-60960-768-5.ch005.

Lazzarini, S., Chaddad, F., & Cook, M. (2001). Integrating supply chain and network analyses: The study of netchains. *Journal on Chain and Network Science, 1*(1), 7-22.

Leat, P., & Revoredo-Giha, C. (2013). Risk and resilience in agri-food supply chains: The case of the ASDA PorkLink supply chain in Scotland. *Supply Chain Management: An International Journal, 18*(2), 219-231.

Lee, H. L., Padmanabhan, V., & Whang, S. (1997). The bullwhip effect in supply chains. *Sloan management review, 38*, 93-102.

Liu, Z. L., Anderson, T. D., & Cruz, J. M. (2012). Consumer environmental awareness and competition in two-stage supply chains. *European Journal of Operational Research, 218*(3), 602-613.

Lo, C.-P. (2010). Perishability as a determinant of vertical coordination: The case of the US egg, poultry, and pork industries. *China Agricultural Economic Review, 2*(1), 49-62.

Louw, A., Jordaan, D., Ndanga, L., & Kirsten, J. F. (2008). Alternative marketing options for small-scale farmers in the wake of changing agri-food supply chains in South Africa. *Agrekon, 47*(3), 287-308.

Louw, A., Schoeman, J., & Geyser, M. (2011). *Broiler industry supply chain study with emphasis on feed and feed-related issues.* Paper presented at the 21st Annual IFAMA World Forum and Symposium Frankfurt, Germany.

Louw, A., Vermeulen, H., Kirsten, J., & Madevu I, H. (2007). Securing small farmer participation in supermarket supply chains in South Africa. *Development Southern Africa, 24*(4), 539-551.

Louw, M., Davids, T., & Scheltema, N. (2017). Broiler production in South Africa: Is there space for smallholders in the commercial chicken coup? *Development Southern Africa, 34*(5), 564-574.

Luke, R., & Heyns, G. (2018). An evaluation of supply chain risk management practices: A developing country perspective, (online) https://ujcontent.uj.ac.za/vital/access/manager/Repository?f0=sm_creator%3A%22Luke%2C+Rose%22&f1=sm_creator%3A%22Heyns%2C+Gert%22 [Accessed: 07 October 2019].

Magdelaine, P. (2011). Egg and egg product production and consumption in Europe and the rest of the world. In *Improving the safety and quality of eggs and egg products* (pp. 3-16). Woodhead Publishing.

Malone, T. W., & Crowston, K. (1990). *What is coordination theory and how can it help design cooperative work systems?* Paper presented at the Proceedings of the 1990 ACM conference on computer-supported cooperative work.

Manuj, I., & Mentzer, J. T. (2008). Global supply chain risk management. *Journal of Business logistics, 29*(1), 133-155.

Marchese, K., & Paramasivam, S. (2013). *The ripple effect: How manufacturing and retail executives view the growing challenge of supply chain risk.* Deloitte Development LLC.

Martínez-Jaramillo, S., Pérez, O. P., Embriz, F. A., & Dey, F. L. G. (2010). Systemic risk, financial contagion and financial fragility. *Journal of Economic Dynamics and Control, 34*(11), 2358-2374.

Martinez, S. W. (1999). *Vertical coordination in the pork and broiler industries: Implications for pork and chicken products* (No. 1473-2016-120713).

Martinez, S. W. (2002a). *A comparison of vertical coordination in the US poultry, egg, and pork industries* (No. 1474-2016-120802).

Martinez, S. W. (2002b). *Vertical coordination of marketing systems: Lessons from the poultry, egg, and pork industries* (No. 1473-2016-120694).

Martinez, S. W. and Zering, K. D., Pork Quality and the Role of Market Organization. USDA-ERS Agricultural Economics Report No. 835. Available at SSRN: https://ssrn.com/abstract=631167

Maslaric, M., Backalic, T., Nikolicic, S., & Mircetic, D. (2013). Assessing the trade-off between lean and resilience through supply chain risk management. *International Journal of Industrial Engineering and Management, 4*(4), 229-236.

