PHARMACEUTICAL SUPPLY CHAIN RESILIENCE:

An exploratory analysis of vulnerabilities and resilience strategies in the face of dynamic disruptions in the UK pharmaceutical supply chain

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Submitted for the Degree of
Doctor of Philosophy

Faculty of Management, Law and Social Sciences
University of Bradford

2019

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Keywords: Supply Chain Resilience; Pharmaceutical Supply Chain; Disruptions; Resilience Strategies; Vulnerabilities.

Abstract

Pharmaceutical supply chains are susceptible to disruptions which impact on the operational and financial performance of firms as well as patient safety. This study aimed to explore why the Pharmaceutical Supply Chain (PSC) in the UK is susceptible to the impact of dynamic disruptions and examine how resilience strategies have were employed to reduce the effects of these disruptions. The Complex Adaptive System (CAS) theory was used as a framework in an exploratory research design using mixed-methods. The qualitative data were gathered through 23 semi-structured interviews with key supply chain actors across the PSC in the UK to explore their experiences. The findings from these semi-structured interviews were used to develop a survey which was distributed to a broader spectrum of supply chain actors where the final sample from the survey was (n=106). The data were triangulated to discuss the research findings. The initial results revealed power, conflict and complexities as drivers of vulnerabilities in the PSC. Antecedents for building resilience strategies included visibility, flexibility and joint decision making as recovery strategies and resource sharing as the resistance strategy. CAS provided a systemic approach to understanding PSC resilience rather than in parts. In doing so, it took into consideration the various elements that make up the entire system. Thus, vulnerabilities and resilience strategies were outcomes of the interactions between supply chain actors. The findings demonstrated that CAS, as a theory, provided a framework that was beneficial in exploring and gaining insights into PSC resilience. Also, by combining the two datasets (interviews and survey), an original output was proposed -the Pharmaceutical Supply Chain Resilience Framework (PSCRF)- which was used to recommend resilience strategies suitable for mitigating disruptions in the PSC.

Dedication

I dedicate this thesis to Zahra and Sani. Thank you for loving me.

Acknowledgement

I am immensely grateful to God for His infinite mercies, blessings and opportunities to carry out this research.

My deepest gratitude goes to my supervisory team: Dr Liz Breen, Dr Jiachen Hou and Dr Julie Sowter. Thank you for their care, patience, guidance, timely feedback and support- the best supervisory team any PhD student.

My sincere appreciation also goes to members of Cost Action 15105 -European Medicine Shortages Research Network - for their valuable insights, contribution and networks.

My gratitude also goes to my family for their love, emotional and spiritual support without which it would have been challenging to complete this thesis. I am also grateful to my friends for their time, encouragement, and support, which spurred me to carry on even in times of difficulties.

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Glossary

ABPI	Association of British Pharmaceutical Industries
ASHP	American Society of Health-System Pharmacists
BCI	Business Continuity Institute
CAS	Complex Adaptive Systems
CMU	Commercial Medicines Unit
DHSC	Department of Health and Social Care
EAHP	European Association of Hospital Pharmacists
EFPIA	European Federation of Pharmaceutical Industries and Association
FMD	Falsified Medicine Directives
GDPR	General Data Protection Regulation
NHS	National Health Services
NPSG	National Pharmaceutical Supply Group
OECD	Organisation for Economic Co-operation and Development
PSC	Pharmaceutical Supply Chain
PSCR	Pharmaceutical Supply Chain Resilience
PSCRF	Pharmaceutical Supply Chain Resilience Framework
PSNC	Pharmaceutical Services Negotiating Committee
PMSG	Pharmaceutical Market Support Group
SEM	Structural Equation Modelling
SSP	Serious Shortage Protocol
UK	United Kingdom
WHO	World Health Organisation

Chapter One: Introduction

1.1. Introduction

This chapter aims to set the scene for this thesis. The chapter briefly describes the fundamental concepts that have framed the foundations of this research and positions the study in the existing literature. This chapter also provides the objectives for the current research, the underlying research questions, the methodological approach adopted as well as the analysis of the research process. The chapter concludes with a summary of the thesis structure, which will guide the readers through this monograph.

1.2. Background of the Study

The current business climate for supply chains is described as the 'Disruption Era'. It follows the finding from a survey by the Business Continuity Institute (BCI) (2018), which indicated that the number of supply chain disruptions in recent years had increased at an alarming rate. The survey by Vuealta (2019) further confirmed that over 90% of supply chains in the UK had experienced some form of disruptions in the last five years.

Supply chain disruptions range from minor incidents, such as labour strikes and absenteeism, to major catastrophic events like a Tsunami or a fire outbreak. These disruptions obstruct the flow of products in the supply chain as well as hinder manufacturing capabilities (Craighead et al. 2007; Jüttner and Maklan, 2011; Purvis et al. 2014; Blackhurst et al. 2018; Parast and Shekarian, 2019). For instance, the earthquake and tsunami that struck Japan in March 2011, directly impacted over 27,000 businesses whose production, warehousing and retail facilities were destroyed or disabled by the natural disaster (Hendricks et al. 2019). One year following the disruption, 22% of those businesses had not yet resumed operations (MacKenzie et al. 2014).

Another example of the impact of disruption was the collapse of an eight-story commercial building, the Rana Plaza, in Savar, Bangladesh in April of 2013, which delayed production capacity for fashion retailers such as Primark and H and M (Anisul Huq et al. 2014; Jacobs and Singhal, 2017; 2019). Also, in 2015,

the explosion of containers at a warehouse for toxic chemicals in Tianjin destroyed 8,000 newly produced vehicles which were estimated to cost £479 billion, caused substantial environmental degradation and led to the halting of production of two of Toyota's manufacturing plants for almost a week (McDonell, 2015). Likewise, the world's most prominent centres for the manufacturing of over 500 pharmaceutical products recorded significant losses as a result of Hurricane Maria, a category five hurricane, in September of 2017 (Torjesen, 2018; Barrera et al. 2018). The disruption significantly increased the cost of healthcare for patients and potentially impacted on patient safety (Mereish et al. 2018).

These disruptive events have influenced the financial performance of a supply chain adversely and to a large extent the final consumers (Hendricks and Singhal, 2009; Urciuoli et al. 2014; Thekdi and Santos, 2016; Hendricks et al. 2019; Hosseini et al. 2019). For instance, Hendrick et al. (2019) in their study on firm performance after the Great East Japanese Earthquake found that shareholders lost an average of 5.21% of their shareholders' value in the first month following the disruption.

Although the actual costs of any supply chain disruption can be difficult to quantify precisely, at least one firm surveyed by Rice and Caniato (2003) estimated that the daily cost impact of a disruption in its supply network was between the ranges of £50 to £100 million. Also, a survey by the European Association for Hospital Pharmacists (EAHP) (2018) provided empirical evidence where medicine shortages in the pharmaceutical supply chain led to the death of a patient (Miljkovic et al. 2019). The examples highlighted above, therefore, identify motivations for supply chain actors to determine why these disruptions impact on the supply chain as well as to seek ways in preventing and/or mitigating the impact of disruptive events.

Existing studies suggest that underlying weaknesses (vulnerabilities) in supply chains may be the reasons why disruptions have an impact on supply chains (Peck, 2005; Craighead et al. 2007; Juttner and Maklan, 2011). Managerial decisions, complexities, global sourcing and supply chain density among others may be the causes of supply chain weaknesses (Wagner and Bode, 2006).

Supply chain resilience may be able to mitigate the impact of disruptive events (Christopher, 2004). Supply chain resilience requires that firms in a supply chain, prepare, respond and recover from a disruptive event in a timely and cost-effective manner (Ponomarov, 2012; Chopra and Sodhi, 2014; Tukamuhabwa et al. 2015; Hendry et al. 2019). Supply chain resilience depends on the idea that not all risks in the supply chain are controllable (Peck, 2005; Wagner and Bode, 2006; Jüttner and Maklan, 2011; Blackhurst et al. 2018).

Resilience in the supply chain hinges on the idea that there are inherent weaknesses (vulnerabilities) in a supply chain which exposes the supply chain to the impact of disruption. Thus, resilience strategies developed adequately can reduce supply chain vulnerabilities and the effect of disruptions (Jüttner and Maklan, 2011; Christopher and Holweg, 2011; Hohenstein et al. 2015; Elleuch et al. 2016, Kamalahmadi and Parast, 2016). Therefore, higher resilience in the supply chain implies lower levels of vulnerabilities (Jüttner and Maklan, 2011; Thun and Hoenig, 2011; Mandal et al. 2016; Purvis et al. 2016; Hendry et al. 2019). However, empirical evidence supporting these assertions has various shortcomings as elucidated below:

While some studies examine static disruptions such as fire outbreaks, constitutional change, financial crises natural disasters (Jüttner and Maklan, 2011; Scholten et al. 2014; Hendry et al. 2019; Sa et al. 2019), other studies just measure the effectiveness of resilience strategies within organizations without focusing on a particular disruption (Ambulkar et al. 2015; Tukamuhabwa et al. 2017). There are however, limited studies examining a dynamic disruption such as medicine shortages where the causes and mode of occurrence change at every point (Fox et al. 2014; Beck et al. 2019). The argument here is that supply chain resilience strategies are dynamic, and as such, their applications should differ concerning the forms of disruption as well as the type of supply chain. It was, therefore, appropriate to examine the applicability of resilience in the supply chain within a dynamic, disruptive context like medicine shortages.

Besides, some studies have tried to examine resilience strategies against disruption without taking into cognisance the vulnerabilities of these supply chains (Jüttner and Maklan, 2011; Hendry et al. 2019; Sa et al. 2019; Scholten et al. 2019). Supply chain resilience relies on the assumptions that some strategies

may increase resilience without necessarily reducing vulnerabilities (Jüttner and Maklan, 2011; Pettit et al. 2013). Thus, understanding the vulnerabilities of a supply chain is pertinent to developing supply chain resilience strategies, to ascertain if these resilience strategies contribute to reducing supply chain vulnerabilities as pointed out by Christopher and Peck, (2004). There are, however, limited studies that have identified drivers of supply chain vulnerabilities in the literature (Wagner and Bode, 2006).

In this study, therefore, vulnerabilities of the supply chain are explored as the first step to understanding resilience strategies and their possible impact in mitigating disruptions. The study of supply chain vulnerability is necessary to evaluate the need for costly strategies developed in resisting disruptions that may rarely occur (Wagner and Neshat, 2010).

Also, it is suspected that; the PSC differs from other supply chains. Some of its distinctive characteristics include longer lead supply times, stringent regulatory frameworks, severe demand forecasting and complex applications (Rossetti et al. 2011; Klueber and O'Keefer, 2013; Mehralian et al. 2015; de lima et al. 2018). These characteristics may influence the applicability of resilience strategies. For instance, resilience suggests that for supply chains to withstand disruptive activities, flexibility should be entrenched in their strategies. Flexibility here requires that idle capacity is tactically selected in the event of disruptive events (Erol et al. 2010; Blome et al. 2015; Scholten et al. 2019). However, the regulations guiding the pharmaceutical industry make the supply chain inflexible and as such limit the capacity of businesses in the face of disruption. With regards to products that have limited numbers of manufacturers, which is usually the case with branded products, it may be challenging to employ flexibility as a resilience strategy.

The motivation for exploring the underlying vulnerabilities and resilience strategies within the pharmaceutical supply chain is, therefore highlighted. Supply chains have been characterised as complex adaptive systems as they exhibit features such as non-linearity, feedback, self-organisations and schemas (Choi et al. 2001; Surana et al. 2005; Day, 2014; Tukamuhabwa et al. 2015). Therefore, it logically becomes pertinent to study supply chain resilience systemically. Systemic thinking thus involves exploring the link between disruptions,

vulnerabilities and resilience strategies in the context of the pharmaceutical supply chain rather than merely analysing them individually. This empirical systemic analysis on supply chain resilience remains limited, although, suggestions in the literature identify CAS theory as a suitable lens for understanding supply chain resilience (Day, 2014; Tukamuhabwa et al. 2017).

This research, therefore, explored the underlying drivers of vulnerabilities and provided insights into the resilience strategies adopted in the pharmaceutical supply chain in the UK when dynamic disruptions like medicine shortages occurred. The study specifically chose the UK because of its stringent regulated pharmaceutical supply chain practices that may be one of the best in the world (OECD, Health Statistics, 2015). The study also examined if the adopted resilience strategies had any impact on vulnerabilities, as suggested in the existing literature and how these strategies helped mitigate the impact of medicine shortages. The following section will provide additional information regarding the objectives of this research and will further explain the rationale behind the research idea and interests.

1.3. Aims and Objectives of the Study

The main aim of this study was to investigate the pharmaceutical supply chain vulnerabilities to dynamic disruption as well as to understand the impact of resilience strategies in mitigating these disruptions.

More specifically, the objectives of this study were:

- ***To explore the vulnerabilities of the pharmaceutical supply chain in the UK.*** This research objective was directed at uncovering underlying weaknesses that may exist in the pharmaceutical supply chain and which might expose the supply chain to the impact of disruptions.

- ***To explore the resilience strategies that supply chain actors adopt in reducing the impact of dynamic disruptions in the pharmaceutical supply chain.*** Here the objective was to assess how the supply chain actors handled dynamic disruptions when they occurred to prevent these disruptions from affecting the performance of the supply chain and in ensuring patients safety.

• ***To identify adequate resilience strategies that can aid in reducing the frequency and impact of disruptions in the pharmaceutical supply chain***. This objective first examined whether the adopted resilience strategies by supply chain actors reduced underlying vulnerabilities and then identified best practice.

1.4. Research Questions

This study argues that to understand pharmaceutical supply chain (PSC) resilience, analysing disruptions, vulnerabilities and resilience strategies systemically rather than as individual elements is essential to reflect the current framing of the supply chain as a Complex Adaptive System (CAS). This study thus aims to address three related research questions outlined below. Each incorporates sub-research questions which are linked to the aims and objectives of the thesis as presented below:

RQ1: Why is the pharmaceutical supply chain in the UK susceptible to dynamic disruptions?

- What are the drivers of vulnerability in the PSC?
- How do these drivers expose the supply chain to the impact of dynamic disruptions?

RQ2: How are resilience strategies used to mitigate the impact of dynamic disruptions in the pharmaceutical supply chain?

- What strategies do supply chain actors adopt to build resilience against dynamic disruptions?
- What are the outcomes of implementing these strategies?

RQ3: What impact do resilience strategies have on vulnerabilities in the pharmaceutical supply chain?

1.5. Theoretical Boundary of the Research

Based on the research questions elucidated in the previous section, this section presents the theoretical boundary of the research to explain the various concepts and the context which forms the foundation of the study. These concepts include:

i) Disruptions; ii) Resilience; iii) Vulnerabilities and iv) Pharmaceutical Supply Chain. Operations management literature provided the theoretical perspectives for this research, and the PSC was the context assessed. The scene on which the research questions were addressed and answered was set by synthesising the fundamental bodies of knowledge. Also, Complex Adaptive System (CAS) theory was adopted as the strategic theory that provided the lens for addressing the phenomenon under investigation. Figure 1.1 below provides a summary of the research boundary in this study.

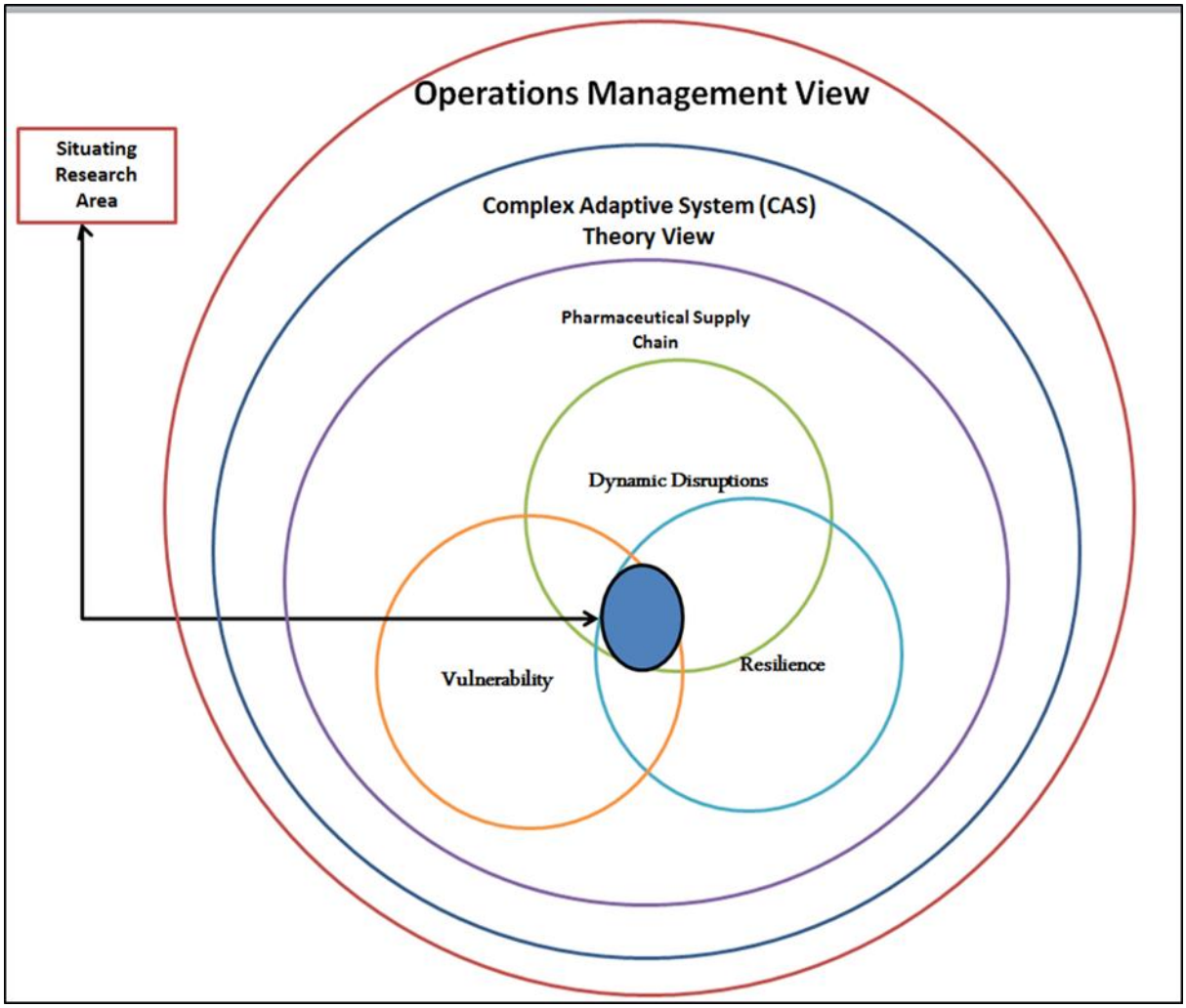

Figure 1. 1 Boundary of the Research
Source: Researcher's Own (2019)

1.6. Research Contribution

The review of the literature highlighted many gaps that needed to be filled in operations management literature. For instance, the types of disruptions for which

resilience strategies have been suggested to mitigate are somewhat static, such as earthquakes and fire outbreaks (Sheffi and Rice, 2005). Also, existing studies focused on causes of supply chain disruptions (Peck, 2005; Craighead et al. 2007); performance implications (Hendricks et al. 2018); management of supply chain risks (Tang, 2006) and strategic behaviour that firms employed in the wake of supply chain disruptions (Bode et al. 2011). However, limited attention has been given to examining the underlying vulnerabilities and the potential impact of supply chain resilience when these disruptions occur. This highlighted the need to understand the dynamics of disruptions like medicine shortages and underlying vulnerabilities, as well as to ascertain the applicability of resilience strategies in mitigating the impact of dynamic disruptions.

It was also suspected that the application of resilience strategies might differ significantly in the context of the pharmaceutical supply chain. This stemmed from on the notion of the intricacies of the pharmaceutical supply chain, which included but not limited to; longer lead supply times, stringent regulatory frameworks and severe demand forecasting. Despite their practical value, studies examining supply chain resilience were scarce, and many of these contributions were normative, anecdotal, or case study based (Shah, 2004; Tucker et al. 2019).

Existing knowledge about the mechanisms that determined the vulnerability of supply chains and the interaction of PSC vulnerability and resilience was quite limited. Therefore, CAS theory was used as a framework, and it provided insights into how the elements of supply chain resilience interacted at various levels of the PSC. The findings offer supply chain managers guidelines that contribute to the development of resilience strategies that are better able to withstand various forms of disruptions and reduce supply chain vulnerabilities.

1.7. Methodological Approach

A mixed-method approach was used to achieve the research objectives of this study. It involved both qualitative and quantitative techniques in collecting and analysing the data to understand the phenomenon under investigation as well as proffer best practice situations (Johnson et al. 2007; Creswell, 2013). This approach to the research was conducted under the pragmatism paradigm, which posits that social reality can be explained based on information (Creswell and

Poth, 2016). By gathering information from multiple sources, current underlying vulnerabilities adopted resilience strategies, and the relationship between both was explored and explained.

Specifically, this was an exploratory research process, made up of two phases which were sequentially developed in order to address the underlying research questions. The first phase of the research was the qualitative phase, where data were collected from 23 key supply chain actors using semi-structured interviews and analysed by thematic analysis. The next stage of the research process was the quantitative phase. The findings from the semi-structured interviews were used to develop a questionnaire, and 106 key supply chain players completed it. The quantitative phase of the study aimed to confirm the findings from the qualitative stage of the interviews. The research process is presented graphically in Figure 1.2 below**.**

The methodology chapter provided information regarding the research strategy, the data and methodological triangulation. The diversity of the data offered this research validity and reliability. It formed the background in developing the framework of the research.

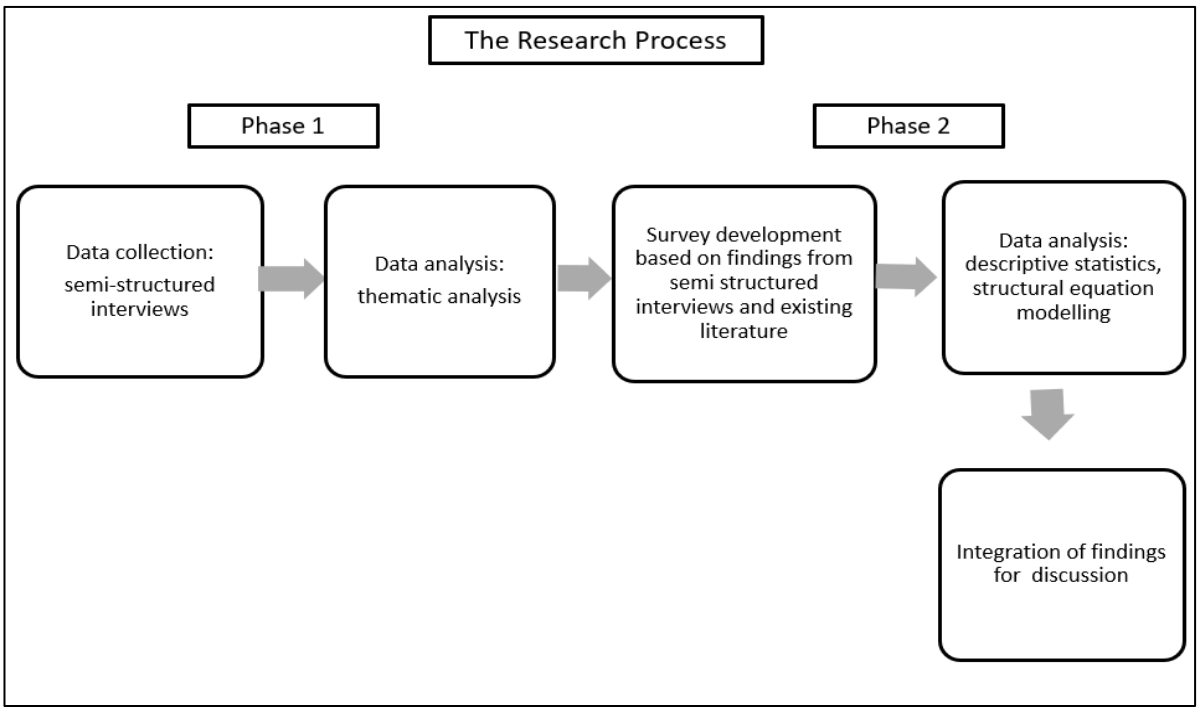

Figure 1. 2 Research Process

1.8. Definition Key Concepts

This study explored pharmaceutical supply chain resilience by first investigating the individual elements such as vulnerability and resilience, then adopted a systemic approach to explore the interrelationship between the components. The review of literature in Chapter Two, thus, identified that the key elements related to supply chain resilience, included risks, disruptions, vulnerabilities and resilience strategies.