Masten, S. E. (1996). Empirical research in transaction cost economics: Challenges, progress, directions. *Transaction cost economics and beyond*, 43-64. Springer, Dordrecht.

Mcleod, A., Thieme, O., & Mack, S. (2009). Structural changes in the poultry sector: Will there be smallholder poultry development in 2030? *World's Poultry Science Journal, 65*(2), 191-200.

Mehta, R., & Nambiar, R. (2007). *The poultry industry in India.* Paper presented at the FAO Conference on 'Poultry in the 21st Century'.

Mench, J., Sumner, D., & Rosen-Molina, J. (2011). Sustainability of egg production in the United States: The policy and market context. *Poultry Science, 90*(1), 229-240.

Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2001). Defining supply chain management. *Journal of Business Logistics, 22*(2), 1-25.

Migliore, G., Schifani, G., & Cembalo, L. (2015). Opening the black box of food quality in the short supply chain: Effects of conventions of quality on consumer choice. *Food Quality and Preference, 39*, 141-146.

Miller, K. D. (1992). A framework for integrated risk management in international business. *Journal of International Business Studies, 23*(2), 311-331.

Mizumoto, F. M., & Zylbersztajn, D. (2004). *Coexistence of institutional arrangements: Analysis of the Brazilian egg chain.* Paper presented at the IAMA conference.

Montesi, G., & Papiro, G. (2018). Bank stress testing: A stochastic simulation framework to assess banks' financial fragility. *Risks, 6*(3), 82.

Moobi, M. N. (2019). *The effects of drought on price transmission in the South African white maize market.* (MSc Dissertation, University of Pretoria).

Naidoo, V., McGaw, L. J., Bisschop, S., Duncan, N., & Eloff, J. N. (2008). The value of plant extracts with antioxidant activity in attenuating coccidiosis in broiler chickens. *Veterinary Parasitology, 153*(3-4), 214-219.

Nair, A., Narasimhan, R., & Choi, T. Y. (2009). Supply networks as a complex adaptive system: Toward simulation-based theory building on evolutionary decision-making. *Decision Sciences, 40*(4), 783-815.

NAMC. (2019). *DAFF-NAMC Trade Probe Issue No 76* (76). Retrieved from https://www.namc.co.za/wp-content/uploads/2019/03/DAFF-NAMC-TRADE-PROBE-ISSUE-NO-76-FEBRUARY-2019 [Accessed: 04 September 2019].

Ncube, P. (2018). The Southern African poultry value chain: Corporate strategies, investments and agro-industrial policies. *Development Southern Africa, 35*(3), 369-387.

Ncube, P., Roberts, S., & Zengeni, T. (2017). The Southern African poultry value chain: Regional development versus national imperatives. Retrieved from https://papers.ssrn.com/soL3/papers.cfm?abstract_id=2958098## [Accessed: 03 March 2019].

Nishat Faisal, M., Banwet, D. K., & Shankar, R. (2006). Supply chain risk mitigation: Modeling the enablers. *Business Process Management Journal, 12*(4), 535-552.

Nkukwana, T. (2018). Global poultry production: Current impact and future outlook on the South African poultry industry. *South African Journal of Animal Science, 48*(5), 869-884.

Nooraie, S. V., & Parast, M. M. (2016). Mitigating supply chain disruptions through the assessment of trade-offs among risks, costs and investments in capabilities. *International Journal of Production Economics, 171*, 8-21.

Noorderhaven, N. G. (1996). Opportunism and trust in transaction cost economics *Transaction cost economics and beyond* (105-128): Springer

Norrman, A., & Jansson, U. (2004). Ericsson's proactive supply chain risk management approach after a serious sub-supplier accident. *International Journal of Physical Distribution & Logistics Management, 34*(5), 434-456.

Oberholtzer, L., Greene, C., & Lopez, E. (2006). *Organic poultry and eggs capture high price premiums and growing share of specialty markets*. Washington, DC: US Department of Agriculture, Economic Research Service.