This section defines the key elements used in this study. The definitions adopted were those most closely aligned with the research objectives and thus, optimally placed to address the research questions.

1.8.1. Supply Chain Disruptions

This study adopted the definition of supply chain disruptions as an "*interference process in the flow of goods within the supply chain"* as defined by Brenner (2015, p26). Disruption therefore implies anything that interferes with goods reaching the final consumer in the supply chain. This definition encompasses several issues such as quality problems with suppliers, delivery outages, supplier defaults, natural disasters, labour strikes, or plant fires; all of which can vary considerably in their causes, characteristics, and effects.

Supply chain disruption is a realized risk. This definition was particularly relevant to this study as the study adopted medicine shortage as a disruption to the supply chain, where the causes of medicine shortages included quality problems, natural disasters, supplier defaults and labour strikes (Fox et al. 2014; Iyangar et al. 2016; DeWeerdt et al. 2017; Beck et al. 2019).

1.8.2. Supply Chain Vulnerability

Supply chain vulnerability has been defined in many ways (Peck, 2005; Wagner and Bode, 2006; Ruel et al. 2018). This study adopted and augmented the definition of supply chain vulnerability by Wagner and Bode (2006). They stated that supply chain vulnerability is the exposure/ susceptibility of the supply chain to the impact of disruption.

The above definition by Wagner and Bode (2006) is particularly relevant to this study because it identified and highlighted the research goal for this study, which

is to understand why the pharmaceutical supply chain is susceptible to the impact of varying degrees of disruptions.

1.8.3. Supply Chain Resilience

Various definitions of supply chain resilience exist in literature; however, this study adopted the definition described by Tukamuhabwa et al. (2015), where supply chain resilience is defined as:

"*The adaptive capability of a supply chain to prepare for and/or respond to disruptions, to make a timely and cost-effective recovery, and therefore progress to a post-disruption state of operations – ideally, a better state than before the disruption*" (p 5599).

This definition is comprehensive as it includes all the essential ingredients of resilience which are: the ability to prepare for disruption, the capacity to adapt to the changes that happen as a result of the disruption and to recover promptly from a disruption using cost-effective strategies. This definition was particularly relevant to this study, as medicine shortages were explored as dynamic disruptions and developing cost-effective strategies in response to dynamic disruptions is essential.

1.8.4. Supply Chain Risk

It was pertinent to define supply chain risk as it is an essential element in the discussions of supply chain resilience. Risk is the probability that an unfavourable event may occur (Tang, 2006a). It differs from disruptions and vulnerabilities. Disruptions are as *realized risks,* and vulnerabilities are '*exposures to disruptions'* (Wagner and Bode, 2006).

This study, therefore, adopted the definition put forward by Ho et al. (2015) which defined risk as.

"The likelihood of unexpected macro and/or micro-level events or conditions that adversely influence any part of a supply chain leading to the operational, tactical or strategic level of failures or irregularities" (p 5035).

This definition encapsulated supply chain risk with regards to the probability of occurrence (*likelihood*) across the supply chain.

1.9. The Research Output

This study aimed to focus on the PSC to extend operations management literature by assessing the applicability of resilience strategies in curbing the vulnerabilities in the pharmaceutical supply chain. The study also aimed to provide a framework to guide professional practice.

1.10. Outline of the Thesis

This thesis consists of eight chapters; the structure of which is presented below.

Chapter One: Introduction

This is the first chapter of the thesis, and it introduces the research by providing information on the research background, motivation, objectives, boundaries and scope of the study. This chapter also includes the gaps in the literature that needed to be addressed and briefly highlights how the stated research questions were addressed, including the choice of the study context, methodological approach and the theoretical frameworks that are used in interpreting the findings.

Chapter Two: Literature review

The review of literature is the second chapter of this study. It presents a comprehensive review of the literature relating to supply chain resilience which includes supply chain disruptions, supply chain vulnerability and supply chain risk management. The chapter also analyses the various definitions of supply chain resilience as (introduced in section 1.8). The thesis is thus, positioned in context with the previous chapter and set up for the next chapter.

Chapter Three: Contextualizing the study

This chapter analyses the characteristics of the pharmaceutical supply chain and explores the extant literature on medicine shortages as a pharmaceutical supply chain disruption. The CAS theory is presented and justified as an appropriate lens for the study of resilience within the pharmaceutical supply chain.

Chapter Four: Methodology

Chapter Four presents the methodological tools and approach employed in achieving the research objectives. This chapter also includes discussion and justification of the methodological choices made in this study.

Chapter Five: Findings from the semi-structured interviews

This chapter presents; the findings from the semi-structured interviews, including the development of the category structure from the data and where taxonomies for supply chain vulnerabilities and resilience strategies have emerged. This chapter also addresses the research objectives and provides deductive remarks that form the benchmark against which helps in developing the quantitative phase of the study.

Chapter Six: Findings from the survey questionnaire

Chapter Six presents the findings from the quantitative study (questionnaire). This phase aimed to confirm the results from the semi-structured interviews with a more integrative level of analysis. It also examined the third research question to measure the relationship between resilience and vulnerabilities of the pharmaceutical supply chain. The quantitative techniques used were descriptive statistics and Structural Equation Modelling (SEM).

Chapter Seven: Discussion

This chapter discusses the implications of the findings provided in Chapters Five and Six of this thesis. The CAS theory is also used to explain the theoretical and practical implications of the research. The Pharmaceutical Supply Chain Resilience Framework (PSCRF) developed from the analysis of both qualitative and quantitative data is presented and discussed.

Chapter Eight: Conclusions and Recommendations

Chapter eight is the final chapter of this thesis. It presents a summary of the research findings; contributions to both academia and practice; the limitations of the study and areas for future research; recommendations for policy and summary of the research.

Chapter Two: Literature Review

2.1. Introduction

This study aimed to investigate why pharmaceutical supply chains are susceptible to the impact of dynamic disruptions and explore the resilience strategies employed to curb these disruptions. In order to deliver to the research objectives, the first step in this research was to review literature pertinent to this agenda. In this chapter, therefore, a review of the literature surrounding the research objectives is presented.

The review begins by examining the literature on supply chain risk management (2.2) as a broader spectrum under which supply chain resilience literature falls. The next section explains the terminologies of various supply chain resilience elements (2.3) and these elements are discussed further in the following sections: supply chain risks (2.4); supply chain disruptions (2.5); supply chain vulnerabilities (2.6); supply chain resilience strategies (2.7); culminating with the conclusion and summary of the research gaps (2.8). These elements are pertinent as they offer a framework that is necessary for contextualising the study in broader related literature. The review of literature, thus, examines the applicability of these resilience strategies within the pharmaceutical supply chain as well as demonstrating the limitations of supply chain resilience thereby identifying gaps that need to be addressed in the existing literature.

2.2. Supply Chain Risk Management (SCRM)

A supply chain consists of all the individuals, organisations, resources, activities, and technology involved in the creation and sale of a product (Mensah and Merkuryev, 2013). Management of a supply chain; therefore, entails that materials, finances and information are managed appropriately as a product is created and moved to the end-user (Christopher, 2016). The three main flows of the supply chain are the product flow, the information flow, and the finances flow. SCM thus involves coordinating and integrating these flows both within and among firms.

Supply chain resilience has been suggested as one of the core elements of supply chain risk management (Ponomarov and Holcomb, 2009). As such, this perspective must be examined to determine how resilience strategies should be incorporated into the resilience conceptual framework.

Supply chain risk management has emerged from the combination of two relatively well-established concepts in the literature: supply chain management and risk management (Ritchie and Brindley, 2007; Trkman and McCormack, 2009; Xie et al. 2011; Sodhi et al. 2012; Chen et al. 2013; Sarker, 2019). This stems from the fact that supply chains are exposed to various risks as a result of complexities in the business environment and as such calls for effective supply chain management (Chen et al. 2013; Sarker, 2019).

Existing studies have, however, commented on the lack of empirical studies on supply chain risk management and on the lack of consensus on how to define supply chain risk management (Ponomarov and Holcomb, 2009; Sodhi et al. 2012). For instance, Jüttner (2005) defines SCRM as "*the identification and management of risks*" (p124). Sodhi et al. (2012), define SCRM as the management of demand-supply uncertainties. Similarly, Lavastre et al. (2012) define SCRM as "*the management of risk that implies both strategic and operational horizons for a long term and short-term assessment*" (p830).

2.2.1. The Relationship between Supply Chain Risk Management and Supply Chain Resilience

The nature of the relationship between supply chain risk management and supply chain resilience has remained inconclusive in literature. Some studies suggest that supply chain resilience is developed from supply chain risk management (Ponomarov and Holcomb, 2009; Pettit et al. 2013). Other scholars have argued that supply chain risk management enhances supply chain resilience (Thun et al. 2011; Thun and Hoenig, 2011). Some scholars posit that the connection between supply chain risk management and supply chain resilience hinges on the focus objective of the supply chain risk management strategies (Jüttner and Maklan, 2011). It has also been argued that ensuring supply chain resilience is the best

way of managing the risk of supply chain disruptions (Xiao et al. 2012; Ambulkar et al. 2015; Chowdhury and Quaddus, 2017; Li et al. 2017).

Several scholars believe that implementing supply chain risk management strategies can increase supply chain resilience (Colicchia et al. 2010). For example, supply chain risk mitigation strategies which were highlighted by Tang and Musa (2011) included multiple sourcing, flexibility, early warning systems, supply chain design, operational hedging, postponement, and contract and incentive alignment. Investing in contingency planning, preparedness, improving visibility, alertness, agility and collaboration as elements of supply chain risk management were also suggested by other researchers as necessary for creating supply chain resilience (Chopra and Sodhi, 2004; Sheffi and Rice, 2005; Zsidisin and Wagner, 2010; Li et al. 2017). In this study, the notion of supply chain resilience as enhancing supply chain risk management has been adopted.

2.3. Related Supply Chain Resilience Concepts

Supply chain resilience as a concept within operations management literature is also related to concepts regularly found within the literature on supply chain risk management. Some of these concepts try to explain issues with the supply chain, such as vulnerability and disruptions. Others focus on responses to such issues, which include supply chain risk management, supply chain mitigation strategies and supply chain robustness. The term supply chain mitigation, for instance, has been often replaced with supply chain resilience in existing literature (Scholten et al. 2014) or considered an element of supply chain resilience (Melnyk et al. 2014). For instance, Craighead et al. (2007) argued that mitigation strategies were necessary elements in building supply chain resilience capable of curbing existing vulnerabilities.

Similarly, some of the concepts linked to supply chain resilience are to a large extent well established in the literature and are more mature than supply chain resilience (Chapman et al. 2002; Peck, 2005). For instance, it is argued that supply chain resilience emerged from supply chain risk management (Ponomarov and Holcomb, 2009). Furthermore, some of these concepts are used interchangeably in the same context as in the case of supply chain disruption and

supply chain risk (Chopra et al. 2007; Li et al. 2009; Ekwall, 2010; Sodhi et al. 2012; Zsidisin and Henke, 2019); resilience and robustness (Saenz et al. 2015) risk and vulnerabilities (Waters, 2011).

Other concepts have been considered essential to the discussions of supply chain resilience literature (Jüttner and Maklan, 2011). For example, some studies have defined supply chain risks as anything that may disrupt the flow of information, materials or products along the supply chain (Peck, 2006). Additionally, supply chain disruption has been portrayed as a form of supply chain risk (Christopher and Peck, 2004; Manuj and Mentzer, 2008; Zsidisin and Wagner, 2010; Singhal et al. 2011; Tang and Musa, 2011: Chen et al. 2013; Hosseini et al., 2019) while supply chain vulnerability is in some instances considered as a risk factor (Lavastre et al. 2012). Further, Peck (2006) claimed that, when something is at risk, it means it is vulnerable. Jüttner and Maklan (2011) added that when the vulnerability of a particular supply chain is addressed, its risks are also addressed. In the same vein, these concepts, which include risk, disruption and vulnerability in supply chains, have often been used interchangeably (Singhal et al. 2011; Huq et al. 2016).

The underlying perceptions above reiterates the fact that an in-depth understanding of supply chain resilience can be achieved through understanding these closely related areas. For instance, understanding vulnerabilities within the supply chain can provide an overview of the importance of developing supply chain resilience strategies. This is pertinent, as existing studies surrounding supply chain resilience have focused on natural disasters such as earthquakes (Johnson et al. 2013; Urciuoli et al. 2014) and financial crises (Jüttner and Maklan, 2011). However, extant literature highlights that supply chain resilience strategies can be applied to smaller, much more frequent disruptive events (Carvalho et al. 2014; Ambulkar et al. 2015).

Therefore, it may be posited that resilience strategies are developed to curb the impact of disruptive activities (Brandon-Jones et al. 2014; Pettit et al. 2019; Polyviou et al. 2019). The sections following this, thus, present a more detailed discussion of the related concepts of supply chain resilience introduced above,

namely: Supply Chain Risk, Supply Chain Disruptions, Supply Chain Vulnerability and Supply Chain Resilience Strategies.

2.4. Supply Chain Risk

Supply chain risk has received increased attention in both academia and practice as a result of the negative effect it has on the efficacy of the supply chain (Xie et al. 2011; Chopra and Sondhi, 2014; Scheibe and Blackhurst, 2018) as well as its effect on shareholders' value (Hendrick et al. 2019). There is, however, no consensus on the definition of the term as authors have failed to capture the concept precisely. Existing definitions have focused on either how risk affects specific functions of the supply chain (Wagner and Bode, 2006) or aspects of the supply chain (Jüttner et al. 2003; Ellis et al. 2011). These definitions do not cover risk as it affects the entire supply chain (Ho et al. 2015).

For instance, Wagner and Bode (2006), define supply chain risk as:

"*A negative deviation from the expected value of a certain performance measure, resulting in negative consequences for the focal firms*" (p303)

While this definition highlights the outcome of the impact of a disruptive event, it does not focus on supply chain risk but overall risk.

Ellis et al. (2011), on the other hand, define supply chain risk as.

"*An individual's perception of the total potential loss associated with the disruption of the supply of a particular purchased item from a particular supplier*" (p 36).

This definition is constrained to the risk associated with supply and does not take into cognisance the weakness of the supply chain when there is a disruption.

This study, therefore, adopts the definition put forward by Ho et al. (2015) which is defined as:

"The likelihood of unexpected macro and/or micro-level events or conditions that adversely influence any part of a supply chain leading to the operational, tactical or strategic level of failures or irregularities". (p 5035)

This definition encapsulates supply chain risk with regards to the probability of occurrence (*likelihood*) across the supply chain.

2.4.1. Classification and Sources of Supply Chain Risk

As supply chains increase in complexity, the drivers of risk have been suggested to increase (Ellegaard and Schibsbye, 2019). There is, however, a lack of consensus in the literature on the dimensions and classifications of risk within the supply chain. For example, Chopra and Sodhi, (2004) categorized risk into groups which are recognized based on supply chain flows, and these include disruption; delays; systems; forecast; intellectual property as well as procurement risk. Tang (2006a), on the other hand, classified supply chain risk as either disruptive or operational. Disruptive risks in the supply chain are unexpected or unforeseen occurrences that prevent the free flow of materials from the manufacturer to the consumer (Wu et al. 2007; Ellis et al. 2011; Chang et al. 2015). Table 2.1 presents the various categories of supply chain risk and their sources.

Table 2.1 Category and sources of supply chain risk as reported in the literature

Authors	Categories of Risk	Sources of Risk
Christopher and Peck (2004)	External Internal	Environmental, Internal risks.
Tang (2006a)	Disruptive Operational	Natural and human-made disasters (flood, hurricanes terrorism) Uncertainty in consumers demands, uncertainty in supply.
Wagner and Bode (2006)	Supply risk Demand risk Distribution network risk Catastrophic risk	Production capacity, product quality, the financial instability of the supplier; quality problems. Uncertainty of random customers' demand, Transportation operation (truck drivers' strike), fire in the warehouse Supply chain disruption, such as natural hazards, socio-political instability, and civil unrest.
Wu and Olson (2008)	Internal risk External risk	Controllable-quality, cost, on-time delivery, production flexibility partial control- accidents, market strength, legal issues business continuity.

		Control-second tier suppliers. External legal issues, demand and security. Uncontrollable: Political stability, natural disasters and market characteristics.
Tang and Tomlin (2008)	Supply Demand Behavioural	Security. Process, intellectual property, political/social. Behavioural risk.
Manuj and Mentzer (2008)	Supply Operational Demand Security	Inbound supply of goods Timeliness, quality, lead time The outbound flow of goods variability and volume Threaten human resources, operations integrity, stolen data, freight, breach, vandalism, crime.
Xie et al. (2011)	Endogenous Exogenous	Endogenous. Exogenous.
Lin and Zhou (2011)	Internal External	Internal Risk External risk and risk within the supply chain.
Tang and Musa (2011)	Material flow risk Financial flow risk Information flow risk	Single sourcing, sourcing flexibility, supplier selection /outsourcing. Exchange rate, financial strength, financial handling and practice, Price and cost Intellectual Property, information accuracy, information security.
Thun and Hoenig (2011)	Internal External	Machine breakdown, information problems, Natural Disasters. Demand risk, distribution risk quality problem risk.
Mensah and Merkuryev (2014)	Supply Demand Regulatory Human	Supply interruption risks, supply planning and integration risks, process inefficiency risks. Demand, purchase price risks, inventory and obsolescence risks Regulatory and compliance risks, information privacy and security risks, contract compliance and legal risks. Customer satisfaction and service risks, employee and third-party fraud risks, product introduction and cycle time risks, human resource skills and qualifications risks, project management risks, corporate culture and change

		management risks, information integrity and availability risks.
Micheli et al. (2015)	Operational risk Disruptive risk	Uncertainties in supply and demand costs Humanmade disasters, earthquakes, floods, hurricane terrorist attacks.
Chopra and Sodhi (2014)	Recurrent risk Disruptive risk	Demand fluctuation, supply delay. Fire, terrorism, political instability.
Ho et al. (2015)	Micro Macro	Information, financial operational supply Natural disaster, terrorism.
Liu et al. (2016)	Internal External	Infrastructure, human, materials and financials. Environment, natural catastrophes, terrorism, laws, trade.
Prakash et al. (2017a and b)	Supply risk Process risk Financial risk Demand risk	Shortages, Quality of raw materials Machine breakdown Cash flow problems, high inventory costs Shifting demand across the market
Fan and Stevenson (2018)	Random Discrete	Natural disasters, disruptive technology, Exchange rate fluctuations in market forecasting.
Schiebe and Blackhurst (2018)	Systemic risk	Supply chain disruptions are viewed as systemic risks

Source: Researcher's Compilation (2019). References are presented chronologically.

From Table 2.1 above, it can be deduced that risk can be categorised as external. Here, the sources of risk may come from outside the supply chain. When supply chain risk is internal, the risk comes from within the supply chain (Christopher and Peck, 2004; Wu and Olson, 2008; Xie et al. 2011; Lin and Zhou, 2011; Thun and Hoenig, 2011). Risk can also be classified as either disruptive where the sources are from natural disasters or operational which involves supply and demand by consumers (Tang, 2006a; Wagner and Bode, 2006; Chopra and Sodhi, 2014; Micheli et al. 2015; Fan and Stevenson 2018). Other supply chain risk authors argue that risk can be categorised as either demand or supply (Manuj and Mentzer, 2008; Tang and Tomlin, 2008; Mensah and Merkuryev, 2014; Prakash et al. 2017a and b). Here, supply risk may emanate as a result of shortages of raw materials or breakdown of manufacturing plant and demand risk

is as a result of the shift in demand of consumers. The classification and sources of risk in Table 2.1 above underline disruptions as a form of risk and one of the major sources of risk that particularly thrives when the supply chain is vulnerable (Tang, 2006; Kim et al. 2015).

Therefore, the various categories of risk can be summarised as either controllable or uncontrollable risk. Controllable risk is the probability that a disruptive event may lead to a risk which is within the control of the supply chain such as manufacturing, transportation, physical plants, quality problems, visibility of stock. Controllable risks are often operational and functional by nature and are within the control of the supply chain actors (internal) while uncontrollable risks are beyond the control of the supply chain (external) (Breen, 2008). In this study, supply chain risk is categorised as either a controllable risk or uncontrollable risk. It is pertinent to understand these different categories as the degree of impact on a firm's performance and financial market differs. Specific focus is on uncontrollable risk as this is the underlying premise of the concept of supply chain resilience which states that not all risks can be controlled (Jüttner and Maklan, 2011, Schiebe and Blackhurst, 2018).

2.5. Supply Chain Disruptions

It is also crucial to understand the concept of disruption within the supply chain as it relates to risks, vulnerability and resilience (Jüttner and Maklan, 2011; Brenner, 2015; Hendricks et al. 2017). Supply chain disruptions are events that disrupt the normal flow of goods and services within a supply chain and have been reported to have adverse effects on the financial and operational performance of the firm (Svensson, 2000; Hendricks and Singhal, 2003; Kleindorfer and Saad, 2005; Schimdt and Raman, 2012; Urciuoli et al. 2014; Thekdi and Sarvos, 2016; Hendricks et al. 2019).

Some scholars suggest that disruptive events are unplanned and unanticipated (Craighead et al. 2007; Ellis et al., 2010; Bode and Wagner, 2015). Other authors extend the concept of disruption to include five scenarios: total halt in the flow of products and/ or information reduced flow, where goods are not delivered within the anticipated time frame or in quantity required; close calls, the length of time

the disruption lasted and how widespread throughout the supply chain (propagation or contagion effect) Habermann et al. (2015).

Supply chain disruption does not differ significantly from supply chain risk; rather it is a realized risk, (Melynk et al. 2014; Habermann et al. 2015), the probability that an unfavourable event occurring in the supply chain has been actualized (Bode and Wagner, 2015). For any affected firm, it is a significant anomaly that may occur in comparison to everyday business. Depending on the severity of the phenomenon, it is referred to as a disaster or a crisis. Rossetti et al. (2011) also refer to disruptions as a major breakdown in the production and distribution nodes of a supply chain.

This study, therefore, adopts the position of disruptions to the supply chain as: "*An interference process in the flow of goods where a disruptive event interferes in the normal supply chain process*" (Brenner, 2015, p26).

This definition encompasses the numerous issues such as natural disaster, quality problems with suppliers, delivery outages, supplier defaults, labour strikes, or plant fires; all of which can vary considerably in their causes, characteristics, and effects. Thus, supply chain disruptions are considered realised risks.

2.5.1. Classifications of Disruptions

Disruptions in the supply chain are financially, economically and operationally costly if not addressed at the right time (Hendricks and Singhal, 2005; Schmidt and Raman 2012; Hendricks et al. 2017). There is, therefore, a need to understand why disruptive events impact on supply chain activities to develop proper strategies to mitigate these impacts. However, existing literature tends to examine disruptive events as identical in impacts, although they may have varying causes and effects and may require different strategies in handling these disruptions (DuHadway et al. 2017). It is imperative, therefore, to elucidate the various forms of disruptive activities to find the right strategies.

Supply chain disruptions can emerge from both within and outside the supply chain. However, the nature of the occurrence can be extremely different. For

example, a disruptive event like an earthquake which destroys production capacity differs significantly from the infiltration of drug counterfeits into the supply chain as their attributes, such as incubation period; severity; ability and probability; affect different aspects of the supply chain (Wagner and Neshat, 2012). Similarly, supply chain disruptions may be time-dependent as their impact emanates from time pressure (Kleindorfer and Saad, 2005). This implies that strategies to be adopted in the face of disruption need to consider the length of time the disruption occurred. Table 2.2 below presents examples of the various classifications of disruptions from existing literature.

Table 2.2 Types of supply chain disruptions

Authors	Categories	Natural Disaster	Labour Strike	Terrorism	Consumer Demand	Economic Events	Manufacturing/Supplier	Counterfeiting	Regulations
Wagner and Bode (2006)	Random/Intentional	X	X	X					
Xu (2008)	Intentional/Unintentional	X				X		X	X
Hendricks et al. (2009)	Internal/External	X					X		
Wagner and Neshat (2010)	Natural /Manmade	X							
Hearnshaw and Wilson (2011)	Random/Targeted	X		X	X			X	
Zhao et al. (2011)	Random/Targeted			X				X	
Golgeci and Ponomarov (2013)	Supply/Demand	X		X				X	
Marley et al. (2014)	Normal/Abnormal	X		X		X	X	X	
Liu et al. (2018)	Unintentional /Abnormal	X							
Scholten et al. (2018)	Non routine events	X	X	X					
Lawson et al. (2019)	Operational						X		X

Source: Researcher's Compilation (2019)

Based on the review of the extant literature as shown in Table 2.2 above, it can be deduced that disruptions can be classified as either unintentional which may include natural disasters, economic crises and terrorism or intentional which may include union strikes, manufacturing plant failure, regulations and or/ counterfeiting (Wagner and Bode, 2006; Hearnshaw and Wilsow, 2011). Some of these disruptions may also be categorised as either internal or external disruptions (Hendrick et al. 2009; Scholten et al. 2014). These classifications are akin to that of supply chain risk, where risk can either be controlled (internal) or

uncontrollable (external). The difference is that these events have occurred; hence they have disrupted the flow of goods and services within a supply chain. There was, however, no mention of medicine shortage as a disruption in supply chains.

Further analysis of the literature on supply chain disruptions reveals that disruptions can be categorised based on their sources, action and/or impact. Saghafian and Van Oyen (2017), suggested that understanding supply chain disruptions based on the source of the disruption, the action/intent of the disruption and the impact of the disruption was pertinent in developing strategies that can mitigate them. Figure 2.1 below provides a graphic presentation of how supply chain disruptions are classified. These classifications have been discussed in the sections following this.

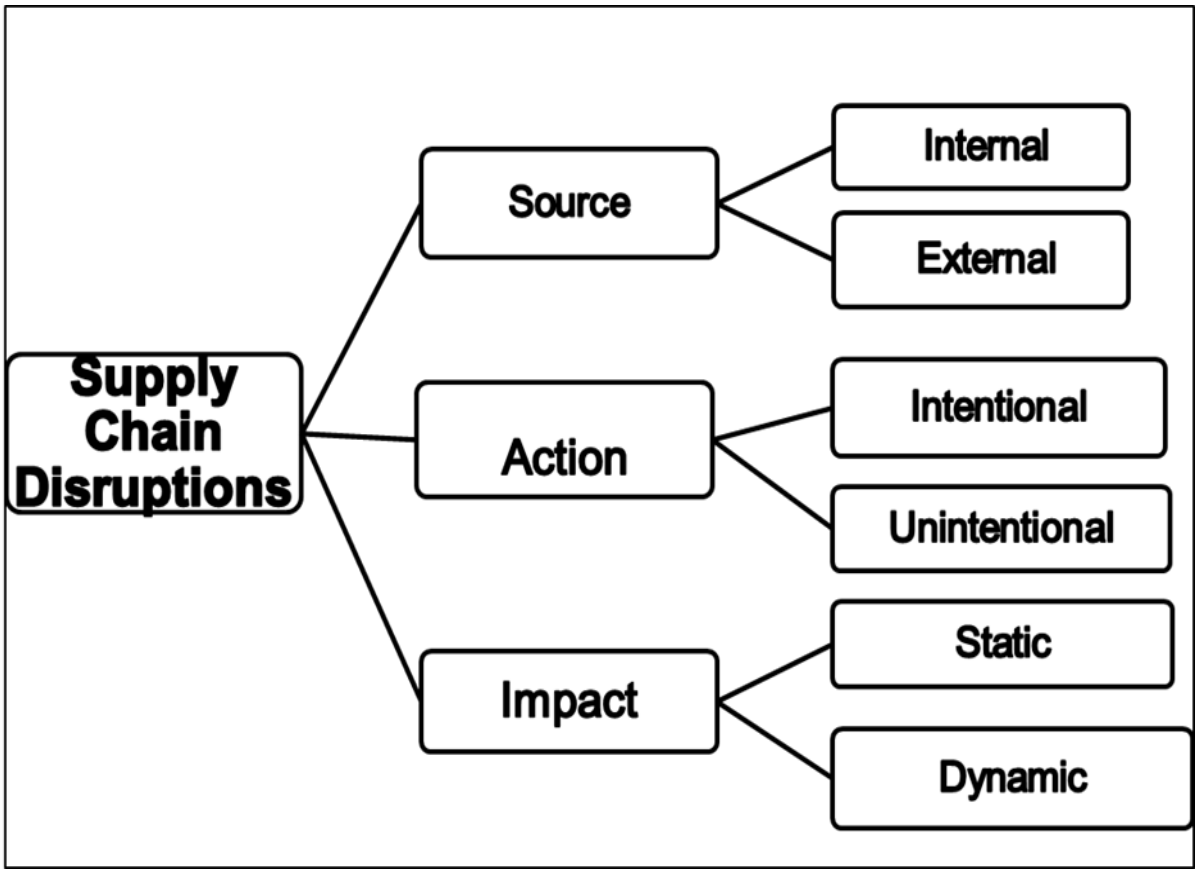

Figure 2.1 Classification of Supply Chain Disruptions
Source: Researcher's Own (2019)

2.5.1.1. Internal versus External Disruptions

Disruptive events have been classed as either internal or external based on their sources (Hendricks et al. 2009; Urciuoli et al. 2014; Gunasekaran et al. 2015; Huq et al. 2016). This implies that a disruptive event may emanate from either within the firm, within the supply chain or outside the firm. External disruptions refer to catastrophic events emanating from outside the supply chain, while the endogenous may be from within the supply chain (DuHadway et al. 2017). Examples of external disruptions include the Japanese Tsunami in 2011 which was large scale and had several implications for businesses (MacKenzie et al. 2012) as well as the 2001 9/11 terrorist attacks which had multiple effects across many firms in various industries.

The effects of these external disruptions have propelled significant amounts of research where various tool have been put forward as strategies in mitigating their impact (Garvey et al. 2015). Internal disruptions include financial misallocations, fraud, and supplier failure. Multiple approaches for managing external disruptions have been suggested, such as supplier audits, volume flexibility (Braunscheidel and Suresh 2009), and contractual controls (Choi et al. 2004).

2.5.1.2. Intentional versus Unintentional Disruptions

Although the exogenous/endogenous dichotomy presented is pertinent in grasping the antecedents and management of disruptions, an adequate understanding of disruptions through the intent lens is also vital (DuHadway et al. 2017). Intentional disruptions are carefully planned disruptions like union strike, lifestyle changes, terrorism and counterfeiting (Stecke and Kumar, 2009). These disruptions may occur endogenously such as; when a supplier deliberately withholds products to create artificial scarcity for abnormal profit or fails to deliver goods as promised or an instance when the supplier decides to use inferior quality in the manufacturing of a product (Wagner and Bode, 2015).

It may also occur exogenously as in the case of counterfeits infiltrating the supply chain, thereby disrupting the flow of products to the end-user (Xu, 2008). The overarching goal of an intentional disruption may not be to cause disruptions, the outcomes, however, lead to disruptive events. The dynamics of proper mitigation strategies are overhauled as a result of intentional disruptions as such current

mitigation strategies may not suffice in curbing the impacts of these disruptions (Xu, 2008).

2.5.1.3. Dynamic versus Static Disruptions

Disruptions are either dynamic or static based on their impact within the supply chain (Saghafian and Van Oyen, 2017). Static disruptions refer to disruptive events that affect a single geographical location or an aspect of a supply chain. Take, for instance, fire at a supplier's plant, or problematic road network to a manufacturing plant which may interfere with production or distribution processes. Here, resilience strategies useful because it is easier to call up alternative suppliers or employ excess inventory (Wagner and Bode, 2011; Jüttner and Maklan, 2011; Tukamuhabwa et al. 2017). Dynamic disruptions, however, refer to disruptions where their source, action and /or impact differ at every point in time. Their modes of occurrences often differ, and their impact to a large extent has a bullwhip effect as with medicine shortages, financial crises and counterfeiting.

Analysing disruptions from an intent perspective is essential as it helps understand the motivation behind a disruption, the vulnerabilities that help these disruptions as well as improving resource allocation in risk-mitigating strategies. Dynamic disruptions have not been explored extensively in supply chain management literature. As such understanding, these disruptions will determine the adequate and necessary response strategy (Azadegan and Jayaram, 2018). The next section examines the concept of supply chain vulnerabilities.

2.6. Supply Chain Vulnerability

The concept of supply chain vulnerability has gained attention amongst researchers in the last decade due to increased interest in supply chain risk management and resilience (Svensson, 2000; Peck, 2005; Wagner and Bode, 2006; Wagner and Neshak, 2012; Chang et al. 2015; Elleuch et al. 2016; Brusset and Teller, 2017; Chowdhury and Quaddus, 2017). Vulnerability is an exogenous variable that defines the risk through the intensity of the impact generated or caused damage (Elleuch et al. 2016). This stems from the notion that resilience and vulnerabilities are interwoven and that not all disruptive activities can be

avoided, controlled, or eliminated (Craighead et al. 2007; Jüttner and Maklan, 2011).

Pettit et al. (2010) confirmed this through an empirical study that found that supply chain resilience increases as capabilities increases and vulnerabilities decrease. Similarly, Christopher and Holweg (2017), using quantitative techniques presented a study where supply chain vulnerability as an avenue to higher costs was challenged while resilience was embraced. Therefore, understanding supply chain vulnerability aids in developing effective capabilities to cope with disruptions. Also, in order to effectively manage supply chain vulnerabilities, it is necessary to have empirically validated methods at hand that support managers in measuring and tracking vulnerabilities, as such; understanding why supply chains are vulnerable to disruptions is of import (Peck, 2005; Wagner and Bode, 2006; Wagner and Neshat, 2012).

However, the concept of supply chain vulnerability is still inconclusive in literature. On the one hand, scholars have interchanged vulnerability with supply chain risk (Lavastre et al. 2012; Heckman et al. 2015). On the other hand, researchers have explored supply chain vulnerabilities conceptually while presenting normative recommendations on how to manage supply chain vulnerability (Peck, 2005). For example, Chen et al. (2013), included vulnerability as a cost of logistics when exploring its impact on a firm, while Wagner et al. (2012), focused on quantifying vulnerability by developing an index which will aid in monitoring and controlling vulnerabilities. This highlights a gap that the conditions that create vulnerabilities in the supply chain remain underexplored.

2.6.1. Drivers of Supply Chain Vulnerability

Most authors define supply chain vulnerability as an elusive concept that is driven by certain traits of a supply chain, such as its design and the environment in which the supply chain exists (Peck, 2005). For instance, Bakshi and Kleindorfer (2009) identify that political turmoil and supply chain characteristics propel supply chain vulnerability. Similarly, Wagner and Neshat (2012), suggest that a firm's size, familiarity with suppliers and location of suppliers propels vulnerability. Fiskel (2015), however, suggests that deliberate threats, limited resources and

sensitivity of a supply chain expose the supply chain disruptions. In Table 2.3, examples of the definitions and drivers of supply chain vulnerability from existing literature are presented.

Table 2.3 Definitions and drivers of supply chain vulnerability

Authors	Definition	Drivers	Sector
Svensson (2000)	Vulnerability is the condition that is caused by time and relationship dependencies in a company's business activities in supply chains. It is the degree of vulnerability may be interpreted as proportional to the degree of time and relationship dependencies, and the negative consequence of these dependencies in a company's business activities towards suppliers and customers.	Strikes Extreme weather conditions Machine breakdown	Car manufacturer automotive industry
Peck (2005)	Risk and vulnerability are interchanged—exposure to serious disturbances.	Outsourcing Network design IT upgrade Leaner supply chains Complex supply chains Global sourcing	Military aerospace/Cross case industries
Wagner and Bode (2006)	Vulnerability is the supply chains susceptibility to the harm as a result of existing organisational or functional practices or conditions.	Supply chain characteristics Single sourcing Global sourcing Firm size Type of disruption	Industrial Service and Trade firms
Craighead et al. (2007)	Unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain.	Supply Chain Design Node Criticality Supply Chain density Supply Chain Complexity	Automobile Industry Pharmaceutical Industry

Bakshi and Kliendorfer (2009)	Possibility of occurrence is determined by the infrastructure already in place for risk mitigation and can be captured through the suppliers' marginal probability of occurrence.	Infrastructures Political Environment The proximity of the fault line	Not specified
Kilbi et al. (2010)	Weakness in the supply chain.	Endogenous Supply Chain Partners Exogenous	Not specified
Pettit et al. (2010)	Supply chain vulnerabilities refer to the fundamental factors that make an enterprise susceptible to disruptions.	Outsourcing Globalisation Technological Innovation Complexity Volatile demand	Multiple Firms
Bharma et al. (2011)	The degree to which a system is susceptible to the effects of climate change which includes exposure to disruptions and external stress.	Non-specified	Not specified
Jüttner and Maklan (2011)	Susceptibility, likelihood and consequences of a disruption. Exposure of the supply chain to risks. A latent condition which becomes evident when a disruption occurs.	Outsourcing Lead time	Manufacturing firms
Wagner and Neshat (2012)	Supply chain characteristics are antecedents of supply chain vulnerability and impact both the probability of a risk.	Supply Chain Structure Supply Chain Density Supply Chain Characteristics Managerial Practices Lean Inventory	Multiple Industries
Vlajic et al. (2013)	Supply Chain Vulnerability is the SC performances as sudden hiccups or surges in the values of key performance indicators (KPIs).	Complexity Cycle Time Productivity levels	Meat industry
Wagner et al. (2014)	No definition.	Tight coupling Supply Chain Characteristics	US offshore oil Industry

Fiskel (2015)	Factors that make a supply chain susceptible to disruptions.	Turbulence Connectivity Sensitivity External Pressures Deliberate Threats Resource limit	Consumer goods firms
Liu et al. (2016)	Supply chain vulnerability is the instability and destructiveness that is caused by supply chain external and internal risks. Supply chain vulnerability is an inherent trait of the supply chain, which is determined by the structure and characteristics of the supply chain itself.	Supply chain structure Supply Characteristics The complexity of the supply chain	Marine Industry
Chowdhury and Quaddus (2017)	No definition. Vulnerability emanates from the quality of supply chain design.	Node Criticality Node Density Complexity	Resilience Scale Developments
Liu et al. (2018)	It is the measure of the impact of the nodes and links to the network robustness.	Node Dependence Node Criticality	Marine Industry
Ruel et al. (2019)	An exposure to serious disturbance, arising from risks within the supply chain as well as risks external to the supply chain	Supply Characteristics Supply Chain Configurations Supply Chain complexity	Recycling

Source: Researcher's Compilation, 2019

Table 2.3 above presents various definitions of supply chain vulnerability from literature. Some authors defined supply chain vulnerability as an exposure, weakness or susceptibility to serious disturbance (Wagner and Bode, 2006; Kilbi et al. 2010; Pettit et al. 2010; Bharma et al. 2011; Fiskel, 2015; Ruel et al. 2019). Other authors interchanged supply chain vulnerability and supply chain risk (Peck, 2005; Liu et al. 2016); and/ or supply chain disruptions (Craighead et al. 2007) and some studies did not have a working definition of supply chain vulnerability but embarked on a study of identifying vulnerabilities (Wagner et al. 2014; Chowdhury and Quaddus, 2017).

It is pertinent that the concept of supply chain vulnerability be defined in this study as it forms a boundary within which this study is focused. Drawing on various definitions in the literature, this study considered supply chain vulnerability within the context of the pharmaceutical supply chain to include exposure to, or susceptibility to, varying degrees of disruptions such as damage and adverse impacts which emanate from disruptions, such as natural hazards, strikes, global warming, thefts and counterfeiting.

Thus, the concept of supply chain vulnerability hinges on the notion that not all supply chain risks can be controlled. Uncontrollable supply chain risk, therefore, makes the supply chain vulnerable to the impact of disruption and this is the premise on which supply chain resilience is built (Jüttner and Maklan, 2011; Christopher and Holweg, 2011; Xie et al. 2011; Cox et al. 2011; Hohenstein et al. 2015; Elleuch et al. 2016; Ivanov et al. 2016).

However, the underlying assumptions that supply chain vulnerability is as a result of a supply chain's lack of resilience to varying forms of threats remain inconclusive in the empirical literature (Jüttner and Maklan, 2011; Xiao et al. 2012). For instance, while Sheffi and Rice (2005) argued that reducing vulnerability implies reducing the likelihood of disruption and thereby enhancing resilience, Jüttner and Maklan (2011) claimed that a highly vulnerable supply chain may either have a high or low resilience based on their ability to plan and recover from a disruption. The contention here is that there are some strategies which may reduce supply chain vulnerability without necessarily improving the resilience of the supply chain, as seen in risk strategies adopted to mitigate geographical risk thereby reducing vulnerability (Pettit et al. 2013).

Also, from Table 2.3 above, it can be deduced that drivers of supply chain vulnerabilities vary and include but are not limited to: supply chain characteristics (Wagner and Bode, 2006; Wagner and Neshat, 2012; Wagner et al. 2014; Liu et al. 2016; Ruel et al. 2019); supply chain complexity (Peck, 2005; Craighead et al. 2007; Vlajic et al. 2013; Chowdhury and Quaddus, 2017; Ruel et al. 2019); supply chain density (Craighead et al. 2007; Wagner et al. 2014; Chowdhury and Quaddus, 2017; Liu et al. 2018); global sourcing (Peck, 2005; Pettit et al. 2010); outsourcing (Wagner and Bode, 2006; Jüttner and Maklan, 2011) and managerial practices (Wagner and Neshat, 2012). Although the studies present empirical

evidence, these drivers are not absolute within supply chain management literature.

The review of literature from Table 2.3, also shows that most of the studies on supply vulnerability drivers focused on the automobile industry (Svensson, 2000; Peck, 2005; Craighead et al. 2007); Meat industry (Vlajic et al. 2013); Recycling industry (Ruel et al. 2019) and the marine industry (Wagner et al. 2014; Lie et al. 2016; Liu et al. 2018). There was, however, only one study carried out with a specific focus on the pharmaceutical industry, which was by Craighead et al. (2007). Thus, this indicates a gap in the literature on PSC vulnerability drivers while taking into account its peculiarities.

Figure 2.2 illustrates the relationships between the drivers of supply chain vulnerability identified in Table 2.3. The rationale for the arrows signifying these relationships is discussed in detail in the sections below. For instance, ‘managerial practices’ although identified as a vulnerability is linked to all the other drivers. Hence, most of the vulnerability drivers stem from the decision making processes of the managers within the supply chain.

The arrow linking global sourcing and supply chain complexity shows that global sourcing increases supply chain complexity. The nature of the supply chain characteristics, which may be either consumer dependent or supplier dependent increases the complexities of the supply chain, and this may stem from managerial practices.

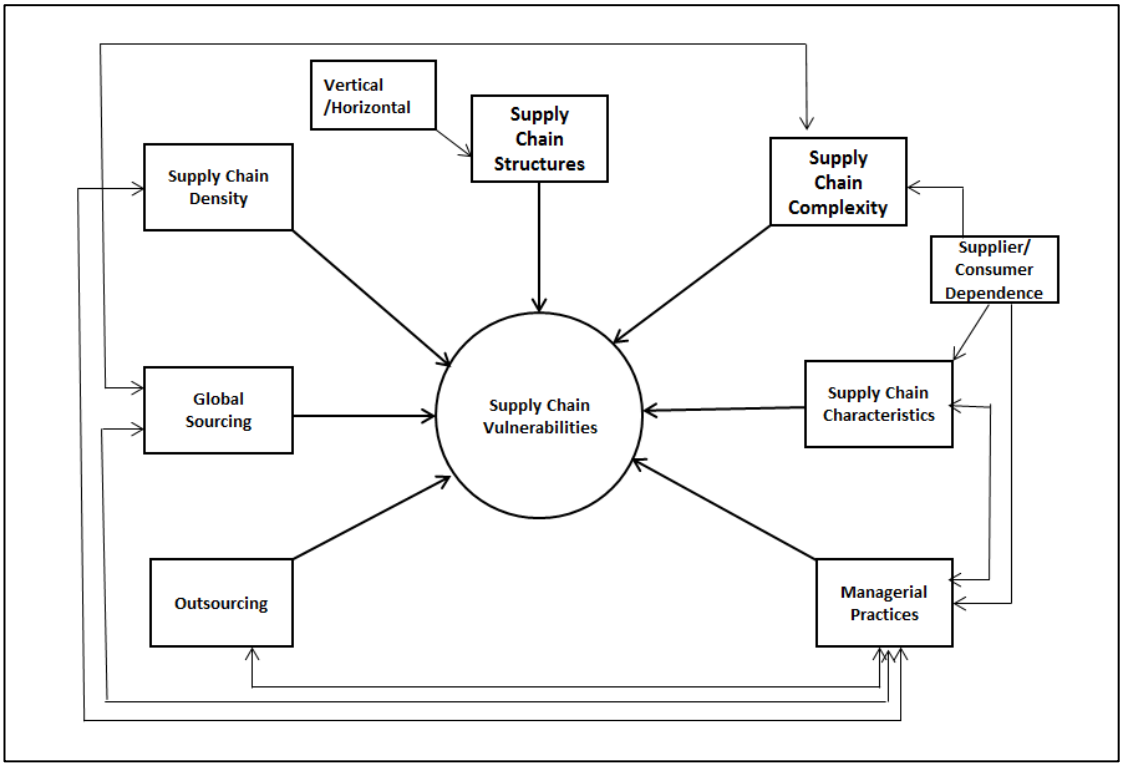

Figure 2.2 Drivers of Supply Chain Vulnerability
Source: Researcher's Own (2019).

2.6.1.1. Managerial Practices

Various management practices have been suggested to weaken the supply chain, thereby making it vulnerable to various risks (Blackhurst et al. 2011; Walters, 2011; Zhao et al. 2011). For instance, in an attempt to remain competitive, cost-effective and profitable, firms have had to implement 'Just In time' (JIT), and other lean principles into their supply chain as JIT seeks to employ adequate resources to reduce waste and increase efficiency (Stecke and Kumar, 2009; Prajogo et al. 2016).

However, researchers argue that lean management principles have no buffer for unforeseen circumstances, as JIT practices and lean principles adopt a pull approach which relies on consumers demand (Wagner and Bode, 2009; Jüttner and Maklan, 2011). Also, when disruptions occur, the supply chain may not be compensated as a result of low inventories which are grossly inefficient in times of turmoil; this exposes the supply chain to various forms of risks, hence weakening supply chain nodes (Thun and Hoenig, 2011). The arrow connecting managerial practices and other vulnerability drivers like outsourcing, global sourcing and supplier/consumer dependence is presented in Figure 2.2 above.

Managerial decisions also propel supply chain complexities, supply chain structures, supply chain characteristics and global sourcing. Strategic decisions with regards to investments, costs incurred, supplier selection and firm orientation, are strategic decisions of the firms and all decisions made by the management team and have an impact on the supply chain. As of consequence, these may inadvertently weaken the supply chain (Christopher and Holweg, 2017).

2.6.1.2. Outsourcing

Modern strategies like outsourcing is a factor that propels a firm's efficiency through improved production, sourcing efficiency and reduced labour costs (Chase et al. 2004). Outsourcing also permits firms to focus on core competencies which speed up innovation processes (Graf and Mudambi, 2005). As such, numerous pharmaceutical firms have adopted these strategies to capture a share of the global market by outsourcing their business activities to specialized suppliers known as third-party logistics (3PLs) (Aktas et al. 2011; Singh et al. 2016).

However, these managerial decisions expose the supply chain to disruptive impacts, as outsourcing increases the number of geographical regions where a product may have to pass. Outsourcing increases the susceptibility of the product to climatic, political and human disruptions (Stecke and Kumar, 2009). Also, the number of ownership surges making it challenging to track a product effectively. The expansion of the supply chain to accommodate different cultures, time zones, locations further complicates the supply chain, thus making it weak to withstand disruptive impacts (Stecke and Kumar, 2009). Managerial practices are, therefore linked to outsourcing and supply chain complexity in Figure 2.2 as drivers for supply chain vulnerability.

2.6.1.3. Supply Chain Characteristics

Existing studies suggest the existence of a link between supply chain characteristics and vulnerability. While a strand of the literature proposes incremental benefits, others posit that supply chain characteristics may propel

vulnerabilities within the network. For instance, Wagner and Bode (2006) highlight that supplier dependence, defined as the degree to which a firm depends on its suppliers for goods with very few alternatives makes the supply chain susceptible to disruptions (Hallikas et al. 2005; Blackhurst et al. 2018). It sometimes leads to a loss of power, less advantageous contracts and the risking continuous replenishment.

Take, for example, a flood (like the Tsunami in Japan in 2011). In this event, a manufacturing firm (Cisco) had limited suppliers based in Japan. The customer firm was exposed to this disruption, as it had very limited choices which made them susceptible to supply risk, as the firm will experience substantial difficulty in substituting its suppliers to meet customers demand. Akin to supplier dependence is customer dependence which is more of a downstream relationship. Since the focal firm depends on a set of customers to purchase its goods, in the face of disruption, these customers may be unable to purchase its goods, or consumer requirements change. The firm may be forced to change its production capacity, thereby exposing the supply chain to various risks (Wagner and Bode, 2006). Figure 2.2 depicts the drivers for supply chain vulnerability.