Oliveira, D., Benelli, P., & Amante, E. (2013). A literature review on adding value to solid residues: Egg shells. *Journal of Cleaner Production, 46*, 42-47.

Ortmann, G. F., & King, R. P. (2010). Research on agri-food supply chains in Southern Africa involving small-scale farmers: Current status and future possibilities. *Agrekon, 49*(4), 397-417.

Panteli, M., Pickering, C., Wilkinson, S., Dawson, R., & Mancarella, P. (2016). Power system resilience to extreme weather: Fragility modeling, probabilistic impact assessment, and adaptation measures. *IEEE Transactions on Power Systems, 32*(5), 3747-3757.

Paulraj, A., & Chen, I. J. (2007). Environmental uncertainty and strategic supply management: A resource dependence perspective and performance implications. *Journal of Supply Chain Management, 43*(3), 29-42.

Peck, H. (2005). Drivers of supply chain vulnerability: An integrated framework. *International Journal of Physical Distribution & Logistics Management, 35*(4), 210-232.

Petersen, K. J., Handfield, R. B., Lawson, B., & Cousins, P. D. (2008). Buyer dependency and relational capital formation: The mediating effects of socialization processes and supplier integration. *Journal of Supply Chain Management, 44*(4), 53-65.

Peterson, H. C., Wysocki, A., & Harsh, S. B. (2001). Strategic choice along the vertical coordination continuum. *The International Food and Agribusiness Management Review, 4*(2), 149-166.

Pieri, F., & Zaninotto, E. (2013). Vertical integration and efficiency: An application to the Italian machine tool industry. *Small Business Economics, 40*(2), 397-416.

Puma, M. J., Bose, S., Chon, S. Y., & Cook, B. I. (2015). Assessing the evolving fragility of the global food system. *Environmental Research Letters, 10*(2), 024007.

Quiggin, J. C., Karagiannis, G., & Stanton, J. (1993). Crop insurance and crop production: an empirical study of moral hazard and adverse selection. *Australian Journal of Agricultural Economics, 37*(429-2016-29192), 95-113.

Rao, S., & Goldsby, T. J. (2009). Supply chain risks: A review and typology. *The International Journal of Logistics Management, 20*(1), 97-123.

Raynaud, E., Sauvee, L., & Valceschini, E. (2005). Alignment between quality enforcement devices and governance structures in the agro-food vertical chains. *Journal of Management & Governance, 9*(1), 47-77.

Reddy, A. (2010). Strategic planning for profitable egg production in India. *World Poultry*, 16-17.

Riordan, M. H., & Williamson, O. E. (1985). Asset specificity and economic organization. *International Journal of Industrial Organization, 3*(4), 365-378.

Ritchie, B., & Brindley, C. (2007). An emergent framework for supply chain risk management and performance measurement. *Journal of the Operational Research Society, 58*(11), 1398-1411.

Rogers, G. B. (1979). Poultry and eggs. *Another Revolution in US Farming, 441*, 148-189.

Rogerson, W. P. (1992). Contractual solutions to the hold-up problem. *The Review of Economic Studies, 59*(4), 777-793.

SAPA. (2013). *A profile of the South African egg industry market value chain.* Retrieved from http://www.fao.org/sustainable-food-value-chains/library/details/jp/c/286746/ [Accessed: 17 July 2019].

SAPA. (2017). *South African Poultry Association 2017 industry profile.* Retrieved from http://www.sapoultry.co.za/pdf-docs/sapa-industry-profile [Accessed: 17 July 2019].

Schiefer, G., Fritz, M., Gellynck, X., & Molnár, A. (2009). Chain governance structures: the European traditional food sector. *British Food Journal*.

Scrinis, G., Parker, C., & Carey, R. (2017). The caged chicken or the free-range egg? The regulatory and market dynamics of layer-hen welfare in the UK, Australia and the USA. *Journal of Agricultural and Environmental Ethics, 30*(6), 783-808.