2.6.1.4. Supply Chain Complexities

Supply chain complexity emanates from forward and backward movements of nodes within the system (Criaghead et al. 2007; Tomlin and Tong, 2008). According to the literature, supply chain complexity is contingent on several drivers which include the number of supplier relationship that must be managed (Choi and Krause, 2006); the degree of differentiation among suppliers (Bozarth et al. 2009), as well as the delivery, lead time and reliability of suppliers.

The effect of supply chain complexity, however, remains a topic of contention within operations management literature. One strand of researchers submitted that it propels performance as well as increases effective buyer-supplier relationship (Gimenez et al. 2012). The proposition here is that the capacity of the firm to include additional suppliers to the supply chain may act as a buffer in the event of a disruption, hence providing a competitive advantage. Similarly, by

expanding the supply chain, firms can reach new markets, the source for cheaper labour, raw materials and access to a variety of products (Isik, 2009).

Complexity within the supply chain has attracted more attention in the last decade as a result of its adverse effects on operational performance (Bozarth et al. 2009), complicating decision making (Manuj and Sahin, 2011), and swift disruptions (Chopra and Sodhi, 2014; Craighead et al. 2007; Narasimhan and Talluri, 2009). Also, complexity in the supply chain may heighten the severity of a disruption (Craighead et al. 2007) and increase risks (Fridgen et al. 2015). Complexity stems from longer supply and multiple layered chains which reduces the transparency of the supply chain and increase vulnerability, plant performance, production costs, and supplier innovation (Choi and Krause 2006; Bozarth et al. 2009; Wagner and Neshat, 2010).

According to literature, there are two forms of complexity: static and dynamic. Static complexity refers to the number of elements defining a system, and dynamic complexity refers to the interactions between elements of a system which increases as the system grows and as such produces variant behaviours (Bode and Wagner, 2015; Nikookar and Nagalingam, 2017). Static complexity is particularly true for various supply chains (Manuj and Sahin, 2011). In this study of supply chains, complexity is examined from a complex adaptive system perspective where supply chains can learn, respond and adapt to changes in their environment (Choi et al. 2001; Pathak et al. 2007; Day, 2014; Bode and Wagner, 2015). The rationale for this will is explained in Chapter Three.

Bode and Wagner (2015) categorized supply chain complexities based on structures and argued that the structures of supply chains complexity are what determine the frequency and type of disruptions that affect a supply chain. In their study of the upstream side of 500 manufacturing firms, they found that vertical supply chain complexities increased the number of disruptive events. Also, Eckstein et al. (2014) explored the impact of agility on the financial and operational performance of manufacturing firms in Germany and found product complexity mitigates the ability of these supply chains to adapt and withstand disruptive events. Other studies such as Azaron et al. (2008) and Falasca et al. (2008) highlighted supply chain design factors which are directed at reducing vulnerabilities and enhancing resilience. They contended that complex supply

chains are vulnerable to disruptions, and as such, the need to reduce complexity was imminent. In this regard, this study posits that the complexities of the pharmaceutical supply chain are a determining factor of the frequency and type of disruptive events.

2.6.1.5. Global Sourcing

Studies around the global sourcing and supply chain have presented mixed evidence. One strand of researchers submitted that global sourcing is necessary if a firm is to meet the demands of its customers. As the incentives for sourcing are to achieve technological innovation, shorten product life cycle, reduce product prices and total cost of ownership, reduce the number of suppliers and establish the strategic relationship (Wagner and Neshat, 2012). The significant benefits for sourcing in different countries are a reduction in material, labour, component service and capital investment cost. To a certain extent, some studies indicate that supply chains can improve service reliability and lead time (Jüttner and Maklan, 2011).

Global sourcing has also been put forward as a propellant of supply chain vulnerability (Wagner and Bode, 2006; Wagner et al. 2014). This stems from the point at which firms decide to source for materials globally. The location of the suppliers, the mode of transportation for these materials and the characteristic of the product to be purchased are taken into consideration to achieve the benefits accrued to global sourcing. The downside of this strategy, however, includes more reduced visibility; longer lead times; exchange rate fluctuations; increased taxes as well as increased uncertainty in the event of a disturbance which contributes to the complexity of the supply chain and exposes the firm to various internal and external risks. (Wagner and Bode, 2006; Jüttner and Maklan, 2011). These vulnerabilities must be counterbalanced with managerial controls to mitigate the impact of disruptions. This is presented in Figure 2.2 as drivers for supply chain vulnerability.

2.6.1.6. Supply Chain Structures

Supply chain structures have also been identified as a weakness within the supply chain as they expose the system to disruptive impacts (Craighead et al. 2007; Bode et al. 2016; Scheibe and Blackhurst, 2018). The structural dimensions of a supply chain can either be horizontal or vertical (Min and Zhou,

2002). The horizontal structure of the supply chain refers to the number of tiers across the supply chain and the vertical structure is the number of suppliers and customers represented within each tier (Wagner and Bode, 2006). The supply chain may be lengthy, with numerous tiers, or short, with few tiers in the supply chain. The longer the supply chain, the more complicated it becomes and distorts visibility and control (Wagner and Bode, 2006; Bode and MacDonald, 2016).

2.6.1.7. Supply Chain Density

The total number of nodes within a supply chain relative to its geographical spacing is often referred to as supply chain density (Craighead et al. 2007; Falasca et al. 2008). It refers to the interconnectedness of the actors of a supply chain within its network (Vurro et al. 2009). Hence, when there is a high number of nodes clustered together, that supply chain is categorized as a high-density supply chain and vice versa (Zhao et al. 2011).

Supply chain density as a driver of vulnerability has been a debatable issue. For instance, Craighead et al. (2007), in their study, found supply chain density as a significant propellant of supply chain vulnerability. The contention here is that, if a firm's suppliers are tightly coupled together and densely populated, in the event of a disruption, the firm may not be flexible enough to withstand the impact of the disruption (Falasca et al. 2008). For example, if firm A had all its suppliers located in Japan, during the tremendous east earthquake of 2015, the firm would have felt the impact of the disruption as all operational activities would have come to a halt. Therefore, the notion that supply chain density and the severity of a supply chain disruption are positively related makes logical sense.

For a supply chain that has a low-density level, the probability of a disruptive event affecting many entities within such a supply chain (i.e., more severe) is likely to be lower than in the case of a dense supply chain adversely affected by the same disruptive event. Vurro et al. (2009) on the other hand argued that centrality of supply chain nodes enhances a firm control over its supply chain network as well as its efficiency, which stems from the ease in the flow of communication and material within the supply chain (Neville and Menguc, 2006).

In summary, the supply chain vulnerabilities literature identifies some debate on what elements contribute to exposing supply chains to the impact of disruptions.

There was only one study that focused on pharmaceutical supply chain vulnerability drivers, which was by Craighead et al. (2007). This indicates a gap in the literature on the vulnerability drivers of the pharmaceutical supply chain and takes into consideration its peculiarities. The review also highlights that understanding vulnerability is essential in developing resilience strategies that are cost-efficient and best suitable to the supply chain in context. As such, the next sections seek to explore the various resilience strategies that may reduce vulnerabilities in the pharmaceutical supply chain.

2.7. Supply Chain Resilience

One approach to dealing with the impact of disruptive events in a supply chain is by adopting resilience strategies (Melynk et al. 2014). Resilience in the Supply Chain Risk Management (SCRM) is an emerging idea which draws upon various disciplines such as Engineering, Ecological Sciences, and Psychology. However, an agreed definition of the concept of what resilience entails remains inconclusive as a result of the varied opinion (Spiegler et al. 2012; Mensah and Merkuryev, 2014). Table 2.4 presents a summary of various definitions of supply chain resilience.

Table 2.4 Definitions of supply chain resilience

Authors	Definition	Elements
Rice and Caniato (2003)	It is a firm's recovery to an original state after a disruption. A firm can react to unexpected disruption and restore normal operations.	Recovery Disruption Restoration
Christopher and Peck (2004)	It is defined as the ability of a system to return to its original state or a more desirable state after being disturbed.	Continuity Adaptability Flexibility Collaboration Disruptions
Sheffi and Rice (2005)	Resilience is defined as the ability of a firm to successfully confront unforeseen events, to a much better state to gain competitive advantage.	Redundancy Flexibility Unforeseen events Competitive Advantage
Peck (2005)	The ability of a system to return to its original or desired state after being disturbed.	Recovery disruption
Zsindsin et al. (2005)	The ability of the system to establish a steady-state and to correct the negative	Sustainability Corrections disruptions

	consequences on the systems after a disruption occurs.	
Fiskel (2006)	A firm's capacity to grow, adapt and survive in the face of turbulent changes.	Adaptability Survival Growth Disruptions
Gaonkar and Viswanadham (2007)	Ability to maintain, resume and restore operations after a disruption.	Response Recovery
Falacia et al. (2008)	The ability of a supply chain system to reduce the probabilities of disruption reduce the consequences of that disruption reduce the time to recover typical performance.	Capability Resistance Recovery
Zhu and Li (2008)	Allowing the supply chain to support itself during disruption and recover quickly after a disruption.	Response Recovery Timely Information Sharing Flexibility
Ponomarov and Holcomb (2009)	The adaptive capability of the supply chain to prepare for unexpected events.	Adaptability Preparedness Recovery Continuity
Barroso et al. (2010)	Ability to react to negative effects caused by disturbances that occur.	Reaction disturbances
Blackhurst et al. (2011)	Firms' ability to recover quickly from disruptive events in the supply chain.	Recovery Timely disruptions
Jüttner and Maklan (2011)	Supply chains ability to cope with the consequences of unavoidable risk events in order to return to its original operations or move to a new more desirable state.	Capability Recovery Growth Flexibility Velocity Collaboration
Carvalho et al. (2012)	The system's ability to return to its original state or to a new more desirable after experiencing a disturbance and avoiding the occurrence of failure nodes, prevent movement to undesirable states.	Diversity Adaptability Cohesion
Ponis and Kronis (2012)	Ability to proactively plan and design supply chain.	Plan Anticipation Robustness Design Response
Pettit et al. (2013)	The ability to survive, adapt and grow in the face of turbulent changes.	Growth Survival Adaptability
Weiland and Wallenburg (2013)	Resilience is both proactive and capacity recovery after experiencing a	Proactive Reactive

	crisis. The ability of a supply chain to cope with change.	Capability Recovery Adaptability
Wu et al. (2013)	Resilience is the ability to respond to and recover from stock out disruption.	Response Recovery
Brandon-Jones et al. (2014)	The ability of a supply chain to return to typical operating performance within an acceptable period after being disturbed.	Capability Recovery Timely
Day (2014)	Capacity to anticipate risk, limit its impact and bounce back rapidly through survival adaptability, evolution and growth in the face of a turbulent state.	Prepare Recover Respond Adaptability Evolve Grow
Scholten et al. (2014)	Adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structures and functions.	Prepare Respond Continuity Recovery Adaptability Collaboration Agility
Urcioli et al. (2014)	The capability of the supply chain to bounce back to a stable condition after a disruption despite the occurrence.	Capability Recovery Adaptability
Fiskel (2015)	The capacity for an enterprise or sets of business entities to survive, adapt and grow in the face of turbulent change.	Capacity Survival Adaptability Growth
Holstein et al. (2015)	Supply chain resilience is the supply chain's ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation or grow by moving to a new, more desirable state to increase customer service, market share and financial performance.	Capability Ability Preparation Response Recovery Survival Market share Financial Performance
Tukamuhabwa et al. (2015)	The adaptive capability of a supply chain to prepare for and respond to disruptions to make a timely and cost-effective recovery and therefore, progress to a post disruption state of operations ideally better than before the disruption.	Adaptability Capability Prepare Respond Timely Cost-effective Growth
Elleuch et al. (2016)	Resilience is defined as the ability of a system to return to its original state or a more favourable condition, after being disturbed.	Recovery Ability
Kamalahmadi and Parast (2016)	The adaptive capability of a supply chain to reduce the probability of facing	Adaptability Capability

	sudden disturbances, resist the spread of disturbances by maintaining control over structures and functions, and recover and respond by immediate and effective reactive plans to transcend the disturbance and restore the supply chain to a robust state of operations.	Resistance Recovery Restoration Robustness
Li et al. (2017)	Supply chain resilience refers to a supply chains capability to cope with changes which are formed through being prepared to endure future changes being alerted to changes and being agile to respond to the changes.	Alertness Preparedness Agility Forecasting
Brusset and Teller (2017)	Operational Capability that enables a disruptive or broken supply chain to reconstruct itself and be more reliable than before.	Capability Recovery Reconstruction
Mohan and Bakshi (2017)	A measure of a firm's ability to recover quickly from disruption.	Ability Recovery Time
Ganguly et al. (2018)	The ability of a supply chain to recover to the 'pre-disruption' or a better state after suffering through a disruption process.	Ability Recovery
Scholten et al. (2019)	The adaptive capability that reduces the effect of non-routine events by identifying strategies that help the supply chain to react to as well as recover from such incidents.	Adaptability Reactive Recovery

Source: Researcher's Compilation (2019)

The definitions reveal that some authors view supply chain resilience at the firm level, where resilience strategies are developed and adapted at firm level rather than at the supply chain level (e.g. Blackhurst et al. 2011). Other authors adopt a systemic/ holistic approach to supply chain resilience which encompasses the entirety of the supply chain (e.g. Scholten et al. 2019). The argument for a systemic approach to supply chain resilience is based on the notion that a single firm within a supply chain cannot successfully develop resilience strategies for an entire supply chain (Weiland and Wallenburg, 2013).

The various definitions in Table 2.4 show that antecedents of supply chain resilience entail responsive and/or recovery strategies. However, the supply chain resilience elements differ among the various proponents of supply chain

resilience, and none captured all the essential elements of supply chain resilience. For instance, some studies focused on only the recovery elements of supply chain resilience which is the capacity of the supply chain to recover, return to and or respond to normal operations after a disruption has occurred (Christopher and Peck, 2004; Peck, 2005; Uricioli et al. 2014; Brusset and Teller, 2017; Mohan and Baski, 2017; Ganguly et al. 2018). The shortfall of focusing on only the recovery antecedents of supply chain resilience is that recovery strategies help the supply chain to return to normal operations but in most cases may be costly (Wieland and Wallenburg, 2013; Tukamuhabwa et al. 2015). Also, the recovery strategies may not be timely and as such may be unable to contain the impact of the disruption which may lead adverse effects as in the case of pharmaceutical supply chains which may lead to the death of the patient.

Other studies identified supply chain resilience to include both resistance and recovery capabilities. This entails the ability of the supply chain to prepare for, endure and recover from a disruption (Falacia et al. 2008; Ponomarov and Holcomb, 2009; Weiland and Wallenburg, 2013; Day, 2014; Scholten et al. 2014; Holstein et al. 2015; Tukamuhabwa et al. 2015; Kamalahmadi and Parast, 2016; Li et al. 2017). The benefits of having both resistance and recovery elements in supply chain resilience are that planning can aid in curtailing the impact of disruption as well as continue operations as usual. The downside to this is that some resistance strategies are costly and as such, may not provide the supply chain with the competitive advantage.

The above definitions and analysis of Table 2.4 depict that most definitions fail to capture all the essential elements of supply chain resilience which include preparedness, adaptability, recovery (to its original state or a much better state), timely recovery and cost-effectiveness in the event of a disruption. As such, this study adopts the definition proposed by Tukamuhabwa et al. (2015), namely:

"*The adaptive capability of a supply chain to prepare for and/or respond to disruptions, to make a timely and cost-effective recovery, and therefore progress to a post-disruption state of operations – ideally, a better state than before the disruption*" (p 5599).

This is because this definition encompasses the essential ingredients of what resilience in a supply chain entails. This section consolidates the various

definitions of supply chain resilience in an attempt at gaining a more in-depth understanding. The next section analyses and categorises the literature on supply chain resilience in order to highlight the research gaps that form the basis of the research questions addressed in this thesis.

2.7.1. Empirical Literature on Supply Chain Resilience

Existing literature on supply chain resilience focuses on outlining the strategies for enhancing resilience in the supply chain. For instance, Jüttner and Maklan (2011) identified flexibility and collaboration as necessary ingredients for supply chain resilience; Wieland and Wallenburg (2013) focused on relational capabilities in supply chain resilience; Kristiano et al. (2014) on supply chain and redundancy; Ambulkar et al. (2015) on scale development; Yang and Xu (2015) on collaboration with the government to acquire government facilitation during disasters; Ivanov et al. (2017) on the interface of resilience and sustainability; Scholten et al. (2019) on building routine for non-routine events; Jain et al. (2017) on model development; Parast et al. (2019) on disruptions and innovation.

Recent theoretical contributions include Day (2014), who focused on a CAS framework that linked supply chain resilience to disaster relief. Pereira et al. (2014), on examined the link between procurement and supply chain resilience. Also, Stevenson and Busby (2015) examined the counterfeiting threat to supply chains and how supply chains can build resilience against product counterfeiting. Meanwhile, Kim et al. (2015a) suggested how different types of structural relationships affect supply chain disruptions, arguing that supply chains should be analysed from a systemic perspective. Most of these studies identified the need for more empirical work on supply chain resilience.

The current empirical literature on supply chain resilience strategies has also used various terms in describing resilience strategies which include: antecedents (Brandon-Jones et al. 2014; Scholten et al. 2014; Gölgeci and Ponomarov, 2014; Scholten and Schilder, 2015), enablers (Blackhurst et al. 2011), practices (Zsidisin and Wagner, 2010; Azevedo et al. 2013), capabilities (Pettit et al. 2010; Jüttner and Maklan, 2011), competencies (Wieland and Wallenburg, 2013) and strategies (Urciuoli et al. 2014). These words all refer to ways in which resilience

can be built into a supply chain. In the systematic review of literature by Hohenstein et al. (2015), all the above terms refer to supply chain resilience strategies which include flexibility improvement, creation of redundancy, building collaboration as well as improving agility.

Furthermore, Melynk et al. (2014) argued that supply chain resilience relates to balancing both recovery and resistance strategies. This implies that incorporating resilience strategies in a supply chain should have the capacity to help the supply chain recover from disruption and/ or resist a disruption (Sáenz and Revilla, 2014). Empirical studies, however, fail to distinguish between recovery strategies and resistance and as such, it is necessary to understand the dimensions of these elements (Christopher and Holweg, 2011; Chowdhury and Quaddas, 2017).

2.7.1.1. Recovery and Resistance

Recovery as an arm of resilience strategies implies that the supply chain adjusts *ex-post* to changes in the environment. Supply chains adopting this strategy are referred to as agile supply chains (Braunscheidel and Suresh, 2009). Recovery elements of supply chain resilience, thus entail the ability of the supply chain to respond and recover from disruptive events (Ponomarov and Holcomb, 2009; Chowdhury and Quaddas, 2017). The response entails mitigating the impact of disruption within the shortest possible time with the lightest impact (Pettit et al. 2013; Pettit et al. 2019). The ability of a supply chain to respond to criticalities in a timely manner is a defining measure of resilience within a supply chain and a distinctive source of competitive advantage (Wieland and Wallenburg, 2013). Recovery is also a crucial and distinctive measure of resilience (Jüttner and Maklan, 2011). However, the cost of recovery is an important parameter to consider when measuring a supply chain's ability to recover from a disruptive event (Tukamuhabwa et al. 2015).

The resistance elements of supply chain resilience are the capability to recognize anticipate and defend against the changing shape of risks before adverse consequences occur (Pettit et al. 2010; Jüttner and Maklan, 2011; Sa et al. 2019). These resistance capabilities may include flexibility, redundancy, adaptability, collaboration and visibility (Pettit et al. 2013; Pal et al. 2014; Scholten et al. 2019).

The existing literature of resilience and its resistance capabilities such as proactive buying, buy-supplier relational quality, readiness to mitigate disruptions in supply chains-are however a handful (Sullivan-Taylor and Branicki, 2011; Grotsch et al. 2013). The outcome of resistance strategies maybe either containment or avoidance of the impact of a disruption.

In contrast to a reactive strategy, resistance strategy implies that the supply chain implements *ex-ante* measures to cope with turmoil, with no adjustment needed during times of change. Supply chains adopting this strategy are robust supply chains (Klibi et al*.* 2010; Vlajic et al*.* 2013). Robustness corresponds primarily with being physically sturdy (Christopher and Peck, 2004) and being able to retain the same stable situation as before changes occurred (Asbjørnslett, 2009). Incorporating redundancy, e.g. in reserves or back-up options, is a commonly used measure to increase supply chain robustness that can reduce vulnerability to change (Azadegan et al. 2013).

Melynk et al. (2014), argue that supply chain resilience moves a firm from simple risk management strategies to resilience growth. In view of this, the outcome of resilience strategies should occur either as a recovery capacity or a resistance capacity (Melynk et al. 2015). The recovery elements include the ability to stabilize the supply chain after a disruption as well as return to normal operations. It is possible to explore these outcomes in regards to medicine shortages as a disruption that will require the supply chain to stabilize. The resistance capacity in the supply chain's ability to avoid a disruptive event as well as contain the impact of its spread throughout the supply chain as in the case of counterfeits.

Figure 2.3. below presents a framework for supply chain resilience based on the author's interpretation of the relationships between antecedents and outcomes of supply chain resilience following an analysis of the existing literature. The figure shows that antecedents of supply chain resilience include flexibility, redundancy, information sharing, trust, velocity and visibility, which is further categorised into supply chain reengineering, collaboration and agility. The outcome of adopting these strategies provide the supply chain with the capacity to recover from or resist disruption by containment or avoidance. There were no empirical studies to identify when supply chain resilience strategies were a recovery strategy or resistant strategy.

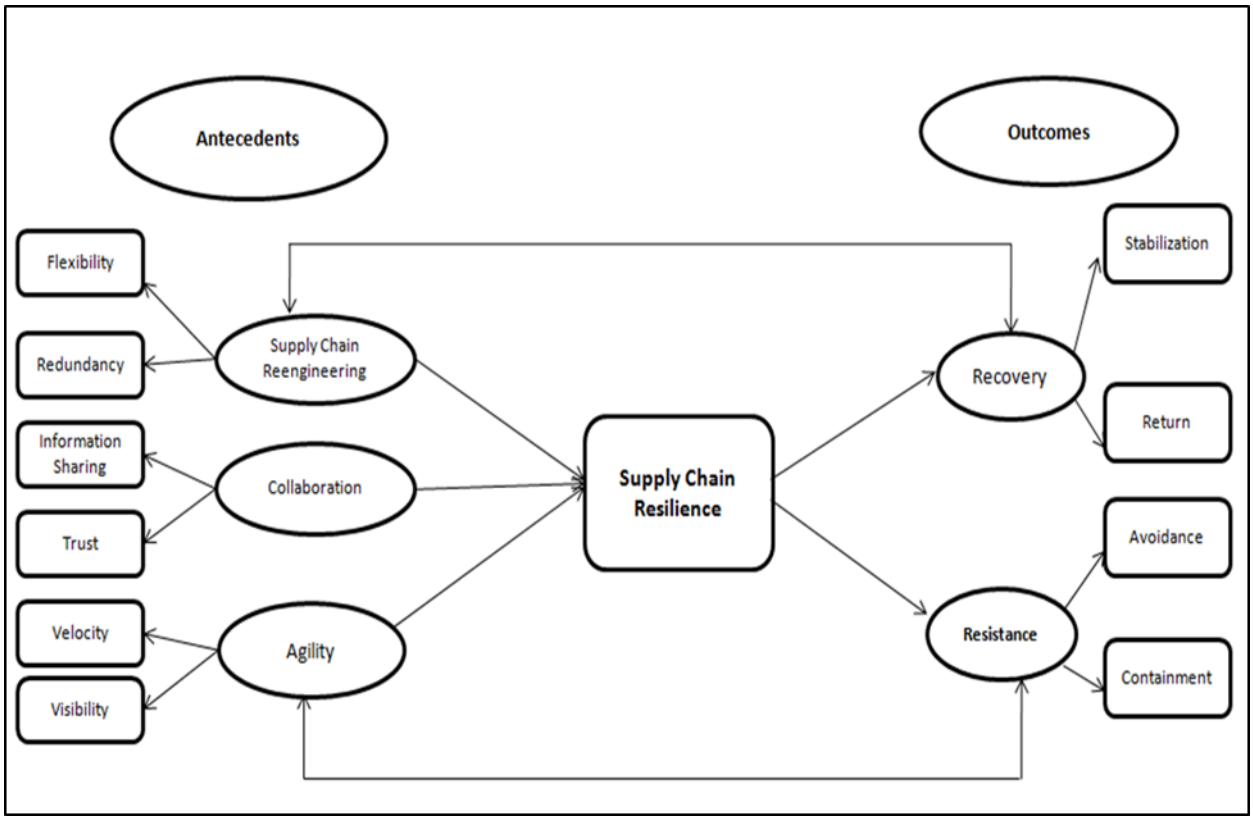

Figure 2. 3 Framework for Supply Chain Resilience
Source: Researcher's Own (2019)

The next section (2.7.2) discusses the recovery and resistance elements of supply chain resilience as antecedents and outcomes of resilience strategies.

2.7.2. Antecedents for Supply Chain Resilience

2.7.2.1. Supply Chain Reengineering

Generally, supply chains are designed to satisfy the customer as well as enhance cost efficiency. Inherent risks in supply chains have increased the need to incorporate SCRM strategies (Wilding, 2013), as such the need to redesign the traditional supply chains to incorporate resiliency strategies is paramount (Ponomarov and Holcomb, 2009; Scholten et al. 2014). Supply chain reengineering entails that the supply chain incorporates mapping the supply network to understand who owns what, as well as what key measures are currently in place (Scholten et al. 2014). A review of the literature on supply chain

resilience provides two broad categories of supply chain reengineering, namely-flexibility and redundancy, which will be discussed below.

2.7.2.1.1. Flexibility

This study also focuses on flexibility as a crucial element of supply chain resilience. Flexibility is defined as a firm's capacity to adjust to the evolving desires of stakeholders as well their environment with minimum efforts and reduced time (Erol et al. 2010; Blome et al. 2015). Most times, this refers specifically to the speed with which a supply chain can adjust production processes, capacities, stock turnover, ramp-up time, and cycle time. Tiwari et al. (2015) defined flexibility as the ability of the supply chain to move products from the supplier to the end-user under all uncertain or risky environments, with the least variation in the difference between the demand and supply at every node, and without much penalty or impact on the SC resources and the costs incurred. An uncertain environment, whether internal or external to the organisation, has been repeatedly emphasised as a critical driver in flexibility definitions (Fayezi et al. 2015).

Although flexibility is often interchanged with agility, the former entails making internal adjustments to withstand changes, while the latter involves external mechanisms on how the firm copes with the internal changes (Chiang et al. 2012; Fayezi et al. 2015). For instance, by postponing demand of products to a future period during a time of crises, the supply chain is prompted to adapt to changes while using the available resources (Christopher and Holweg 2011). Similarly, by encouraging alternative choices, substitute suppliers' swift response and recovery from disruptions are facilitated (Sheffi and Rice 2005). It, therefore, involves the supply chain's capacity to handle unanticipated difficulties (Jüttner and Maklan, 2011).

Flexibility also permits the easy redeployment of various resources such as labour and transportation (Pettit et al. 2013). Blome et al. (2013), provide empirical evidence of the impact of flexibility in responding to disruptions through knowledge transfers. They assert that flexibility is constrained due to complexities in the supply chain. Fayezi et al. (2015) in their study of flexibility and agility in a

supply chain using 50 manufacturing firms, found that flexibility is a direct response to a disruptive event which is dependent on time and cost, as its provision and realisation were identified as being related to an event, whether expected or unexpected, planned or unplanned.

Zsidisin and Wagner (2010) found that most flexibility practices were directed at influencing individual suppliers but not the whole supply market. Therefore, depending on the configuration of the supply market (number of suppliers; the number of buyers; competition among suppliers), these measures might not be effective. For instance, the shortage of medicine in the supply chain as a result of high demands would result in supply disruptions for stakeholders such as patients, doctors and nurses. An individual resilience-focused firm may not be able to lessen the effect of the disruption by implementing flexibility measures since it may be a supplier wide disruption. Similarly, Blome et al. (2014) investigated the impact of flexibility on complexity as a driver of supply chain vulnerability using procurement and supply chain professionals in Germany. They found that while knowledge transfer was pertinent in enhancing flexibility within the supply chain, these strategies were mitigated as a result of complexities within the supply chain.

2.7.2.1.2. Redundancy

Zsidisin and Wagner (2010), posit that resilience can be achieved by building redundancy into its resilience strategies. This entails focusing on reducing the negative consequences of a disruption. As such, resources are kept in reserve, e.g. safety stock, multiple suppliers, operations running at low utilization costs and used to buy time for recovery. Redundancy has been suggested to be an independent resilience strategy (Sheffi and Rice, 2005). However, Jüttner and Maklan (2011), propose a redundant strategy that is a pathway to flexibility because it entails duplicating the capacity of the supply chain to guarantee the stability of operations in the event of failure. It involves selectively and tactically using idle capacity in the event of crises (Christopher and Peck, 2004). This strategy slightly differs from flexibility because of the cost involved in adopting suppliers since the geographical location of the suppliers and the demand from consumers must be taken into consideration. For instance, in an earthquake

disaster, if the backup suppliers are around the crisis's locations, their ability to salvage the pressing demand may be reduced as they may also be affected by the crises (Tukamuhabwa et al. 2015).

Researchers, however, argue that this form of resilience practice has high-cost implications. Tying down capital to inventory is expensive and risky, as additional costs are accrued due to the management of multiple suppliers (Kamalahmadi and Parast, 2016). Zsidisin and Wagner (2010) in their study, however, found that redundancy practices often did not reduce the impact of disruptive activities. They argued that although these practices gained time for adequate recovery, they were not a specific strategy for recovery, as most firms overestimated the benefits of redundancy.

Existing literature suggests that most disruptions, such as natural disasters that affect the supply chain, cannot be stopped, (Jüttner and Maklan, 2011). However, if vulnerabilities are reduced, supply chains exposure to risk can be curbed. Resilience strategies have been touted as appropriate instruments in reducing existing vulnerabilities in the supply chain. For instance, lean management practices require that low inventories be kept reducing waste and boosting supply chain performance. Redundancy is an element of resilience which supports the use of redundant suppliers which may be useful when a disruptive event occurs.

Nevertheless, existing literature has only studied redundant suppliers in the context of static disruptions. The challenge, therefore, is to understand what happens when this disruption becomes dynamic and affects a multitude of players in the supply chain. This can often be the case with a pharmaceutical product that requires an active pharmaceutical ingredient (API), which must comply with stringent regulations.

2.7.2.2. Collaboration

Factors in today's business environment, such as longer lead times and globalisation have increased businesses' exposure to risks by weakening their network levels. The need to address this vulnerability, therefore, necessitates collaboration. This element of resilience entails that two or more independent firms can work together successfully for mutual benefits (Pettit et al. 2010; Chen

et al. 2013; Scholten and Schilder, 2015). It is based on the notion that information between supply chain parties is often inconsistent, as suppliers, for example, may have incomplete information on market demand, thus requiring all production partners to keep higher than required inventories to respond effectively to market changes (Wu et al. 2014). This may increase production costs, reduce the profit margin and lead to waste (as in the case of pharmaceuticals).

Supply chain collaboration, therefore, requires sharing of information (Cao et al. 2010); sharing of knowledge (Wieland and Wallenburg, 2013); sharing of risk and benefits; sharing of resources; postponement as well as forecasting (Cao et al. 2010), as it curbs uncertainty by redistributing risks. Two broad dimensions of collaborative resilience practices can occur within an organisation they are vertical and horizontal collaboration (Barratt, 2004; Barrat and Oke, 2007). The former emphasizes collaborating with customers, internal marketing functions and the suppliers. The latter seeks collaboration with competitors, external manufacturing and logistics. The underlying strategy, therefore, in terms of collaboration, is to know who to collaborate with and how to collaborate for adequate buffering in the event of a disruption (Wu et al. 2014).

Several studies have provided empirical evidence in highlighting the importance of collaboration. For instance, Wieland and Wallenburg (2013), in their study of interrelation competencies of resilience, asserted the importance of communication and cooperative relationship between partners in enhancing resilience practices. Similarly, Soni et al. (2014), found that collaboration ranked second in the fourteen supply chain resilience enablers when they assessed the elements of resilience practices. Also, Scholten and Schilder (2015), showed that information sharing as a collaborative activity enhanced resilience by fostering visibility, velocity and flexibility. In the same way, Jüttner and Maklan (2011), emphasised the need for collaboration after a disruptive event as it facilitates the sharing of information amongst suppliers and other members of the supply chain of how they coped during the disruption. This kind of information sharing is essential as it guides the firm in dealing with future disruptions.

Other studies submitted that, although collaboration was the most effective of the resilience capabilities, very few firms harness these in curbing disruptive events,

as firms lack adequate knowledge of what collaboration entails and as such overlook investment in its practices (Min et al. 2005; Christopher et al. 2011; Wilding, 2013; Ramanthan and Gunasekaran, 2014). Some researchers also contended that collaboration within the supply chain was challenging to implement (Fawcett and Magnan, 2002), and with the failure of knowing whom to collaborate with, collaboration may be farfetched (Barratt, 2004).

However, Kemblo and Naslund (2014), found information sharing, a form of collaboration, irrelevant in supply chain resilience strategies. Wang et al. (2014b) further alienated the importance of collaboration in the supply chain. They argued that, disruptions, damage collaboration, mainly if the disruption was induced by the supplier, as in some cases of medicine shortages. It is therefore essential, to manage antecedents of collaboration such as commitment and loyalty, before a disruptive event (Brinkhoff et al. 2015).

Information sharing and trust have been put forward as preconditions for building collaboration between parties (Barratt, 2004; Faisal et al. 2007). Reville et al. (2017), in their study of resilience strategies, found that firms that engaged in collaborative practices encountered low impact of disruptive events. Resilience strategies also suggest that collaboration between buyers and suppliers ensures the efficacy of internal business continuity plans and security procedures.

2.7.2.2.1 Information Sharing

Researchers have contended that the management of both demand and supply related information, plays a vital role in building the capability to flexibly respond to changes in upstream and downstream markets (Lummus et al. 2005; Wei and Wang, 2010; Sinkovics et al. 2011). Information sharing is therefore vital for the success of any relationship and can be used to monitor performances as well aid in identifying any issues that may occur in the supply chain (Melnyk et al. 2014; Wu et al. 2014). Mandal (2012), showed that for collaboration to be effectively harnessed, members of the supply chain require accurate and timely information. Christopher and Peck (2004), noted that the exchange of information among partners in a supply chain is essential for collaborative practices to be entrenched and mitigation of risk.

Similarly, in a multi-case analysis, six out of seven firms emphasized the need to have predefined communication protocols to mitigate the effects of disruptions through effective information sharing (Blackhurst et al. 2011). All firms in their study stressed the need to develop supplier relationship management programs to mitigate supply risk. Li et al. (2015), recruited 350 manufacturing firms for their research in China and found that the duration of supplier relationship and information sharing helped improve collaborative practices. Does the question then become what type of information should be shared that does not expose a firm's competitive capacity, especially for pharmaceutical firms who spend years in research and development? Sharing information entails a degree of trust between supply chain partners as discussed in the next section

2.7.2.2.2. Trust

Trust is the confidence in an exchange partner's reliability and integrity that directly and indirectly through commitment, affects exchange outcomes (Morgan and Hunt, 1994). Trust can, therefore, positively influence performance and relational behaviours, as buyers are more likely to act favourably toward and in the best interest of committed, trusted sellers (Ganesan and Hess, 1997). Trust as an element of collaboration facilitates cooperation between firms as well as across members in the supply chain (Barrat, 2004; Wang et al. 2014a). Affective trust (honesty, mutual understanding, credibility, respect and compliance) and trust in the competence (knowledge/technique, commitment in the relationship) are both necessary for keeping the relationship (Hudnukar et al. 2014). The absence of trust is one of the propellants of vulnerabilities within the supply chain (Brinkerhoff et al. 2015). A study by Ponomarov (2012) showed that where there is a higher degree of trust among buyers and suppliers, collaboration is enhanced, and there is a higher capacity for resilience.

2.7.2.3. Agility

Agility, defined as a firm's ability to thrive in an unpredictable business environment, has been proposed to enhance resilience practices in the supply chain (Erol et al. 2010). It hinges on customers' responsiveness and the firm's dominance in the face of market volatility to achieve competitive advantage (Swafford et al. 2006). Thus, intense competitive pressures, complexity, as well as turbulent marketplaces, increase vulnerability. Therefore, if a firm can

systematically decrease its vulnerability, it may lessen any potential harm faced (Prater et al. 2001; Brandon-Jones et al. 2014).

Agility is also the value for mitigating disruptions, and as such firms require that their supply chains be agile (Christopher and Peck, 2004; Ponomarov and Holcomb, 2009; Carvalho and Cruz-Machado, 2011). Bakshi and Kleindorfer (2009) explain that agility entails a reconfiguring system swiftly in the face of unforeseeable changes. In a continuously changing and globally competitive environment, the agility of an organisation's supply chain directly affects its ability to produce. Therefore, firms need several distinguishing attributes to deal with the evolving nature of the business environment promptly. These attributes include responsiveness, speed and flexibility.

Two dimensions inherent in the discussions of agility are *Velocity* and *Visibility* (Wieland and Wallenburg, 2013; Scholten et al. 2014; Azadeh et al. 2014). The former is a measure of the time it takes for a firm to adjust to changes in its business environment (Stevenson and Spring, 2007). Velocity determines the rate at which losses may occur during a disruption, with emphasis placed on how efficient the supply chain in responding to and recovering from a disruption (Christopher and Peck, 2004; Jüttner and Maklan, 2011). The forms of velocity include the pace at which risk events are discerned; risk occurrences and risk losses (Manuj and Mentzer, 2008). velocity supports the capability of the supply chain to adapt to changes before, during and after a disruptive event (Jüttner and Maklan, 2011). Three criteria have been put forward for enhancing velocity in the supply chain which include: the use of the streamlined process, where activities are carried out in parallel rather than in series; elimination of time allotted to activities that do not add value to the customers' perspective and the ability to respond to and cope with short term changes (Christopher and Peck, 2004; Tang, 2006a; Spiegler et al. 2012; Carvalho and Cruz-Machado, 2012).

Supply chain visibility has been extensively studied in the literature (Cardi et al. 2010; Dubey et al. 2017). In any case, there appears to be contention as to the focal point of visibility. For instance, Swaminathan and Tayur (2003) focus their attention on the exchange of information, where visibility entails sharing information across the supply chain. Barratt and Oke (2007), on the other hand, emphasize visibility as an outcome of collaborative efforts and a capability to

achieve competitive advantage (Jüttner and Maklan, 2011). Information sharing, however, differs distinctively from visibility as its focus is with the quality and relevance of information (Cao and Zhang, 2011). Visibility entails the flow of material as well as information through the supply chain to make it more transparent (Braunscheidel and Suresh, 2009).

Wieland and Wallenburg (2013), reported a positive relationship between communication and cooperation in enhancing visibility and speed. Carvalho et al. (2011), explained that the deployment of agile and resilience practices was mainly related to improvement in supplier flexibility and velocity as well as improvement in the responsiveness of suppliers to changes in markets or unexpected events. Lenort (2012) contended that velocity would enhance supply chain resilience through the process design phase. Evidence of incorporating velocity in the design of processes in their study included shorter waiting time, higher flexibility, and faster reaction to market requirements. The latter, on the other hand, referred to the ability of firms to see through the entire supply chain to identify signals of following disruptive events (Tukamuhabwa et al. 2015). Visibility may imply that manufacturers have complete information about the position of their assets in the environment within the supply chain operation. This helps in mitigating unproductive decisions in the event of risks, unnecessary interventions, and in most cases, overreactions (Pettit et al. 2013). Visibility propels efficiency and adequate supply chain planning (Yu and Goh, 2012).

Also, the supply chain's ability to identify vulnerable suppliers and nodes within a network, aids in the effective response and recovery from disruptions. An example of supply chain visibility can be seen in Cisco a computer manufacturing company, who was able to develop a resilient supply chain through its ability to map out its tier-one supply base made up of more than 300 suppliers within 12 hours, as well as mark out and file its consumers' enquiries within 24 hours of the Tsunami and earthquake that hit Japan in 2011 (Saenz and Revilla, 2014). Hence, agility is essential within the supply chain to be able to combat unfavourable events. Papert et al. (2016) provided four dimensions of supply chain visibility to include: availability, identity, position and status-quo. Li et al. (2017) provided empirical evidence of the impact of supply chain agility on financial performance and superior firm value. The argument is that a firm

requires both proactive (preparedness) and reactive measures (agility and alertness) to enhance supply chain resilience,

In summary, although the above strategies are cited in the literature as critical in building a resilience supply chain (Ponomarov and Holcomb, 2009; Wieland and Wullenburg, 2013), empirical evidence supporting these assertions are rare (Lakovou et al. 2007). Similarly, the bulk of existing evidence in examining the effect of resilience practices in supply chains has examined those using static disruptions like fire disasters, earthquakes, labour union strikes. However, resilience strategies possess dynamic properties and as such, assessing its efficacy on dynamic disruptions, like medicine shortages will be appropriate. The definition and strategies of supply chain resilience presented above, show the importance of building resilience into a supply chain which aims at reducing firms' losses in the face of disruption by curbing their exposure to these risks (Jüttner and Maklan, 2011; Tukamuhabwa et al. 2015).

Jüttner and Maklan (2011), suggested that these resilience strategies could cope with diverse disruptive events and could enhance firms' outcomes by mitigating possible risks that may occur. For instance, an agile and collaborative supply chain may plan for a disruptive event like counterfeiting by understanding prevailing counterfeiters strategies used in gaining access into the supply chains and develop proactive strategies to curb the existing vulnerabilities, thereby reducing the probability of reputational, quality, security and supply risk (Stevenson and Busby, 2015). In the same way, velocity, as a subset of resilience, entails firms' lead-time in responding to the crises. Therefore, in the face of disruption like medicine shortage, firms could switch network suppliers as well as transportation and logistics (Jetly et al. 2012).

Over-dependence on resilience strategies may lead to potential losses. Take, for example, information sharing as an efficient collaboration strategy which requires commitment and trust. While these dynamic capabilities can foster sustained competitive advantage, sharing of information can also expose the firm's sensitive details, making them vulnerable to competitors.

Similarly, in the bid to improve visibility within the supply chain, firms may substitute higher-priced goods for cheaper ones or change the geographical

location of the suppliers. This may, however, expose a firm to other forms of risk like exchange rate risk or quality risk, which are usually outside the control of the manufacturer (Xie et al. 2011). Even more daunting are the cost implications attributed to developing the resilience supply chain. Encouraging redundant suppliers to be called upon in the face of a disruptive event may increase a firms' cost of production per unit. Although these firms may meet consumers' demand before their competitors, the firm's production capacity may likely be running at a loss.

2.8. Disruptions and Supply Chain Resilience

The underlying assumption on supply chain resilience is that it can withstand the impact of disruptions (Ponomarov and Holcomb, 2009; Jüttner and Maklan, 2011; Tukamuhabwa et al. 2017; Hendry et al. 2019). However, empirical studies exploring the link between supply chain resilience and disruptions remain inconclusive and limited, as shown in Table 2.5 below.

This table summary reveals that studies examining the link between disruptions and supply chain resilience became more apparent in 2017. Most studies were generic and did not define the type of disruptions and which resilience strategies were employed (see Craighead et al. 2007). These studies failed to identify the supply chains which the resilience strategies were for developed. Exemptions to these limitations, however, were the studies by Jüttner and Maklan (2011), who studied resilience strategies and financial crises on three supply chains, namely:- manufacturing, automobiles and pharmaceuticals; Purvis et al. (2016) who studied business cycle fluctuations as a disruption in the beverage sector; Behzadi et al. (2017) who studied resilience strategies with high-rare harvest disruption in the agro-food supply chain and Hendry et al. (2019) who examined constitutional change and resilience strategies in the food sector. These studies identified collaboration, information sharing and flexibility as strategies necessary in curtailing the impact of disruptions. These studies, however, did not capture the recovery and resistance element of supply chain resilience as elucidated in its definition (see Tukamuhabwa et al. 2015).

Table 2.5 Empirical evidence examining the link between disruptions and supply chain resilience

Authors	Methodology	Disruptions	Supply Chain	Resilience Strategies
McKinnon (2006)	Simulation	Road disaster	Freight	Flexibility
Craighead et al. (2007)	Mixed-method	Not defined	Automobile and Pharmaceutical	Warning and recovery capabilities
Steecke and Kumar (2009)	Qualitative	Intentional disruptions/ Terrorism	Not defined	Visibility, coordination, flexibility and redundancy.
Zsidisin and Wagner (2010)	Quantitative	Purchasing and Supply risks	The building, construction, equipment and aircraft	Flexibility and redundancy.
Jüttner and Maklan (2011)	Qualitative/Longitudinal case study	Financial Crises	Three supply chains, including manufacturing automobile.	Flexibility, collaboration and Velocity
Thun and Hoenig (2011)	Quantitative	Risks	Automobile industry	Reactive and proactive measures of resilience.
Zhao et al. (2011)	Case study/Computer simulations	Military logistics network	Random and targeted	collaboration
Pettit et al. (2013)	Mixed-methods (Focus groups, questionnaires)	Unspecified	Not defined	SCRAM
Thomas et al. (2014)	Mixed research approach	Not defined	Manufacturing firms	FOM resilience model.
Bowman (2015)	Qualitative research	Not defined	Warehousing	Information sharing, agility coordination,
Ambulkar et al. (2015)	Quantitative	Unspecified	Not defined	Supply chain disruption orientation.
Falkowski (2015)	Quantitative	Dairy products in Poland.	Argo-food supply chain.	Fragmentation
Mandal et al. (2016)	Quantitative/ Survey	Not defined	Supply Chain professionals	Collaboration, flexibility, agility
Purvis et al. (2016)	Qualitative, single case study,	Financial crises/	Beverage Manufacturer	Agility, flexibility and leanness. A

	unstructured interviews, company documents	Business cycle.		framework for developing resilience.
Behzadi et al. (2017)	Simulation/ Real-life case study	Agriculture	Rare high impact harvest disruptions	Robust and Mixed resilience strategies.
Hendricks et al. (2017)	Quantitative /Event study	460 Publicly traded firms	Great East Japan Earthquake	Fairly resilience abilities.
Huatuco et al. (2017)	Case study	Manufacturing	Not specified	Redundancy information sharing and visibility.
Kamalahmadi and Parast (2017)	Quantitative	Manufacturing	Not specified	Redundancy
Liu et al. (2017)	Quantitative: Partial differential equation	Chaos	Not Specified	Restoration and invulnerability through collaboration.
Rezapour et al. (2017)	Real-life case study /Mixed-integer non-linear model	Automobile	Suppliers and Competition	Redundancy, flexibility.
Scheibe and Blackhurst (2018)	Case study/ Grounded theory approach.	7 broad supply chains	Not specified	Agility capacity, dual sourcing.
Hendry et al. (2019)	Qualitative	Food Sector	Constitutional Change	Vertical and horizontal collaboration

Source: Researcher's Own (2019)

Table 2.5 also shows that most studies employed either qualitative, quantitative or simulation techniques in studying the link between disruptions and resilience strategies. The use of a mixed-methods approach was conspicuously absent. The mixed-method approach is essential as it would enable a greater breadth and more comprehensive range of research questions to be addressed. Also, there are no significant interests in pharmaceutical supply chains and disruptions like counterfeits and medicine shortages. As such, this study seeks to contribute

to the empirical literature by exploring resilience strategies and disruptions in the pharmaceutical chain.

2.9. Summary of Research Gap

This study aimed to explore why the pharmaceutical supply chain in the UK is susceptible to the impact of dynamic disruptions as well as to assess how resilience strategies have been used in mitigating these vulnerabilities. As such, in this chapter, the literature supporting supply chain disruptions, supply chain vulnerabilities and supply chain resilience strategies were explored. Several gaps in identified in literature below:

Firstly, although the review of the literature revealed that understanding vulnerability is essential in developing resilience strategies that are cost-efficient and best suitable to the supply chain in context, the drivers of supply chain vulnerability remained underexplored. Only one study focused on vulnerability drivers in the pharmaceutical supply chain, which was by Craighead et al. (2007). This thus, indicates a gap in the literature on the vulnerability drivers of the pharmaceutical supply chain while taking into consideration its peculiarities. Although there were empirical studies that identified when supply chain resilience strategies are limited, there were, however, no studies that distinguished recovery strategies from resistance strategies.