Segerstedt, A., Olofsson, T., Bankvall, L., Bygballe, L. E., Dubois, A., & Jahre, M. (2010). Interdependence in supply chains and projects in construction. *Supply Chain Management: An International Journal*, ISSN: 1359-8546.

Sexton, R. J. (2012). Market power, misconceptions, and modern agricultural markets. *American Journal of Agricultural Economics, 95*(2), 209-219.

Sheffi, Y., & Rice Jr, J. B. (2005). A supply chain view of the resilient enterprise. *MIT Sloan Management Review, 47*(1), 41.

Shleifer, A., & Vishny, R. W. (1989). Management entrenchment: The case of manager-specific investments. *Journal of Financial Economics, 25*(1), 123-139.

Simba, S., Niemann, W., Kotzé, T., & Agigi, A. (2017). Supply chain risk management processes for resilience: A study of South African grocery manufacturers. *Journal of Transport and Supply Chain Management, 11*(1), 1-13.

Similä, J. O. (2013). Vertical integration in the poultry industry: Why different governance structures? *Informe GEPEC, 17*(1), 84-98.

Srai, J. S., & Gregory, M. (2008). A supply network configuration perspective on international supply chain development. *International Journal of Operations & Production Management, 28*(5), 386-411.

Sjauw-Koen-Fa, A. R., Blok, V., & Omta, S. (2016). Critical success factors for smallholder inclusion in high value-adding supply chains by food & agribusiness multinational enterprises. *International Food and Agribusiness Management Review, 19*(1030-2016-83100), 83-112.

Skipper, J. B., Craighead, C. W., Byrd, T. A., & Kelly Rainer, R. (2008). Towards a theoretical foundation of supply network interdependence and technology-enabled coordination strategies. *International Journal of Physical Distribution & Logistics Management, 38*(1), 39-56.

Sodhi, M. S., Son, B. G., & Tang, C. S. (2012). Researchers' perspectives on supply chain risk management. *Production and Operations Management, 21*(1), 1-13.

Spiegler, V. L., Naim, M. M., & Wikner, J. (2012). A control engineering approach to the assessment of supply chain resilience. *International Journal of Production Research, 50*(21), 6162-6187.

Sporleder, T. L., & Boland, M. A. (2011). Exclusivity of agrifood supply chains: Seven fundamental economic characteristics. *International Food and Agribusiness Management Review, 14*(1030-2016-82782), 27-52.

Stecke, K. E., & Kumar, S. (2009). Sources of supply chain disruptions, factors that breed vulnerability, and mitigating strategies. *Journal of Marketing Channels, 16*(3), 193-226.

Stonebraker, P. W., Goldhar, J., & Nassos, G. (2007). *Toward a framework of supply chain sustainability: The fragility* index. Citeseer. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.493.8826&rep=rep1&type=pdf [Accessed: 20 November 2019].

Stonebraker, P. W., Goldhar, J., & Nassos, G. (2009). Weak links in the supply chain: Measuring fragility and sustainability. *Journal of Manufacturing Technology Management, 20*(2), 161-177.

Storey, J., Emberson, C., Godsell, J., & Harrison, A. (2006). Supply chain management: Theory, practice and future challenges. *International Journal of Operations & Production Management, 26*(7), 754-774.

Svensson, G. (2004). Key areas, causes and contingency planning of corporate vulnerability in supply chains: A qualitative approach. *International Journal of Physical Distribution & Logistics Management, 34*(9), 728-748.

Taleb, N. N. (2005). *The black swan: Why don't we learn that we don't learn?* Random House.

Taleb, N. N. (2007). *The black swan: The impact of the highly improbable* (Vol. 2). Random House.

Taleb, N. N. (2009). Errors, robustness, and the fourth quadrant. *International Journal of Forecasting, 25*(4), 744-759.

Taleb, N. N. (2012). *Antifragile: How to live in a world we don't understand* (Vol. 3). Allen Lane.

Taleb, N. N., Canetti, E., Kinda, T., Loukoianova, E., & Schmieder, C. (2012). A new heuristic measure of fragility and tail risks: Application to stress testing. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2156095 [Accessed 15 May 2019].