Also, the supply chain vulnerabilities literature identifies some debate on what elements contribute to exposing supply chains to the impact of disruptions. There is no mention of medicine shortage as a disruption within supply chains. As such, this has not been categorised within existing literature as either intentional or unintentional. Dynamic disruptions have not been explored extensively in supply chain management literature. As such understanding, these disruptions will determine the adequate and necessary response strategy (Azadegan and Jayaram, 2018).

The issue that not all supply chains can adopt resilience strategies in mitigating the effects of disruptions has also been raised. The debate here is that since the properties of resilience strategies are dynamic, specific supply chain

characteristics may inhibit its application as in the case of the Pharmaceutical Supply Chain. In view of this, the next chapter explores the nature of the pharmaceutical supply chain, as well as factors that may inhibit resilience strategies in this supply chain.

Chapter Three: Contextualizing the Study

3.1. Introduction

This study aimed to explore why the pharmaceutical supply chain is susceptible to dynamic disruptions as well as examine the impact of resilience strategies in mitigating these disruptions. In this chapter, therefore, the context of the underlying research will be situated within existing vulnerabilities, disruptions, resilience and the pharmaceutical supply chain literature. Thus, the nature and characteristics of the pharmaceutical supply chain, prevalence and causes of medicine shortages as a form of pharmaceutical supply chain disruption are explored. The Complex Adaptive System (CAS) theory as a theoretical lens in exploring supply chain resilience within the pharmaceutical supply chain is also critically examined, and the necessary conclusions reached.

3.2. The Pharmaceutical Supply Chain (PSC)

The pharmaceutical industry is responsible for the manufacturing, development and marketing of medications. A report by the research and development arm of CMR Pharmaceuticals indicates that the sales of pharmaceutical products are on the increase with global sales at 1 trillion dollars in 2015 and are expected to peak at $1.5 trillion in 2020 (Shah et al. 2015). This has been suggested to be driven by the increased access to healthcare in various countries as well as the increased prices for breakthrough medicines in cancer and other critical ailments (Rossetti et al. 2011).

The PSC comprises of multifaceted procedures and operations that facilitate medicine discovery, development, manufacture and distribution (see Figure 3.1) (Narayana et al. 2014). A PSC is highly regulated from the sourcing of raw materials to the manufacturing of active ingredients, as well as formulation, packaging, outsourcing, distribution and product discontinuation (ISPE, 2012). It entails the delivery of healthcare products to the consumers, and as such it requires that the supply of medicines is safe, reliable and meets the set quality through a supply chain which responds to actual demand and recognizes the needs of the consumer (Sousa et al. 2015).

While pharmaceuticals are one of the most regulated industries in the world with regards to marketing and sales, their regulations have been argued to be like the food industry (Ahmad et al. 2009). However, medicines involve metabolism in the body, which is only understood by the specialized individual, and as such, must be proven to be safe and effective in fulfilling its intended purpose. The approval process includes additional controls such as medical and scientific review, as well as clinical patient trials, to empirically test their effectiveness within the population (Jetly et al. 2012).

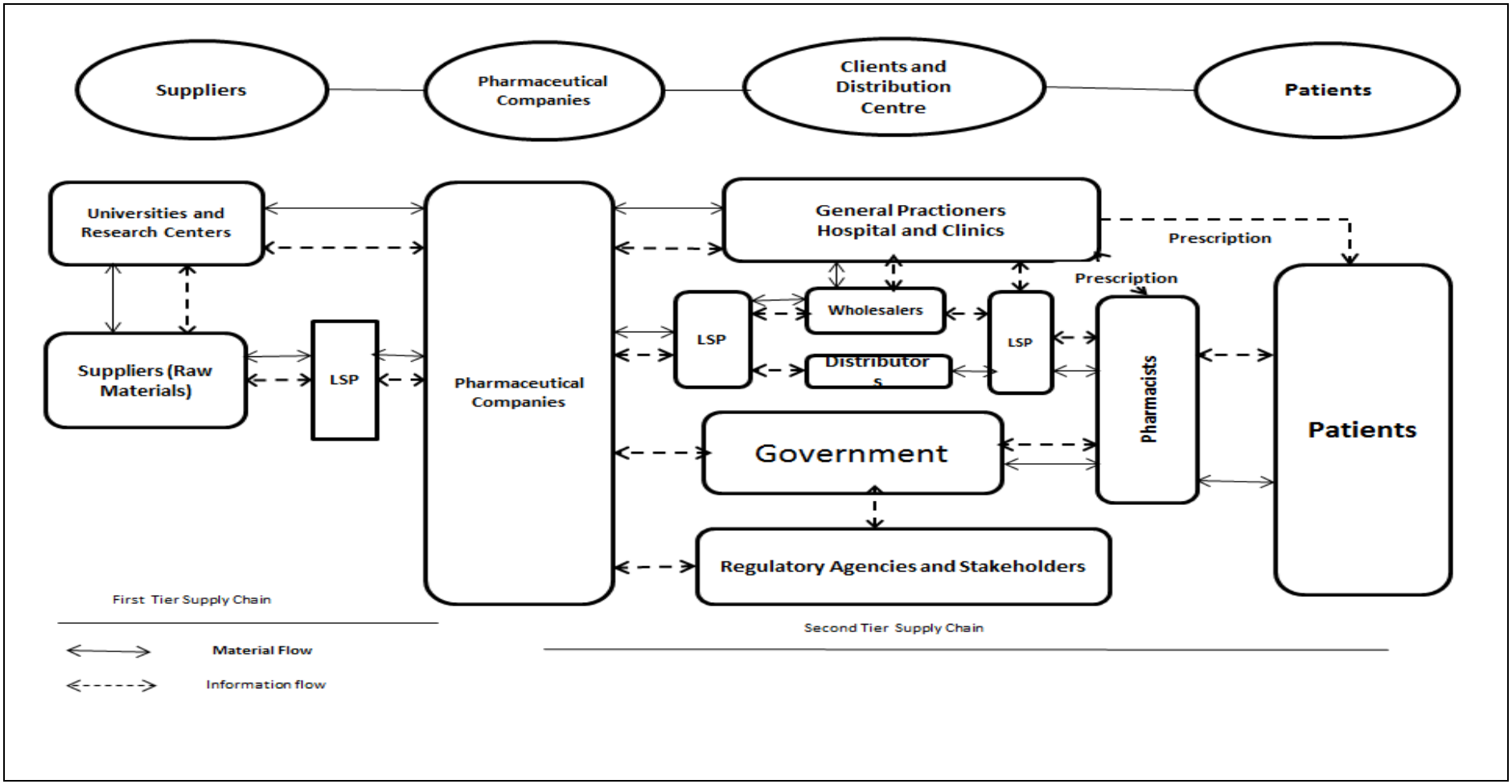

Figure 3.1 The Pharmaceutical Supply Chain
Source: Adapted from Evans and Gruber (2014)
*LSP: - Logistic Service Provider

3.2.1 Characteristics of the PSC

Researchers and practitioners suggest that pharmaceutical products differ from other types of products (Mehralian et al. 2014). For instance, the high costs associated with the research and production of pharmaceuticals as well as the adverse effect that may occur if a pharmaceutical product is unavailable are defining traits (Breen, 2008).

Some unsubstantiated factors characteristically distinguish the PSC include: the level of regulation involved at each stage of the manufacturing, distribution, storage and consumption of the product by the final consumer due to the unique nature of supply and demand in this sector (Yu et al. 2010; Li et al. 2013; Mehralian et al. 2014). According to the characteristics of the competition in the pharmaceutical market, governments must balance both clinical and economic interests (Hakonsen et al. 2009; Rasekh et al. 2012).

Narayana et al. (2014) conducted a survey of literature which further elucidated some unique issues associated with the PSC which include: multiple categories of medicines; highly regulated environment requiring extensive data collection and information exchange to ensure the chain of custody; monitoring of various controls and management of product expiry for safety; error prevention; reassignment; safe disposal; cold chain required for temperature-controlled product movement and intricate demand patterns of predictable pattern for mid-life cycle products.

Another interesting fact about this industry is the transition of the paying responsibilities from individuals to governmental agencies and insurance companies, which in association with high demands for pharmaceuticals, due to ageing populations, puts intense pressure on prices and prescription policies (Shah, 2004; Sousa et al. 2011). Also, in a PSC, the number of consumption points, the role and number of intermediaries, the long lead times and highly unpredictable nature of pharma manufacturing have created a web of vulnerabilities, interdependencies, and uncertainties (Rossetti et al. 2011). As evidenced in Chapter 2, existing research does not address the peculiarities of PSC, and there is an acute need for supply chain researchers to begin investigating these phenomena.

There are two stages of manufacturing with pharmaceuticals which further complicates the supply chain, as shown in Figure 3.1. The first stage is termed the first-tier supply chain, which includes sourcing for raw materials to the manufacturing by the pharmaceutical companies. This stage of production may span into years of research and clinical trials. It is made up of the research centres, the suppliers and logistic service providers. Here the goods and information flow back and forth within the members of the supply chain with a series of testing and high investment costs. The second tier of the supply chain begins from the pharmaceutical companies to the patients with the wholesalers, hospital, pharmacies and governing bodies interacting in terms of information and goods flow to produce the goods to the end-user. The second tier is; therefore, the focus of this study as the operations here focuses on getting the pharmaceutical products to the end-user.

3.2.1. Components of the PSC

The PSC, like any other industry, begins with the sourcing of active and inactive ingredients for approved products. Dosages are planned and packed into different configurations. Products moved along to companies' warehouses, wholesale distributors, retail pharmacies, medicinal organisations (hospital pharmacy), and finally to end-users. The data and funds flow to start from the producer to the end-user through different channels (Mehralian et al. 2014).

In general, a PSC is made up of two tiers and indicated in Figure 3.1, and this includes primary manufacturers, secondary manufacturers, central and local distribution centres' (DC), and destination zones/demand points (e.g., pharmacies, hospitals, clinics) (Jetly et al. 2012). The primary manufacturers oversee the production of required active ingredients (RAI), which generally include either several chemical synthesis and separation stages to build up the complex molecules involved, or purification and product recovery in case of biochemical processes (Shah, 2004). Secondary manufacturers are responsible for further production processes with different technology levels, packaging and finalising the products that are usually in the Stock Keeping Unit (SKU) form. Compared to a typical manufacturing supply chain, primary

manufacturers can be referred to as suppliers of raw materials, and secondary manufacturers as manufacturing centres. Consequently, secondary manufacturers not only play a significant role in the production of final goods, but they can also store a limited number of products within the facility.

3.2.2. PSC Risk

The PSC provides the channel through which healthcare products are delivered to end-users in the appropriate quantity and at the right time (Eyinda et al. 2010). It entails the participation of various stakeholders such as pharmaceutical manufacturers, wholesalers, distributors, pharmacists, customers, logistic service providers and regulatory agencies. However, in recent years, the PSC has been faced with various risks stemming from various forms of disruptions and vulnerabilities (Enyinda and Tolliver, 2009). Supply chain risk management provides the firm with a competitive advantage, the ability to balance threats and enhance competition, as well as the capacity to handle threats (Eyinda et al. 2010; Jaberidoost et al. 2013).

Existing literature highlights that the most challenging aspects of supply chain risk management are the ability to understand the nature of risks the firm is exposed to (Elleuch et al. 2014). It is necessary, therefore, to assess the various sources of risks the PSC is exposed to develop appropriate resilience strategies. This is because, the absence of appropriate risk mitigation strategies, can erode the trust in public health, compromise patients' health and cause a decrease in the profit margin as well as shareholder value (Hendricks et al. 2017). Although the pharmaceutical firms cannot eliminate the risk portfolio, they face in their daily operations, developing an environment which can reduce vulnerabilities and exposure to risk is essential.

Researchers have attempted to determine risks in the PSC. For instance, Breen (2008) affirms that most risk sources are associated with product discontinuity, product shortage and technological errors. Jaberidoost et al. (2013) also found that PSC risks emanate from regulatory, supply and supplier, organisations strategy, financial and logistics issues.

3.2.3. PSC Disruptions

Various disruptions may affect the PSC; these include natural disasters, medicine shortages, counterfeit medicines, and thefts, which all have an adverse impact on all stakeholders. For this study, however, medicine shortages are explored as the dynamic, disruptive activities that may affect the PSC as explained in the next section.

3.2.4.1. Medicine Shortages

One of the critical objectives of the PSC is to ensure that medicines flow to patients continuously with minimal delays at optimal prices (HDMA, 2009). However, the increased incidences and discussions of medicine shortages in the supply chain (Kweder and Dill, 2013), calls for closer scrutiny of the supply chain. A recent example is a survey by the European Association of Hospital Pharmacists (EAHP, 2018), which revealed that about 50% of hospital pharmacists in the United Kingdom, experienced critical medicine shortages daily with patients waiting up to six months to receive treatment. Also, restricting the supply of medicines to patients has an adverse impact on the whole health care system (Pauwels et al. 2015), resulting in extra therapeutic care for the patient (Kaakeh et al. 2013; McLaughlin, 2013); stress on the pharmacists (DeWeedrt et al. 2015) and increased cost to stakeholders as they have to seek for alternatives and this causes increased complexity of the supply chain (Beck et al. 2019).

There is a lack of consensus on the definition of medicine shortages, as presented in Table 3.1 below. While some studies regard shortages of medicines as the inability of patients to access the required medicine as and when due (Pauwels et al. 2014), other studies refer to medicine shortages with particular reference to the pharmacies (ASHP, 2011), or delay in supply on a particular day (Dragic, 2012; Costello et al. 2014). These definitions highlight significant differences such as the scope of a medicine shortage and the time frame for a medicine to be classed as short in supply (De Weerdt et al. 2015).

Table 3.1 Defining medicine shortages

Authors	Definition
ASHP-American Society of Health-system Pharmacists (2011)	Supply issue that affects how the pharmacy / dispenses a medicine product or influences patients care when prescribers must use alternatives agents.
Gu et al. (2011)	A situation in which total supply of all clinically interchangeable versions of FDA-regulated medicines is inadequate to meet the current demand and user level.
EFPIA European Federation of Pharmaceutical Industries and Association (2013)	A potential medicine shortage is defined as the occurrence of internal or external situations (single or in a combination of both), which result in an interruption of supplies of a medicinal product, if not adequately addressed and controlled.
Dragic (2012)	Medicine shortage as every delay in monthly medicine supply.
Birgli (2013)	Medicine shortages are the adverse effects on the continuity of supply and or unavailability at the point of dispensing as a result of natural disasters, manufacturing problems, noncompliance with regulatory standards, packaging shortages and unexpected demand.
Heiskanen et al. (2014)	A medicine supply issue requires a change that impacts patient care and requires the use of alternative agents.
Costello et al. (2014)	A medicine shortage is the inability to purchase a particular medicine from wholesalers on a particular day.
Pauwels et al. (2014)	Medicine shortages are shortcomings in the supply of a medicinal product which makes it impossible for suppliers to meet the demand for the product at the patient level. It affects all stakeholders of the health care system such as patients, pharmacists, clinicians, the pharmaceutical industry and policy.
De Weerdt et al. (2018)	Drug shortages involve at supply-side' and 'demand-side'. A drug shortage at supply side is defined at 'pharmacy level' and is defined as the situation 'when the Medicine Authorisation Holder (MAH) is unable to supply to wholesalers/pharmacies, or when the wholesaler is unable to supply to pharmacies'. A drug shortage at demand-side implies a supply problem at 'patient-

	level', that is when pharmacies are unable to supply the drug to patients.
European Medicines Association (EMA) (2018)	A shortage of a medicinal product for human or veterinary use occurs when supply does not meet demand at a national level.
Bochenek et al. (2018)	A drug is unavailable when enterprises that are responsible for the marketing of the drug are unable to deliver that drug for an uninterrupted period of four consecutive days to the community pharmacies, hospital pharmacies or wholesalers in Belgium.
Beck et al. (2019)	The unexpected unavailability of a drug, often without precise knowledge of when, or if, the desired drug will be available again, what alternatives are available, and/or which risks the use of these alternatives entails.

Source: Researcher's Compilations (2019)

Defining medicine shortages is, therefore, pertinent as it aids in setting the scope on how issues of medicine shortages should be addressed. This research, therefore, defines medicine shortage as the disruption that leads to the inability of stakeholders in the supply chain, to access medicines when needed. This definition was chosen in this study because it provided a holistic view of the phenomena.

3.2.4.2. Medicine Shortages versus Rationing and Quota Systems

Another critical component of medicine shortage within PSCs is the issue around rationing or as some referred to as the 'the quota system' (Gloor et al. 2013). Some authors argued that rationing within healthcare systems differs significantly from medicine shortages, as rationing is a managerial decision which involves withholding beneficial medical care as a result economic constraints and/ or unforeseeable limitations on financial resources (Williams et al. 2012; Beck et al. 2019). Rationing here is measured based on its actual impact on patients' care.

Other studies, however, argued that, although rationing was a standard method used in mitigating the impact of a pharmaceutical shortage, withholding of

pharmaceutical products (rationing limited supplies) from other supply chain actors appeared as a form of shortage to some end users and detrimental to patients care (Rosoff et al. 2012; Rider et al. 2013; Fox et al. 2014). For instance, Breen and Yaroson (2018), indicated product rationing by firms was a possible cause of medicine shortages. The explanation was that pharmaceutical firms employed rationing as a strategy in curbing wholesalers who took advantage of favourable exchange rates to sell medicines abroad. However, the practice has taken a different toll as these critical medicines created short supply in the United Kingdom.

3.2.4.2.1. Causes of Medicine Shortages

Various reasons have been underlined as possible causes of medicine shortages. Some studies identify price fluctuation (DeWeerdt et al. 2015; 2017), regulatory policies (Ventola, 2011), manufacturing difficulties (Ventola, 2011), natural disasters (Fox et al. 2003; 2014), product recall and shortages in raw materials as some other possible reasons. The Birgli report by Gloor et al. (2013) has categorized these causes into two broad spectrums, namely: anticipated and unanticipated causes. However, these reasons stem from limited rigorous academic research. Therefore, the need to explore these aspects from an operations management point of view is essential.

Although medicine shortages can affect the adequate flow of medicines from and to the end-user, their impact on the supply chain has not been adequately addressed in operations management literature, and as such, this calls for further research with regards to the phenomenon. In this study, therefore, medicine shortages were classified as a dynamic disruption. Here, the sources were either internal or external to the supply chain and the impact dynamic. Table 3.2 below provides an overview of global studies on medicine shortages.

Table 3.2 Studies on medicine shortages

Authors	Objectives	Country	Methodology	Findings
Fox et al. (2003)	Described the experience in monitoring medicine shortages between 1996 and 2002.	US	Document analysis, track and trace.	224 Medicines were in short supply during that period where 28% stemmed from manufacturing issues and 54% as a result of unfamiliarity with alternatives.
Chabner and Bruce (2011)	Examined the challenges for generic medicine market shortages and solutions in the US.	US	A contextual paper	Highlighted the need to develop alternative medicine management regimes.
Gu et al. (2011)	Explored the causes, impact, strategies of medicine shortages.	US	Contextual paper	Good understanding of causes, legal and trade requirements
Ventola et al. (2011)	Assessed the causes, impact and management of medicine shortages.	US	Literature review	Manufacturing difficulties, natural disasters, voluntary recall, economic problems regulatory controls, Advocate for an advanced warning system in managing medicine shortages.
Kaakeh et al. (2011)	Quantify personnel required to manage medicine shortages in the US.	US	An online survey of 1322 members of ASHP, directors of pharmacy.	Labour costs and time required to manage medicine shortages are significant. Changes in dispense practice, allocation of remaining supplies, identification and implementation of alternative therapies.
Gray and Manasse (2012)	Explored the complexity of medicine shortages	Global	Technical report	Policymaking which avoids the winner takes all syndrome
Metzger et al. (2012)	Explore the impact of medicine shortages on children with cancer.	None	Experimental event-free technique on 181 survivals of cancer.	The devastating impact on patients.

Pauwels et al. (2014)	Collected and presented data on medicine shortages in European countries.	Europe	Contextual literature review	Medicine shortages was a global phenomenon.
Bogeart et al. (2015)	Analysed, characterised and assessed problems of medicine shortages in Belgium and France, adopting an EU perspective.	EU	Qualitative-28 semi-structured interviews of respected National health authorities.	Defined medicine shortages; understand its dynamics and perspectives, highlighted determinants ad role of EU and national institutions in curbing medicine shortages.
Pauwels et al. (2015)	Investigated the characteristics, clinical impact, financial impact and management of medicine shortages in European hospital pharmacies and identify opportunities for prevention and mitigation of medicine shortages in Europe.	Europe	An online survey was designed based on a review of the literature and interviews and was sent to subscribers of Hospital Pharmacy Europe between June and September 2013.	Pharmaceutical companies and wholesalers are already involved in the management of medicine shortages, while a role is still reserved for the government. Mandatory notification in advance and centralized information can help to reduce workload for hospital pharmacists, will allow early anticipation of medicine shortages and will facilitate mitigation of the clinical impact on patients.
Saedi et al. (2016)	Examined medicine shortages through inventory management.	None mentioned.	Simulation and optimization techniques	Proposed a stochastic model to find the optimal inventory policy level.
Claus et al. (2015)	Described management and impact of medicine shortages for hospital pharmacies in Belgium.	Belgium	Mixed-method. Qualitative use of semi-structured interviews with Federation for Belgian	Medicine shortages represent a substantial workload and an increased medicine acquisition cost. Causes of shortages are production-related but also distributional in

			pharmacists quantitative the use of GUH database for medicine shortages.	equivalences and quota play an important role.
De Weerdt et al. (2015)	Explored the length of time pharmacists spent in handling medicine shortages in Belgian hospitals.	Belgium	Action research.	Substantial economic and social impact. Build an infrastructure to addresses shortage. Develop a plan to minimize the impact.
De Weerdt et al. (2015)	Examined the regulations affecting medicine shortages.	Europe	Content analysis of available documents.	Price and quality regulations are detrimental to the supply of medicines.
Yang et al. (2016)	Analysed, characterised and assessed problems of medicine shortages in China.	China	Qualitative-30 semi-structured interviews of hospital pharmacists' wholesalers and pharmaceutical producers.	Too low prices, medicine shortage as multifaceted and complex, public bidding as well as material issues.
Fox and Tyler (2017)	Explored the relationship between medicine shortages and high costs of medications in the US.	US	Quantitative techniques, where data was extracted from voluntary manufacturers report on the UUDIS database between Jan 2011 and Dec 2015.	Sole source manufacturer and infrequently used medications significant medicine causes shortages. Argue for a strong relationship between medicine shortages and costs of medications as both possess similar risks factors.

Heiskanen et al. (2017)	Explored the reasons for medicine shortages from the wholesaler and manufacture perspective in Finland	Finland	Qualitative-30 Semi-structured interviews/Thematic analysis.	The small size of the pharmaceutical market, long delivery time, complex production chain, small stock size, fluctuating demand and country-specific traits of Finland are the root cause of medicine shortages.
Jia and Zhao (2017)	Examined if medicine shortages could be solved from a supply chain perspective in the US.	US	Simulation techniques, inventory management through scenario analysis.	Proposes medicine shortages mitigation through purchase contracts, parento-improving contracts and group purchasing.
Schwarzberg et al. (2017)	Analysed medicine shortages in Israel for period 2013-2015, as well as explore steps taken to mitigate the issue.	Israel	Quantitative sourced from the Israeli database on medicine shortages.	Raw materials, quality problems, sole supplier /manufacturer, price irregularities, just in time inventory were identified as causes of medicine shortages. Risk minimization strategies, as well as strategies outside regulatory control, will aid in solving the problem.
Scioli (2017)	Assess leadership strategies in mitigating medicine shortages in the US	US	Semi-structured interviews.	Leadership styles can be employed to mitigate the impact of disruption
Walker et al. (2017)	Ascertained the causes, impact, and possible solution of medicine shortages in Fiji.	Fiji	Semi-structured interviews in the Fijian medicine supply chain.	International solutions proposed by WHO is feasible but have to be tailored to suit the uniqueness of Fiji.
Dave et al. (2018)	Investigated the predictors of medicine	US	Quantitative analysis, data from UUDIS	Lower priced generic drugs were at risk for shortages. Prevalence of shortage increased after 2008.

	shortages between 2008-2014			Relationship between drug price and medicine shortage
Said et al. (2018)	Relevance and challenges of medicine shortages	Germany	Quantitative techniques, an online survey	Medication errors, life threatening occurrences for patients as challenges of medicine shortages. Limited manufacturers, pricing, recalls, demand related
Miljkovic et al. (2019)	Highlighted the impact of medicine shortages on hospital pharmacists	Europe	Quantitative online survey	Causes of medicine shortages include the absence of swift information sharing.
Hernadez et al. (2019)	Examined the link between drug pricing and medicine shortages	US	Quantitative / Regression analysis	Found that drug prices increased when there was a shortage

Source: Researcher's Compilation (2019)

Table 3.2 above shows that empirical evidence on issues around medicine shortages is limited in the literature. The number of empirical sources is limited, and analysis of empirical literature revealed that most articles became more prominent from 2011. For instance, Ventola (2011) highlighted that medicine shortage in the US reached its peak in 2011. Also, most studies centred on causes, characteristics and impact of medicine shortages. Most studies focused on the US and European countries such as Belgium, France and one study from Finland. Although the department of health of various countries does their best to alleviate the impact of this common problem, there is no doubt that despite these efforts, medicine shortages have the potential to affect patient care negatively. Medicine shortages may also be categorised as a security risk, as pharmacists may be compelled to alter how a product is dispensed and clinicians may have to prescribe unfamiliar alternatives which may affect patients care (Tanzi, 2019).

Similarly, although medicine shortages have been identified as a supply issue, only four studies have attempted to address the issue of medicine shortages from a supply chain perspective. For instance, Saedi et al. (2016) advocated the use of optimization techniques in curbing medicine shortages. Also, Jia and Zhao (2017), presented the use of inventory management through parento improving contracts, while Scioli (2017) suggested the use of leadership strategies in curbing disruptions. This study, therefore, seeks to extend existing supply chain management literature by assessing the application of resilience strategies in curbing the impact of medicine shortages in the PSC.

3.2.4.2.2. Tendering Market, Medicine Shortages and the PSC

In the discussion surrounding medicine shortages and the PSC, the concept of the tender market is pivotal as it sets out the medicine procurement process in the UK. The structure of the tender system in the UK consists of: the Commercial Medicines Unit (CMU) which is responsible for awarding and managing the framework of the tendering process; The National Pharmaceutical Supply Group (NPSG), which is made up of the secondary care chief pharmacists representing their geographical area who ratify procurement decisions; The Pharmaceutical

Market Support Group (PMSG), the generic, branded and biosimilar medicines sub-group and the National Homecare Medicines Committee (NHMC) (PSMG, 2018). The PMSG and CMU explain that the geographical demographics represented on a tender market table supports hospital trusts in facilitating networks as well as medicine procurement leads (PSMG, 2018).

The CMU manages the tender system in England, and this covers the ten regional groups. The groups are designed to present sufficiently high usage volumes to attract the best prices for both branded and generic medicines. The configurations are designed to maintain continuity of supply and avoid monopolies. Table 3.3 below presents the various regions and sub-regions represented in the UK.

Table 3.3 Pharmacy procurement regions and purchasing groups

Region	Pharmacy Purchasing Groups
North of England (NOE)	North West North East Yorkshire and Humber
Midlands and East (MAE)	East Midlands West Midlands East of England
London	London
South of England (SOFE)	South East Coast South West Thames Valley and Wessex

Source: Pharmaceutical Market Support Group (PMSG) (2018)

Tenders add another level of complexity to the PSC. The continuous changing of suppliers between tenders increases the difficulty associated with business continuity and in some cases, is simply not attractive. For instance, if a major generic manufacturer is required to supply products within two months of winning a tender and for which a minimum of 80% of the products shelf-life on delivery is stipulated. This, coupled with a monthly tender frequency, is an unsustainable model (Gloor et al. 2013). Some generic manufacturers have opted simply not to supply or respond to tenders, others have been unable to supply after successful tender.

3.2.4.2.3. Other Factors that Influence Medicine Shortages and The PSC in the UK

Several other factors have been identified to influence medicine shortages and PSC. Some of these factors include UK pricing procedures, parallel trade, and reimbursement policies (Gloor et al. 2013). There are, however, limited studies examining the link between medicine shortages and various regulations.

3.2.4.2.3.1. UK Pricing Procedures for Branded Medicines

In the UK, there are two types of pricing arrangements for branded medicines: (1) the voluntary scheme for branded medicine pricing and (2) the statutory scheme. In January of 2011, a new voluntary scheme was flagged as a continuation of the voluntary scheme that has been in existence since 1957 (Ranson et al. 2019). The Pharmaceutical Price Regulation Scheme (PPRS), commonly known as the voluntary scheme is made up of the Department of Health Service Commission (DHSC) and pharmaceutical industries in the UK where prices of pharmaceutical products are negotiated. This scheme aims to provide a stable environment to introduce medicines into the National Health Service (NHS) as well as to ensure that patients get access to the most innovative and effective treatment available (PSNC, 2018). When setting pricing of an individual branded medicine under this scheme, there are several factors that firms must consider to include; how well the medicine treats patients, the value that the health systems may attach to the medicine that it is supposed to cure and the price of the competing products (Ranson et al. 2019).

The National Institute for Health and Care Excellence (NICE) is an executive non-departmental public body of the Department of Health in England, which publishes guidelines for the NHS on the cost-effectiveness of new medicines. It does this by paralleling the costs associated with giving a patient an extra year of ‘quality life’ in comparison to the treatment already being used (ABPI, 2019). The branded drug price is set using the Pharmaceutical Price Regulation Scheme (PPRS), and the NHS then reimburses the drug according to the manufacturer's list price. The underlying aim of the set prices is to cap the spending of the NHS. The regulatory pricing regime for medicinal products is

contained in the National Health Service Act 2006 and the Health and Social Care Act 2012 (DHSC, 2017).

The Statutory Scheme has also operated like the Voluntary Scheme in the last year (ABPI, 2019). Here manufacturers are required to pay a rebate to the Department of Health Service Commission which reflects a percentage of their sales of branded medicines to the NHS. The pricing scheme that was introduced in April of 2018 set the rebate at 7.8%. However, manufacturers are expected to pay 9.9% in 2019 and 14.7% and 20.5% in 2020 and 2021 respectively. These prices are for contracts entered into after the 1st of January 2019 (Ranson et al. 2019).

The pricing schemes elucidated in the preceding paragraphs highlight that, although manufactures can set their price lists, the total income of manufacturers are regulated by the Pharmaceutical Price Regulation Scheme (PPRS) which is renegotiated every five weeks. This implies that although theoretically, the UK operates a free price market in principle, this is not the case, as manufacturers to an extent are constrained in what they can charge for their patent-protected medicines. Thus, once a manufacturer sets their price lists, there are tight controls on the circumstance that prices can be increased. This implies that if prices are too low, manufacturers may be forced to withdraw their products from the market which may lead to medicine unavailability (Gloor et al. 2013; De Weerdt et al. 2017). These low market prices can also incite medicine shortages through parallel trading (Kanavos et al. 2011).

3.2.4.2.3.2. UK Pricing Procedures for Generic Medicines

In the UK, regulatory policies for the pricing of generic or off-patent medicines are covered by the drug tariff produced by the Pharmaceutical Directorate of the NHS Business Services Authority and provided to pharmacists and health care practices. Here, the drug tariff contains information on the levels of reimbursement and remuneration to be paid to contractors for NHS Services. Reimbursement pertains to the cost of drugs and appliances supplied on an NHS Prescription form and remuneration relates to professional fees/allowances payable as part of the NHS pharmacy contract.

Part, VIIIA of the Drugs Tariff, lists basic prices for generic drugs. This Part is divided into:

- Category A items include generics that are widely used and are widely available. The price of these is based on a weighted average of list prices from wholesalers and generic manufacturers.
- Category C items are based on a brand or manufacturer's price.
- Category M items include readily available drugs. For these, the DHSC calculates the price based on information submitted by manufacturers.

Part VIIIB lists basic prices for some unlicensed medicines. It provides that, in that case, the pack size listed for the product will be used as the minimum amount for reimbursement. Where prescription orders are any more than the minimum amount, the price will be based on the listed pack size plus the 1ml or 1g list price for every additional 1ml or 1g prescribed (DHSC, 2019).

Category M prices are based on information gathered from manufacturers on volumes and prices of products sold plus information from the prescription services on dispensing volumes to calculate margins in the supply chain. Its purpose is to help ensure that the total contract funding available to pharmacies contains the agreed amount of retained purchase profits (£800 million in England, and proportionate amounts in Wales and Scotland).

The £800m retained margin element is a target that the Department of Health and Social Care (DHSC) aims to deliver by adjusting the reimbursement prices of drugs in Category M of the Drug Tariff. PSNC and the DHSC carefully monitor the delivery of margin to the pharmacy. Where the Margins Survey identifies the delivery rate of margin to community pharmacy will under or over-deliver on the £800m target, the DHSC will re-calibrate Category M Drug Tariff prices to bring the margin delivery rate back on track.

3.2.4.2.3.3. Reimbursement Policies

Another regulatory framework that has been identified as pivotal to the discussions of medicine shortages, especially in the UK, is the framework for reimbursement policies (De Weerdt et al. 2015). Although the costs of new health care technologies are on the increase, there are tight constraints to health

care spending. With reference to the UK, pharmacies are reimbursed by the NHS for products dispensed which are dependent on their submissions of NHS prescription and reimbursement prices in the drug tariff. In the absence of drug tariffs, the manufacturers' list price is used (Ranson et al. 2019).

Primary care pharmacies often purchase drugs in bulk from wholesalers or pharmaceutical companies at lower prices (that is within the price band set by the NICE) and therefore marginal gain is expected from the difference between the purchase price and reimbursement price. Also, as at the 1st of April, 2019 these pharmacies received a fixed payment of £9.00 for prescribing medicines. The elderly, pregnant women, women who have had a baby in the previous 12 months, citizens with a medical exemption certificate and children do not pay these prescription charges (PSNC, 2017; NHS, 2019). The underlying issue with these reimbursement policies is that most payments are made after the pharmacies have dispensed the drugs and so in most cases, pharmacies may not stock medicines that are not in high demand in seeking to free up cash (Kanavos et al. 2011).

Another exciting facet of the reimbursement policies is the framework related to retained margin often referred to as the category M. Category M was introduced into the Drug Tariff in April 2005 when the new community pharmacy contracts were revamped. It requires pharmacies to earn a maximum of £800m per annum. This £800m is the retained buying profits, i.e. the profit pharmacies can earn on dispensing drugs through cost-effective purchasing (PSNC, 2019).

Pricing and reimbursement procedures allow national authorities to set or negotiate prices for pharmaceuticals. These prices are however influenced by many factors, such as the national gross domestic product (GDP) and willingness to pay, resulting in different prices between the Member States of the EU (Vogler et al. 2008; Kanavos et al. 2011). The differences in pricing procedures can lead to (high) price differences between the Member States. These price gradients may result in practices of parallel trade which may result in medicine shortages (Bart, 2008; Forrester and Dawes, 2010). The presence of parallel markets may also highlight the weakness in the supply chain, which may increase the incidences of medicine shortages.

Medicine prices may also lead to the unavailability of drugs since manufacturers avoid low price markets for market placement of new and innovative drugs to recover high investments (Gloor et al. 2013). There is, therefore, a need for further research to address these exposures that may facilitate supply chain disruptions (Gloor et al. 2013).

3.2.5. Summary

From a supply chain perspective, medicine shortages can be categorised as a type of demand risk, because of the inability of supply to meet the demand. However, medicine shortages have spread into supply risks as a result of raw materials being unavailable, failure of quality inspection, insolvencies of suppliers, mergers and acquisitions and reputational problems; and as such are termed a dynamic disruption. In the last decade, issues relating to medicine shortages in the UK have been on the increase with their underlying causes differing at every point in time (Bogaert et al. 2015; Pauwels et al. 2015; Burki, 2019; Rimmer et al. 2019). While some supply chain actors are better able to withstand the impact of these disruptions, others still lag.

The continuity of operations in PSCs is essential to human welfare and the span and quality-of-life of patients. However, the uniqueness of the PSC such as stringent regulations, the criticality of the product, limited availability of alternatives, the need for specialist knowledge about the effects of medicines in humans, the necessity to balance clinical versus economic interest and to consider patient safety all increases complexity in the event of disruptions. This, therefore, reinforces the need to understand how and if suggested resilience strategies may be used in mitigating the impact of disruptions in PSCs.

3.3. Overview of Empirical Research on Resilience and the PSC

Chapter Two elucidated the elements of supply chain resilience, and Chapter Three identified the peculiarities of the PSC and contextualised elements of resilience within the PSC. This section reviews empirical literature that has focused on examining resilience strategies in the PSC in order to identify the underlying gaps. A search of empirical literature surrounding resilience in the

PSC revealed that there were only seven papers relevant to this study's research objectives (Klueber and Keefe, 2013; Mehralian et al. 2015; Aigbogun et al. 2015; Lücker and Seifert, 2017; Lücker and Seifert; 2017; Ward and Hargaden, 2019; Tucker et al. 2019). The findings from these articles, however, remained inconclusive about optimal strategies for building resilience in the PSC and did not take a systemic approach nor take account of the complexities and interrelationships within the PSC.

For instance, some of the papers focused on specific aspects of supply chain resilience, as seen in the study by Klueber and Keefe (2013). Their paper suggested that supply chain visibility cannot be achieved in a highly regulated environment as the government may require additional information relating to its supply chain. Furthermore, Mehralian et al. (2015) argued that as a result of the emerging demand and complexities of the PSC, it might be challenging to see through the nodes in the supply chain, thereby making it difficult to prepare or respond to disruptions. In regulated industries, there is, therefore, a requisite level of visibility that should be assessed.

Lücker and Seifert (2017), also provided empirical evidence for agility capacity in mitigating the impact of disruption in the PSC concerning life-saving medicines. Their argument here is that the PSC has no unique peculiarities, and as such resilience strategies can be applied. Also, they assert that resilience strategies are predominantly implemented at mature stages of the medicine life cycle when demand is stable. However, resilience strategies are dynamic, and the implementation stages of resilience strategies cannot be restricted to only a stage of a medicine's life cycle as disruptions have no timeline. In the same vein, Sabouhi et al. (2018) explored supply chain design and resilience strategies under operational and disruption risks in PSCs. With the use of simulation techniques, the study found that redesigning supply chains in the face of disruptions was paramount in developing resilience.

Other studies failed to explain why vulnerabilities occurred in the supply chain and how resilience strategies could be used in mitigating the vulnerabilities. Take, for example, the study by Aigbogun et al. (2015), who used the grounded

theory approach to examine vulnerabilities and capabilities of the Malaysian PSC. The study found vulnerabilities to include turbulence, sensitivity as well as external pressures. Adaptability, collaboration and reserve capacity were the adapted resilience strategies.

It can also be observed that although these studies have focused on how to achieve resilience in PSCs, the studies failed to explain why the supply chain was vulnerable to the impact of disruptions. The exceptions to this were the study by Tucker et al. (2019) who used optimisation techniques to study the resilience of the PSC to medicine shortages in the US. Their study concluded that deliberate managerial decisions were a primary vulnerability driver within PSCs, but this was targeted at low-cost medicines. Also, Ward and Hargaden (2019) explored risk and resilience in PSCs. In their study, the Pettit et al. (2013) resilience framework SCRAM was used to measure the level of resilience in PSCs to medicine shortages as disruption. Their findings suggested that for PSCs to develop resilience, visibility, collaboration, and flexibility had to be enhanced. They, however, did not justify if the low levels of resilience strategies increased the supply chains vulnerabilities.

By reviewing the literature above, issues reported which impact on supply chain resilience in the pharmaceutical supply chain includes visibility, vulnerability, product life cycle and system maturity as indicated by the studies presented in Table 3.4 below.

Table 3.4 Empirical evidence of PSC resilience

Author	**Focus**	**PSC insight**
Klueber and Keefe (2013),	Visibility, Regulations	Supply chain visibility cannot be achieved in a highly regulated environment
Mehralian et al. (2015)	Visibility	As a result of the emerging demand and complexities of the PSC, it may be difficult to see through the nodes in the supply chain, thereby making it difficult to prepare or respond to disruptions.
Aigbogun et al. (2015)	Vulnerabilities and resilience	Vulnerabilities include turbulence, sensitivity and

		external pressures. Resilience strategies include adaptability, collaboration and reserve capacity.
Lücker and Seifert (2017)	Agility capacity	No unique peculiarities and as such, any resilience strategy can be applied. Resilience strategies are employed at the mature stages of the PSC.
Sabouhi et al. (2018)	Supply chain design	Redesigning supply chain is paramount in developing resilience.
Ward and Hargaden (2019)	Risk and resilience using SCRAM tool by Pettit et al. (2010)	PSCs develop resilience, visibility, collaboration and flexibility.
Tucker et al. (2019)	Vulnerabilities and Resilience	Deliberate managerial decisions were a primary vulnerability driver within PSCs, but this was targeted at low-cost medicines

Source: Researcher's Compilation (2019)

The summary table showed that the studies failed to explain why vulnerabilities occurred in the supply chain and how resilience strategies could be used in mitigating the vulnerabilities. Also, there was no observed use of theory in any of the studies, and these studies failed to adopt a systemic approach to understanding how the various elements of PSC resilience (vulnerabilities and antecedents of resilience strategies) are interrelated. The literature reviewed in this section revealed that existing studies had explored resilience strategies from a fragmented perspective: as parts of a whole, rather than using a systemic, holistic approach. This study, therefore, posits that if PSC resilience is explored from a CAS perspective, which adopts a holistic approach, our understanding of PSC resilience will be enhanced.

The next section, therefore, explores the use of theory within supply chain resilience literature.

3.4. Use of Theory in the Supply Chain Resilience Literature

In this section of the study, a review of theories that have been used to understand and explain supply chain resilience within the more extensive empirical literature is examined, and the most relevant to this study is identified.

The use of established theories in empirical research is pertinent, as it provides a framework to help understand a phenomenon, identify the link between variables as well as enhance generalisability of findings across various contexts (Foy et al. 2011). Several theories have been employed to elucidate resilience as a phenomenon within the supply chain literature: Resource-Based View (RBV) (Holweg and Pil, 2008; Blackhurst et al. 2011); Dynamic Capability Theory (Ponomarov, 2012) and Systems Theory (Erol et al. 2010; Spiegler et al. 2012). Table 3.5 below presents a summary of the theories and discusses their limitations for gaining an understanding of PSC resilience (PSCR).

Table 3.5 Summary of theories used in supply chain resilience literature

Theories	Use in supply chain resilience studies	Limitations for PSCR discussions
Resource-Based View (RBV) Holweg and Pil (2008); Ponomarov and Holcomb, (2009); Park (2011); Brandon-Jones et al. (2014); Brusset and Teller, 2017; Cheng et al. (2017) Dubey et al. (2017).	Resilience strategies are the firm's redundant, capital or flexible resources which are used to gain competitive advantages	Antecedents of resilience strategies are limited to the internal environment of the firm in the supply chain. This theory and not explain how these resources work within a complex supply chain
Dynamic Capability Theory: Chowdhury and Quaddus, (2017); Gu and Huo (2017); Hendry et al. (2019); Sabahi and Parast, (2019).	Advocates for supply chain resilience as the ability of the firm to sense and adapt to changes in the external environment that will foster sustainability and competitiveness.	The theory does not describe the nature of intangible competencies and resources such as strategy, which may be a key factor in the success of an organisation. It also does not explain the systemic nature of resilience.
System Theory: Erol et al. (2010); Blackhurst et al. (2011); Spiegler et al. (2012); Kaviani et al. (2016)	The supply chain is viewed as an open system that constantly interacts with its environment, and resilience strategies are elements within the supply chain.	System theory does not explain the dynamism and adaptability in supply chain resilience. Supply chains in the modern world are complex systems and dynamic with various elements that interact with each other continuously, and

		strategies are developed as a result of these interactions with the environment in an adaptive way.

Source: Researcher's own (2019)

Table 3.5 above shows that three major theories have been used to explain supply chain resilience, but that they have shortcomings as a result of their inability to incorporate all the significant features of supply chain resilience. For instance, the Resource-Based View (RBV), Dynamic Capability Theory and the Systems Theory, are the most significant theories used in the study of supply chain resilience. The RBV by Barney (1991) suggests that a firm's internal tangible and intangible resources can be used to achieve competitive advantage. These internal resources, however, must be valuable, inimitable, rare and non-substitutable to determine the reaction to several internal and external threats as well as opportunities (Barney, 1991).

In supply chain resilience literature RBV has been used to explain antecedents of resilience within firms as resources and capabilities (Ponomarov and Holcomb, 2009) redundant and flexible resources (Park, 2011) and capital resources (Blackhurst et al. 2011). All these studies have examined the resilience of the supply chain at the firm level. Within this framework, it was suggested that a firm's assets and capabilities, such as -logistic capabilities, human capabilities and capital resources: - can be used to foster resilience within a supply chain. However, this theory limits resilience to only the internal workings of the firm. It does not take into cognisance the suppliers, systems, dynamism and co-evolution features of resilience (Tukamuhabwa et al. 2015) and as such fails to incorporate some essential elements required in explaining what resilience entails.

Supply chain resilience is a system-level phenomenon that occurs at a supply chain level rather than an individual firm, and it requires the interconnections between firms. Thus, the RBV does not provide comprehensive insights into understanding supply chain resilience. System-level thinking is in line with the arguments by Kim et al. (2015) who advocate for supply network analysis for

understanding resilience. Further, supply chain resilience has emergent characteristics as a result of the dynamic and unpredictable nature it may respond to. System-level thinking contrasts with the RBV, which focuses on internal firm-level individual and separate resources and ignores the synergies and interactions of these resources between firms (Kraaijenbrink et al. 2010). In view of this, it can be argued that pharmaceutical supply chain resilience cannot be objectively measured nor appropriately described using reductionist approaches such as RBV (Brownlee, 2007).

Similarly, the Dynamic Capability Theory has been employed as a lens in comprehending resilience strategies in the supply chain (Ponomarov, 2012). Dynamic capability theory by Teece et al. (1997) advocates for supply chain resilience as the ability of the firm to sense and adapt to changes in the external environment that will foster sustainability and competitiveness. It can be regarded as appropriate, as it captures the dynamic aspects of resilience in the supply chain. This theory is, however, insufficient as it does not describe the nature of intangible competencies and resources like a strategy, which may be a key factor in the success of an organisation. It also does not explain the systemic nature of resilience (Day, 2014).

The Systems theory, on the other hand, takes into cognisance resilience strategies as a system (Blackhurst et al. 2011; Erol et al. 2010; Speigeler et al. 2012; Kiavani et al. 2016). The supply chain is a system that continually interacts with its environment, while resilience (agility, flexibility, redundancy and reengineering) is an element of this system. Although resilience factors are elements of a system, it is, however, not static as pointed out by Blackhurst et al. (2011). More so, today's supply chains go beyond traditional systems; they are complex systems with elements that continuously interact with each other and with their environment in an adaptive way. Resilience entails dynamism as it is ever-changing, evolving and adapting to the environment in which the supply chain operates. This means that supply chains are complex adaptive systems (Day, 2014; Carter et al. 2015), and their resilience is achieved through adaptive and co-evolving processes.

This study, therefore, proposes Complex Adaptive System (CAS) theory (Holland, 2006; Choi et al. 2001, Holweg and Pil, 2008; Day, 2014) as the most compelling theory in explaining supply chain resilience and the PSC. This is based on the notion that resilience strategies deal with a high level of abstractions concerning business environments. As such, businesses can gain a competitive advantage from their complex interactions with their environment (Levy, 2000). CAS theory will be discussed in more detail in section 3.4.1.

Day (2014) employed CAS theory in elucidating how resilience strategies worked in disaster relief supply chain networks and concluded that disaster relief networks differed significantly from other supply chains in operations. In the same vein, Tukamuhabwa et al. (2017) used CAS theory to explain resilience strategies from a developing economy context and established that embeddedness contributed to the phenomenon of supply chain risk mitigation in developing economies. These supply chains may, for instance, designed to withstand threats inherent to the economy in context. There are many other supply chains, such as the PSC that are exposed to varying forms of disruptions-including dynamic disruptions. These supply chains also need to be resilient, and features like complexity, adaptation, coevolution and feedback loop may be identified as relevant. Therefore, CAS can offer insights into understanding and interpreting empirical studies on resilience in PSCs. In the next section, an overview for using the CAS theory as a framework for studying PSC resilience is outlined.

3.4.1. CAS Theory and Resilience in the PSC

CAS theory bears its roots in complexity theory which emerged to provide explanations as to how order emerges in natural sciences that are complex and non-linear such as the human system and the galaxy (Mason, 2008). CAS theory has gained popularity in the social sciences in contexts such as; organisations studies (Schiender and Somer, 2006), stock markets (Maboussin, 2002) and supply chain networks (Choi et al. 2001; Surana et al. 2005; Day, 2014; Tukamuhabwa et al. 2015), advocating that most social systems have complex features which require simple reasoning (Corbacioglu et al. 2016).