Tang, C. S. (2006). Perspectives in supply chain risk management. *International Journal of Production Economics, 103*(2), 451-488.

Thompson, J. D. (2003). *Organizations in action: Social science bases of administrative theory*. Transaction publishers.

Thompson, J. M., Pendell, D. L., Boyer, T., Patyk, K. A., Malladi, S., & Weaver, J. T. (2019). Economic impacts of business continuity on an outbreak of highly pathogenic avian influenza in Minnesota egg laying operations. *Journal of Agricultural and Applied Economics, 51*(2), 235-248.

Thurner, S., Farmer, J. D., & Geanakoplos, J. (2012). Leverage causes fat tails and clustered volatility. *Quantitative Finance, 12*(5), 695-707.

Trkman, P., & McCormack, K. (2009). Supply chain risk in turbulent environments: A conceptual model for managing supply chain network risk. *International Journal of Production Economics, 119*(2), 247-258.

Ulrich, D., & Barney, J. B. (1984). Perspectives in organizations: Resource dependence, efficiency, and population. *Academy of Management Review, 9*(3), 471-481.

Van der Merwe, M. (2017). *Asymmetric information, principal-agent behaviour and governance mechanisms in the South African lamb supply chain.* PhD, Department of Agricultural Economics, Extension and Rural Development,University of Pretoria, South Africa.

Van der Merwe, M., Kirsten, J., & Trienekens, J. (2018). *Aligning enforcement and governance mechanisms to protect and govern food products with a protected designation of origin.* DOI*:* 10.22004/ag.econ.277232.

Van Plaggenhoef, W. (2007). *Integration and self regulation of quality management in Dutch agri-food supply chains: A cross-chain analysis of the poultry meat, the fruit and vegetable and the flower and potted plant chains* (Vol. 4). Wageningen Academic Pub.

Vanany, I., Zailani, S., & Pujawan, N. (2009). Supply chain risk management: Literature review and future research. *International Journal of Information Systems and Supply Chain Management (IJISSCM), 2*(1), 16-33.

Vermeulen, H., Kirsten, J., & Sartorius, K. (2008). Contracting arrangements in agribusiness procurement practices in South Africa. *Agrekon, 47*(2), 198-221.

Vespignani, A. (2010). Complex networks: The fragility of interdependency. *Nature, 464*(7291), 984.

Vilko, J., Ritala, P., & Edelmann, J. (2014). On uncertainty in supply chain risk management. *The International Journal of Logistics Management, 25*(1), 3-19.

Vlajic, J. V., van der Vorst, J., & Hendrix, E. (2010). On robustness in food supply chain networks. *Trienekens et al.(Eds.). Towards effective food supply chains,* Wageningen Academic Publishers, 63-82.

Vlajic, J. V., van der Vorst, J. G., & Haijema, R. (2012). A framework for designing robust food supply chains. *International Journal of Production Economics, 137*(1), 176-189.

Vlajic, J. V., van Lokven, S. W., Haijema, R., & van der Vorst, J. G. (2013). Using vulnerability performance indicators to attain food supply chain robustness. *Production Planning & Control, 24*(8-9), 785-799.

Vorley, B., Fearne, A., & Ray, D. (2016). *Regoverning markets: A place for small-scale producers in modern agrifood chains?* CRC Press.

Vukina, T. (2001). Vertical integration and contracting in the US poultry sector. *Journal of Food Distribution Research, 32*(856-2016-56380), 29-38.

Wagner, S. M., & Bode, C. (2006). An empirical investigation into supply chain vulnerability. *Journal of Purchasing and Supply Management, 12*(6), 301-312.

Wagner, S. M., & Bode, C. (2008). An empirical examination of supply chain performance along several dimensions of risk. *Journal of Business Logistics, 29*(1), 307-325.

Wagner, S. M., & Bode, C. (2009). Dominant risks and risk management practices in supply chains. *Supply Chain Risk,* 271-290.

Wagner, S. M., Bode, C., & Koziol, P. (2009). Supplier default dependencies: Empirical evidence from the automotive industry. *European Journal of Operational Research, 199*(1), 150-161.

Wagner, S. M., & Neshat, N. (2010). Assessing the vulnerability of supply chains using graph theory. *International Journal of Production Economics, 126*(1), 121-129.

Wagner, S. M., & Neshat, N. (2012). A comparison of supply chain vulnerability indices for different categories of firms. *International Journal of Production Research, 50*(11), 2877-2891.

Wang, E. T., Tai, J. C., & Wei, H.-L. (2006). A virtual integration theory of improved supply-chain performance. *Journal of Management Information Systems, 23*(2), 41-64.

Watabaji, M., Molnar, A., & Gellynck, X. (2016). Integrative role of value chain governance: Evidence from the malt barley value chain in Ethiopia. *Journal of the Institute of Brewing, 122*(4), 670-681.

Weather-SA. (2018). *South Africa annual rainfall report.* Retrieved from https://www.weathersa.co.za/Documents/AnnualReports/SAWS_AR_2017_2018_v40.pdf [Accessed: 19 June 2019].

Weseen, S., Hobbs, J., & Kerr, W. A. (2014). Reducing hold-up risks in ethanol supply chains: a transaction cost perspective. *International Food and Agribusiness Management Review, 17*(1030-2016-82979), 83-106.

Wever, M., Wognum, N., Trienekens, J., & Omta, O. (2010). Alignment between chain quality management and chain governance in EU pork supply chains: A transaction-cost-economics perspective. *Meat Science, 84*(2), 228-237.

Wever, M., Wognum, N., Trienekens, J., & Omta, O. (2012a). Managing transaction risks in interdependent supply chains: An extended transaction cost economics perspective. *Journal on Chain and Network Science, 12*(3), 243-260.

Wever, M., Wognum, N., Trienekens, J., & Omta, O. (2012b). Supply chain-wide consequences of transaction risks and their contractual solutions: Towards an extended transaction cost economics framework. *Journal of Supply Chain Management, 48(1*), 73-91.

Williams, S. (2019). *Agribusiness and the small-scale farmer: A dynamic partnership for development*: Routledge.

Williamson, O. E. (1979). Transaction-cost economics: The governance of contractual relations. *The Journal of Law and Economics, 22*(2), 233-261.

Williamson, O. E. (1987). Transaction cost economics: The comparative contracting perspective. *Journal of Economic Behavior & Organization, 8(4),* 617-625.

Williamson, O. E. (1991). Comparative economic organization: The analysis of discrete structural alternatives. *Administrative Science Quarterly, 36(2),* 269-296.

Williamson, O. E. (1993). Calculativeness, trust, and economic organization. *The Journal of Law and Economics, 36*(1, Part 2), 453-486.

Williamson, O. E. (2008). Transaction cost economics. In *Handbook of new institutional economics* (pp. 41-65). Springer.

Windhorst, H., Grabkowsky, B., & Wilke, A. (2015). *Atlas of the global egg industry*. International Egg Commission.

Wognum, N., & Wever, M. (2008). *Quality and co-ordination in supply chains: The case of pork chains in the Netherlands.* Paper presented at the 2008 IEEE International Technology Management Conference (ICE).

Wu, T., Blackhurst, J., & Chidambaram, V. (2006). A model for inbound supply risk analysis. *Computers in Industry, 57*(4), 350-365.

Yang, N. (2011). Social economic aspects of egg production in China. In *Improving the safety and quality of eggs and egg products.* Elsevier, 17-26.

Yang, Z., Rose, S., Yang, H., Pirgozliev, V., & Wang, Z. (2018). Egg production in China. *World's Poultry Science Journal, 74*(3), 417-426.

Ye, F., Li, Y., & Yang, Q. (2018). Designing coordination contract for biofuel supply chain in China. *Resources, Conservation and Recycling, 128,* 306-314.

Yeboah, N. E., Feng, Y., Daniel, O.-S., & Joseph, N. B. (2014). Agricultural supply chain risk identification: A case finding from Ghana. *Journal of Management and Strategy, 5*(2), 31-48.

Zhong, Z., Zhang, C., Jia, F., & Bijman, J. (2018). Vertical coordination and cooperative member benefits: Case studies of four dairy farmers' cooperatives in China. *Journal of Cleaner Production, 172,* 2266-2277.

Zsidisin, G. A., Melnyk, S. A., & Ragatz, G. L. (2005). An institutional theory perspective of business continuity planning for purchasing and supply management. *International Journal of Production Research, 43*(16), 3401-3420.

APPENDIX

The measure of fragility of the South African egg value chain

Overview

Introduction

The value chain must deliver value and derive returns on investment in an increasingly challenging environment. These challenges are brought about the interdependencies, interconnectedness, and the complexity of the value chain to minimise costs. Therefore, the value chain faces adverse events that are not only frequently changing but also, they are have massive impact. Consequently, the decisions must be made in the environment of growing risks and uncertainty.

Goals

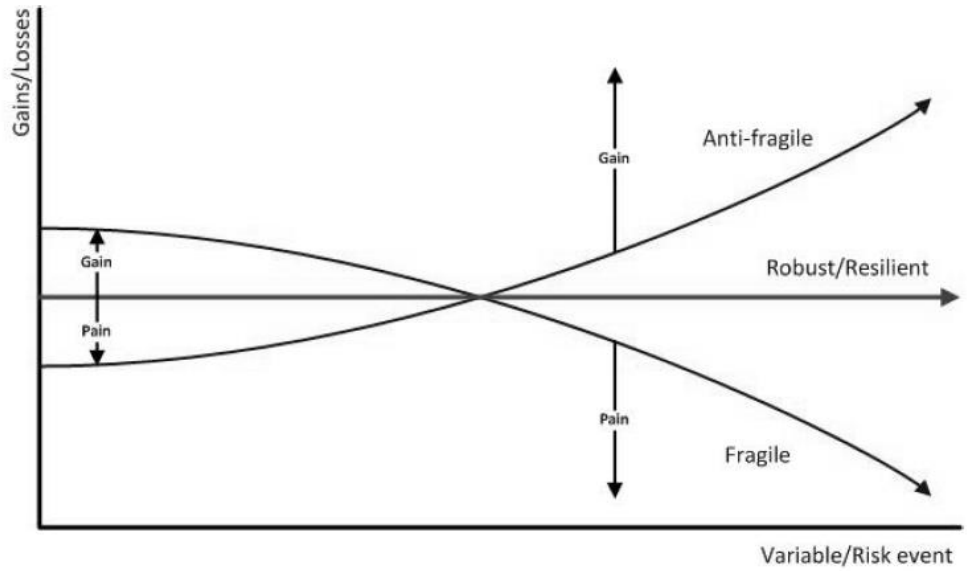
The goal of this questionnaire is to measure fragility of the South African egg value chain, to conduct a comparative value chain fragility analysis of the egg chain configurations (strategies). These measures and analyses will enable chain players to make improved and informed strategic decisions when it comes to coordination management of their businesses' chains.

Definition

Fragility in the concept of value chain is relevant 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.

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.

The graph below illustrates the concepts of fragility and anti-fragility



The agribusiness value chain fragility factors

The factors below were identified as the most influential in causing the fragility of the agribusiness value chain. therefore, these factors will be used to quantify South African egg 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 supporting infrastructure

Internal factors

- Operational reliability

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

The measure of fragility of the South African egg value chain

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 company or business unit's function in the value chain (More than one option is available for vertically integrated operations)

☐ Input provider (Animal health, Animal feeds, etc)

☐ Farmer/Producer

☐ Breeders (Parent stock)

☐ Hatcheries (Pullets)

☐ Packers and processors (Egg grading, liquid egg)

☐ Retailers (Small, Medium, and Micro-sized Enterprises, informal traders, supermarkets)

☐ Intermediary/Support function (Broker, Financier, Insurer, Consultant, State agencies)

The measure of fragility of the South African egg value chain

Overview of relational interdependencies

3. Please provide your top three suppliers and top three buyers, by their names, in your value chain (e.g. Letlama egg producers or Hatfield packers)

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

Suppliers (Starting with the biggest). Please name the specific companies or persons to include in further analysis

1	
2	
3	

Buyers (Starting with the biggest). Please name the specific companies or persons to include in further analysis

1	
2	
3	

4. What is your company's degree of the interdependency with each listed supplier?

The information below describes the degree of interdependency starting with (**1**) meaning no interdependency to (**5**) which means extreme interdependency.

1 Not interdependent at all/Independent (Characterised by self-interest, short-term, limited information sharing, flexibility)

2 Slightly interdependent

3 Somewhat interdependent

4 Very interdependent

5 Extremely interdependent (Characterised by self-interest, short-term, limited information sharing, flexibility)

To question 4 above, use the matrix below by ticking under each supplier indicating the degree of the interdependency as explained above.

Degree of interdependency		**Suppliers**		
		Supplier 1	Supplier 2	Supplier 3
	1			
	2			
	3			
	4			
	5			

5. **What is your company's degree of the interdependency with each listed buyer?** The information below describes the degree of interdependency starting with (**1**) meaning no interdependency to (**5**) which means extreme interdependency.

   1 Not interdependent at all/Independent (Characterised by self-interest, short-term, limited information sharing, flexibility)

   2 Slightly interdependent

   3 Somewhat interdependent

   4 Very interdependent

   5 Extremely interdependent (Characterised by self-interest, short-term, limited information sharing, flexibility)

To question 5 above, use the matrix below by ticking under each buyer indicating the degree of the interdependency as explained above.

Degree of interdependency		**Buyers**		
		Buyer 1	Buyer 2	Buyer 3
	1			
	2			
	3			
	4			
	5			

The measure of fragility of the South African egg value chain

Instructions

Please complete all the following questions in the contest of South African egg value chain. please significantly indicate the impact of changes in each of the factors to 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 business operations can continue and that products and services are delivered at predefined levels, that brands and value-creating activities are protected, and the reputations and interest of chain players are safeguarded whenever, disruptive incidents or disturbances occur in the value chain.**

The measure of fragility of the South African egg value chain

Chain factors

8. Please indicate the impact of deterioration in **the strength and alignment of the relationship with the supplier** (business culture, ethics, size, goals, duration of relationship, quality of the 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 deterioration in **the strength and alignment of the relationship with the buyer** (business culture, ethics, size, goals, duration of relationship, quality of the 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%	○	○	○	○	○	○	○	○	○	○

10. Please indicate the impact of deterioration in **the information sharing with the buyer** (prices, volumes, 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 deterioration 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
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 deterioration in **the degree of chain-wide communication** (market prices, market trends, industry events, [like drought, diseases, floods]) 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%	○	○	○	○	○	○	○	○	○	○

13. Please indicate the impact of 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%	○	○	○	○	○	○	○	○	○	○

The measure of fragility of the South African egg value chain

External factors

14. Please indicate the impact of deterioration in **the state of 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 deterioration in **the social stability and public relations your business** (strikes, protects, socio-economic-political conditions, business public image) 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 deterioration in **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%	○	○	○	○	○	○	○	○	○	○

17. Please indicate the impact of in **changes in the number and intensity of public and private compliance requirements** (laws, regulations, certifications, 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	○	○	○	○	○	○	○	○	○	○

The measure of fragility of the South African egg value chain

Internal factors

18. Please indicate the impact of 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 deterioration in **your business's product quality and 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 deterioration in **the quality and training of your business's human resource** 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 deterioration in **information visibility** (business management systems) 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 deterioration in **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 deterioration in **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 deterioration in **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%	○	○	○	○	○	○	○	○	○	○

The measure of fragility of the South African egg value chain

Thank you so much form your valued time and respected inputs.

THANK YOU