According to CAS theory, a complex adaptive system is made up of a range of elements, referred to as agents who follow sets of internal rules or schemas that guide their actions (Choi et al. 2001). These schemas provide the agents with reference points for their behaviour and can be applied to new situations rather than assessing new rules for every possible situation (Nair and Reed-Tsochas, 2019). CAS theory proposes a higher level of interaction between components of a complex system with its distinguishing feature of adaptability (Holland, 2006). The complex adaptive system focuses on the interactions between the agents and how these agents interact with their changing environment. This determines the system's behaviour. Since most of the interactions between agents and their environment are non-linear, the outcome and/or the behaviour of the system is usually unpredictable (Choi et al. 2001).

Other features of a CAS include *emergence*, which is a central feature of a CAS where new behaviours emerge based on the interactions between each agent and the overall system. Agents can be eliminated, or new agents emerge as a result of interactions. Closely linked to emergence is *adaptability*; the ability of the system to adapt to changes that stem from agents' reactions to their environment as well as how they learn new behaviours (Holland, 2006). A complex adaptive system is also decentralised. Since agents' interactions determine the system's behaviour, self-organisation is inherent as no single agent controls the way a system may behave. This is referred to as *self-organisation*. *Anticipation* is the outcome of rules developed in seeking to adapt to the changing circumstances with the environment, as described by Holland (2006). A CAS, therefore, anticipates the consequences of these actions or activities.

Choi et al. (2001) and recently updated by Nair and Reed-Tsochas (2019), provide a CAS framework as presented in Table 3.6 below. This framework categorises elements of CAS into three significant dimensions which are the internal mechanisms, external mechanisms and co-evolution. Thus, agents, schema, self-organization and emergence, network connectivity, and network dimensionality are the critical elements of internal mechanisms. The external mechanisms represent the environment to which those decision-making agents

respond. More precisely, changes in the environment are the basis for a CAS to display dynamism. Agents respond to the changing environment and react to other agents' actions. Coevolution characterizes the nonlinear changes in schemas, network connectivity, network dimensionality, and the external environment that result from their decisions. The changes made by the agents in responding to the environment cause further changes to the environment, thereby causing the agent and the environment to coevolve. It is against this categorisation that the contribution of CAS theory to PSC resilience will be drawn.

3.4.2. Contribution of CAS Theory to PSC Resilience

A Complex Adaptive System has been suggested to mirror supply chain resilience as they both possess similar characteristics (Choi et al. 2001; Surana et al. 2005; Wycisk et al. 2008; Hearnshaw and Wilson, 2013; Day, 2014; Tukamuhabwa et al. 2015; Nair and Reed-Tsochas, 2019).

PSC resilience conceptualised as a CAS thus indicates the existence of the internal mechanism, external mechanism and coevolution. The internal elements of the PSC resilience include supply chain characteristics, the agents in the PSC and the decisions made in response to the environment in which it exists. Therefore, the agents referred to in CAS theory are suppliers, distributors and consumers within the supply chain (supply chain actors) while the system will be the network of firms that collectively supply part or all the consumers' demands.

The external element of CAS involves the environment in which the system operates (Day,2014). The environment consists of government policies, labour unions, economic volatility and nature (Choi et al. 2001).

Coevolution in PSC resilience is the outcome of the actions and interactions of the external system to the decision-making process of the internal system (Nair et al. 2009). For example, when a disruption like medicine shortages occurs, supply chain actors adapt to this event by taking individual decisions such as: using flexibility, joint decision making, quota/rationing and stockpiling. These elements are referred to as emergent behaviours according to CAS theory. This

suggests that the interactions and responses to the interactions between supply chain actors lead to emergent behaviours, as mentioned. The process of responding to a disruption, according to CAS theory, is referred to as adaptability (Choi et al. 2001; Wysick et al. 2008; Day, 2014). The actions and interactions of supply chain actors within the system and with the environment result in new behaviours within the system which differ from previous behaviours. The constant changes in behaviour by supply chain actors as a result of the decision made, the interaction with other supply chain actors and actions taken based on the consequences of the interaction, brings about coevolution.

PSC resilience depicts features which are inherent to that of a CAS. As such, the study of PSC resilience strategies appears to rest comfortably within the theoretical lens of CAS. For instance, resilience strategies propose adaptive features which emerge as a result of the supply chains' interaction with their environment. This implies that for a supply chain to be resilient, it has to adapt to threats within its environment without violating the integrity of the system. Usually, this adaptive feature requires modifying the supply chains environment such as selecting new members in the supply chain, enhancing information flow and collaboration. The process of modifying its environment is referred to as co evolution.

Table 3.6 below provides a summary of how the components of CAS (internal, external and coevolution mechanisms) logically fits into the concept of PSC resilience. The table shows that CAS features such as internal mechanisms, external mechanisms and coevolution can be employed to explain the application of supply chain resilience strategies. The table depicts that resilience strategies emerge as a result of the supply chain's interaction with its environment. These emergent features occur in a nonlinear and dynamic manner as a result of the collective decisions and actions of individual firms.

Table 3.6 A summary of PSC resilience as a CAS

Features CAS	CAS and PSC	CAS and PSC Resilience
Internal Mechanisms	For CAS theory, internal mechanisms imply the ability of the PSC as a complex system to be flexible in responding to changes in an environment, such as;- new regulations, change in consumer lifestyle, disruptive activities the PSC will have to adapt to meet up with consumers demand as well as remain competitive.	Internal mechanisms refer to the interactions of supply chain actors with each other and their decision-making process in response to the changes within the environment. These decisions could include information sharing, outsourcing, supply chain design, power, strategic alliance. The decision-making process also reveals how supply chain reacts with each other. The interaction process between supply chain actors may be non-linear, and so their outcomes are uncertain.
External Mechanisms	External mechanisms in the PSC refers to consumer prescription habits, pandemics such as natural disasters medicine shortages, government regulations, financial crises	External mechanisms refer to disruptions which can be dynamic or static.
Coevolution	Supply chains demonstrate coevolution features when responding to disruptions from the as government policies, disruptions and economic environment changes, the firms within the supply chain respond to these changes, which may, in turn, affect the environment they operate.	The outcome of the decision-making process by supply chain actors in response to environmental changes may either build resilience into the supply chain or vulnerable to the impact of dynamic disruptions, for instance, in the event of an outbreak. The decision of supply chain actors to engage in flexible operations (Tukamuhabwa et al. 2015, Scholten et al. 2019) to meet the growing demand for flu-related medicines may build resilience into the supply chain. However, if supply chain actors decide to ration medicines in seeking to control medicine flow, the supply chain may become vulnerable to the impact of disruptions.

Source; Researcher's own (2019)

3.5. Summary of Research Gaps

This chapter aimed to provide the context of the underlying research within existing vulnerabilities, disruptions, resilience and the PSC literature. The review of the literature highlighted the peculiarities of the PSC as well, justified the need for the use of CAS theory and examined existing studies that have contextualised resilience within the PSC. There is still a need to understand how resilience strategies can be employed to mitigate various forms of disruptions. This is because the types of disruptions for which resilience strategies have been suggested to mitigate are static in nature, such as natural disasters and fire outbreaks (Sheffi and Rice, 2005).

Limited attention has been given to examining the potential of resilience strategies in the face of dynamic disruptions, and the use of CAS theory may provide a different perspective. There is a need to understand dynamic disruptions like medicine shortages to ascertain the applicability of resilience strategies. Also, in the context of the PSC, which differs from other supply chains in having longer lead supply times, stringent regulatory frameworks, severe demand forecasting and complex applications will influence the applicability of resilience strategies.

Although various vulnerabilities have been highlighted in the literature as possible reasons for weaknesses within the supply chain, empirical evidence supporting these assertions is limited in the literature. Analysing vulnerabilities is the first step to implementing resilience strategies; this is line with the conventional business wisdom ‘’you can’t manage, what you don’t measure’’. This calls for the need to quantify the vulnerabilities the supply chain is exposed to, to evaluate the need for costly strategies for resisting disruptions that may rarely occur (Wagner and Neshat, 2010). Therefore, an adequate understanding of the vulnerabilities of the supply chain in tandem with forms of disruptions and reference to the pharmaceutical supply is of the essence to ascertain if resilience strategies can be applied effectively.

The studies on supply chain resilience strategies rely on the premise that by building resilience strategies, inherent vulnerabilities will be reduced; an assumed interaction that will be inevitable from a CAS perspective (Christopher

and Peck, 2004; Peck, 2005, Jüttner and Maklan, 2011). There are no empirical studies; however, to support these assumptions, and there is a lack of understanding of how vulnerabilities interact with resilience strategies within supply chains. Are resilience strategies developed to reduce specific vulnerabilities, or are they generic?

The review of literature also reveals that there has been limited application of theory in understanding supply chain resilience and situating it in context. Therefore, to adequately interpret the research findings as well as understand in detail the empirical evidence that will be provided, the study seeks to harness supply chain resilience by introducing CAS as a theoretical lens in a PSC context. Specifically, three significant gaps can be identified in the literature:

First, there is a need for further empirical work in understanding vulnerabilities from a PSC perspective. The PSC has been argued to possess unique characteristics and as such may differ from other supply chain networks. The PSC is, however, exposed to varying degrees of disruptions and supply chain managers may be adopting strategies that are detrimental to the health of these supply chains. Understanding supply chain vulnerabilities within this context is limited.

Secondly, there is a need to understand how supply chain managers use the various strategies proposed in building resilience to reduce the impact of disruptions.

Thirdly, understanding the interactions between resilience strategies and vulnerabilities is pertinent. Do the antecedents of resilience decrease vulnerabilities or reinforce them? Therefore, this thesis adapted CAS as its theoretical lens, to systematically explore vulnerabilities and the outcomes of adopted strategies. A summary of how the literature informed the research questions is presented in Table 3.7.

Table 3.7 Linking the literature to the research questions

Studies in the literature (Authors)	Gaps identified in the literature	Research questions proposed in this study
Christopher and Peck (2004); Peck (2005); Wagner and Bode (2006); Craighead et al. (2007); Klueber and Keefe (2013); Mehralian et al. (2015); Aigbogun et al. (2015); Lücker and Seifert (2017); de Lima et al. (2018).	First, there is a need for further empirical work in understanding vulnerabilities from a PSC perspective.	Why is the PSC in the UK susceptible to dynamic disruptions?
Ponomarov and Holcomb (2009); Wagner and Neshat (2010); Jüttner and Maklan, (2011); Ponomarov (2012); Day (2014); Kim et al. (2015); Tukamuhabwa et al. (2017). Mehralian et al. (2015); Aigbogun et al. (2015); Lücker and Seifert (2017); de Lima et al. (2018).	There is a need to understand how supply chain managers use the various strategies proposed in building resilience to reduce the impact of disruptions in the PSC.	RQ2: How are resilience strategies used to mitigate the impact of dynamic disruptions in the PSC?
Pettit et al. (2010); Jüttner and Maklan (2011). Ruel et al. (2019)	There is a need to understand the interactions between resilience strategies and vulnerabilities is pertinent. Do the antecedents of resilience decrease vulnerabilities or reinforce them?	RQ3: What impact do resilience strategies have on vulnerabilities in the PSC?

Building on the above gaps, the aim of this thesis, therefore, was to explore vulnerabilities from a PSC context. It will do this by investigating what PSC actors in the UK perceive as the vulnerabilities and what they do to expose their supply chain to the impact of disruption like medicine shortages. Secondly, how do supply chain managers use the various strategies proposed in building

resilience to reduce the impact of disruptions? What are the outcomes of the interactions between supply chain vulnerabilities and resilience strategies in the PSC?

By answering these research questions, this thesis hopes to contribute to operations management literature by exploring the dynamics of the pharmaceutical supply with regards to its disruptions and vulnerabilities. It also seeks to extend the existing literature by assessing the applicability of resilience strategies in curbing the impact of disruptions (medicine shortages) in the PSC.

In seeking to answer the research queries justified in this chapter, the next chapter, presents and describes the methodology to be adopted in the study. This is mainly centred on elaborating the choice of the instruments used, data collection as well as data analysis techniques. The objectives also justify adopting these tools.

Chapter Four: Methodology

4.1. Introduction

This study aimed to investigate why pharmaceutical supply chains (PSC) are susceptible to the impact of dynamic disruptions and to explore the resilience strategies employed to curb these disruptions. In this chapter, therefore, the research methodology used in this study is described. The chapter begins by discussing how the literature informed the research design (4.2). This is followed by outlining and justifying the research design, which was adapted from Creswell (2009) research design framework (4.3). The following sections build on the research design framework and entail: the research philosophy (4.3.1) and, research approach (4.3.2). The research techniques and procedures were divided into two major phases, and these are discussed in section 4.3.3. Section 4.4 provides explanations about the quality of the research design and the guiding ethical considerations in this study. The chapter is concluded by identifying the methodological limitations of the study.

4.2. How the Literature Informed the Research Questions

The first three chapters of this thesis focused on the key research questions, highlighting the lack of empirical studies on resilience within the PSC and the gaps identified in the literature. The review of literature in the preceding chapters provided evidence to contend that there is scanty information regarding vulnerabilities and resilience strategies in the PSC. More specifically, the review of the literature revealed a need for further empirical work in understanding vulnerabilities from a PSC perspective as a result of the uniqueness of the PSC which hitherto has been limited. There was also a need to understand how supply chain managers used resilience strategies to reduce the impact of disruptions as well as examine the interactions between resilience strategies and vulnerabilities from a CAS perspective.

Based on the identified gaps from the literature, a review of the research questions has been set out in Table 4.1 as they are pertinent in the research design and inform the choices of the research strategy, data collection techniques and analysis (Saunders et al. 2012).

Table 4.1Linking the research questions to the research design

Studies in the literature (Authors)	Gaps identified in the literature	Research questions proposed in this study	Research aims	Proposed methodological approach
Christopher and Peck (2004); Peck (2005); Wagner and Bode(2006); Craighead et al. (2007); Klueber and Keefe (2013); Mehralian et al. (2015); Aigbogun et al. (2015); Lücker and Seifert (2017); de Lima et al. (2018)	There is a need for empirical work in understanding vulnerabilities from a PSC perspective.	RQ1: Why is the PSC in the UK susceptible to dynamic disruptions?	The aim is to gain insights into the PSC by exploring the perception of actors at various levels of the PSC.	Qualitative techniques (Creswell and Poth, 2016).
Ponomarov and Holcomb (2009); Wagner and Neshat (2010); Jüttner and Maklan, (2011); Ponomarov and Holcomb (2012); Day (2014); Kim et al. (2015); Tukamuhabwa et al. (2017); de Lima et al. (2018)	There is a need to understand how supply chain managers use the various strategies proposed in building resilience to reduce the impact of disruptions in the PSC.	RQ2: How are resilience strategies used to mitigate the impact of dynamic disruptions in the PSC?	The aim was to explore resilience strategies that supply chain actors adopt in reducing the impact of dynamic disruptions in the pharmaceutical supply chain.	Qualitative techniques (as above)
Jüttner and Maklan (2011) ; Scholten et al. 2014	The need to understand the interactions between resilience strategies and vulnerabilities is pertinent. Do the antecedents of resilience decrease vulnerabilities or reinforce them?	RQ3: What impact do resilience strategies have on vulnerabilities in the PSC?	The aim was to examine the relationship between the various elements of PSC resilience and ascertain their interactions.	Quantitative techniques (Saunders et al. (2012)

Table 4.1 above, therefore summarises the link between the literature, identified gaps, research questions and the methodological approach used to answer the research questions. It also identified the need to use both qualitative and quantitative techniques in this study. This suggests that the study might adopt a mixed-methods approach, as described by (Johnson et al. 2007; Creswell, 2009). A mixed-method approach requires both qualitative and quantitative techniques to answer the research questions.

4.3. Research Design

Research designs are the plans and processes for research that cover the decisions from broad assumptions to detailed methods of data collection and analysis (Creswell, 2009). Designing a research study is vital as it provides explanations and justification on: the type of data to collect, how the data is to be collected, where the data is collected as well as how it is to be analysed interpreted and presented (Yin, 2013). The research design framework by Creswell (2009) has been adapted to guide the research design in this study. The framework consists of three broad components: philosophical underpinning, research approach and research techniques which provides clarity and depth explaining the necessary components of research methodology. Figure 4.1 below summarizes the framework that has been used in this study.

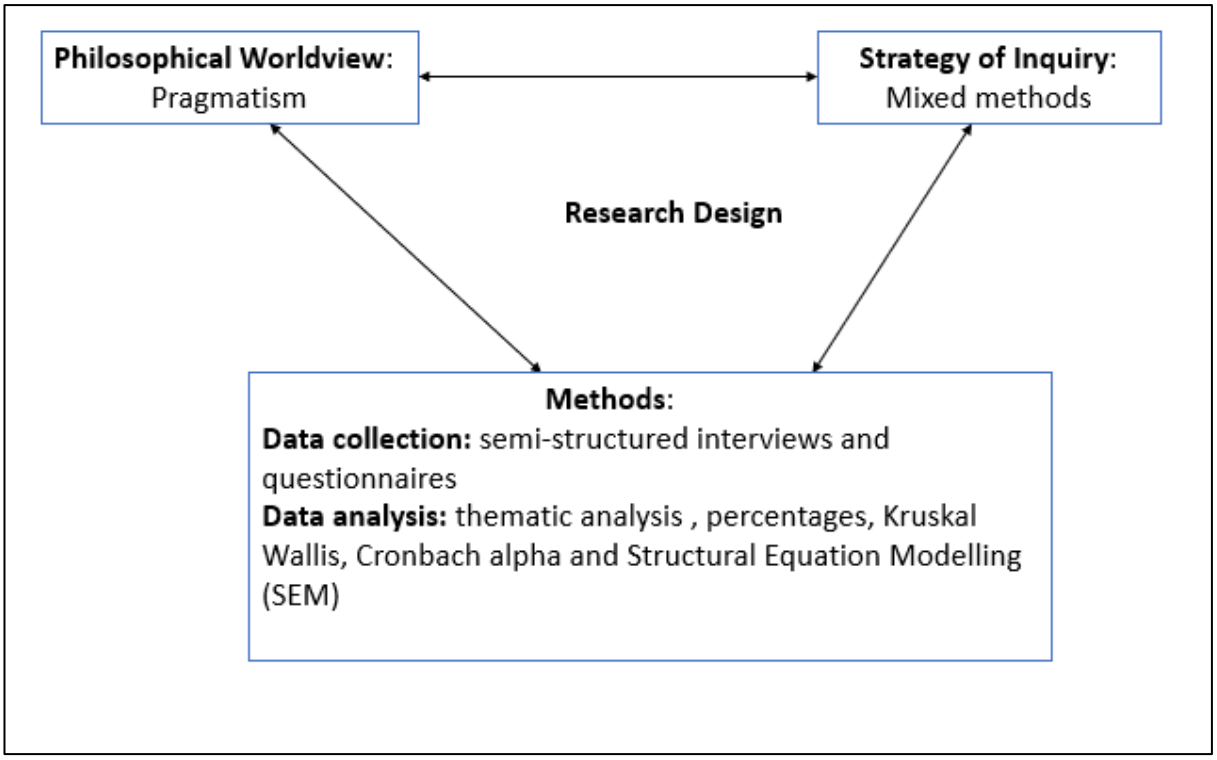

Figure 4.1 Research Design Framework adapted from Creswell (2009).

The framework from Figure 4.1 shows that the research design in this study was the mixed-methods and the philosophical worldview for the study adopted was pragmatism. The strategy of inquiry adopted the mixed-method strategy, which entailed the use of both qualitative and quantitative methods. A detailed discussion of the research design are provided in the sub-sections below.

4.3.1. Philosophical Worldview: Pragmatism

Before discussing and justifying the relevant methods used in addressing the key research questions in this study, it was imperative to gain insight into the underlying philosophical perspectives around the methods adopted in this research. This is based on the premise that research is grounded on philosophical assumptions (Amaratunga and Baldry, 2001).

Saunders (2012) defined research philosophy as the nature and development of knowledge. Research philosophy can be categorized into different research paradigms which are reliant on the researcher's beliefs about how knowledge is created (Johnson and Onwuegbuzie, 2004). The research paradigm refers to

the rudimentary belief system or theory that guides a researcher's actions by providing the lens through which empirical research is viewed (Weaver and Olson, 2006). It refers to the shared belief systems that shape how researchers seek knowledge as well as how they interpret the evidence they have gathered (Morgan, 2007).

According to the metaphysical paradigm, there are three linked components: ontological, epistemological and methodological assumptions which are crucial in guiding researchers (Kirkwood and Campbell-Hunt, 2007; Easterby-Smith et al. 2012). Ontology relates to the nature of the social world and has been suggested to be the starting point of any social research (Danermark et al. 2002; Alvesson and Ashcraft, 2009). It refers to the way researchers perceive reality; the point at which the form and nature of reality are conceptualized (Guba and Lincoln, 1994; Lincoln et al. 2011). Ontology questions the assumptions the researcher has about the way the world operates, and the commitment of views, the way they view social entities to identify their world perspective (Bryman, 2013). Ontology positions itself on two ends of a continuum from left (subjectivism) to the right (objectivism). Epistemological discussions entail the process of acquiring knowledge in the social world. It is concerned with what constitutes adequate knowledge in the field of study (Saunder et al. 2012). In other words, epistemology is primarily about the best way of obtaining knowledge about the nature of reality (Crotty, 2003).

There is an on-going debate regarding the most appropriate philosophical paradigm for social science and management research. The extreme contrast, however, falls between positivism and constructivists on a continuum. Positivism is based on the belief that scientific knowledge should be verified with the ability to be generalized (Guba, 1990). On the extreme left of the continuum are the constructivists with a subjectivist's stance who propose that the process of acquiring knowledge is intertwined with the researcher and reality of a phenomenon is subject to the actor's interpretations'-and experiences of an event (Creswell and Plano-Clark, 2017). Constructivists believe that knowledge is acquired through human concepts and perceptions, and as such, it is impossible to distinguish the knower from the known (Guba, 1990).

Research scholars also argue that research may be built on both positivism and anti-positivism philosophical stance (Burrell and Morgan, 1979). This type of research should occupy a certain position along the continuum between the two philosophical stances (positivism and constructivist). Thus, appropriating this, and pondering the nature of the research phenomenon at hand that is PSC resilience, this research can be positioned between post-positivism and constructivism.

With regards to the ontology, for example, most supply chain research assumes that supply chains exist irrespective of whether they are analysed at any point in time. This implies that supply chains exist because they behave in a particular manner. It is also argued that the performance of how well supply chains respond to disruptions can be measured objectively. However, performance measurements of supply chains are relative as the relevance may differ based on stakeholders' interests. Also, some scholars have argued that the supply chain is a relative concept and may depend on what the focal firm perceives it to be (Carter et al. 2015).

Also, while resilience perception can be measured objectively, attributes of resilience remain subjective and have been interactively and culturally determined phenomenon (Jones and Tanner, 2015). This study, therefore maintained that the interpretation and meanings attached to elements of supply chain resilience such as disruptions and vulnerabilities might differ among various stakeholders. Similarly, some scholars (Walker et al. 2004) have recognised that different groups of people interpret resilience according to how their interpretation fits their understanding and purpose. For example, while manufacturers in the PSC may interpret medicine shortages as a form of disruption, it may not be viewed in other commercial supply chains as a disruption, as manufacturers may source for substitute alternatives to achieve supply chain objectives.

Therefore, given the nature of the research phenomenon at hand as explained above (i.e. occupying a position along the positivism-constructivism continuum), an ontological assumption that creates a middle ground between these two philosophical positions is pragmatism. Pragmatism is a philosophical

assumption that transcends beyond paradigm wars and is the position adopted in this study. Pragmatism recognises the existence of objective reality as well as what is lodged in ones' mind (Creswell 2009). The pragmatist believes that experiences are as a result of the nature of the world (positivists) while actions come from our perceptions and understanding of the world (constructivist) (Morgan, 2014). Proponents of pragmatism, therefore, discard the traditional dualisms such as objectivism and subjectivism (Creswell and Plano-Clark, 2017).

Advocates of pragmatism appreciate the importance of using multiple methods, different world views, assumptions, forms of data collection and analysis (Creswell and Plano-Clark 2017). Pragmatism is referred to as a creed of meaning and a philosophy of truth. The pragmatist contends that the meaning of an event or the understanding of reality rests on the superiority of human experience (Denzin, 2010). Here, experiences are regarded as social in nature since they are created through the interactions of belief and action. These beliefs and actions are triggered by history or culture with entrenched emotional elements (Morgan, 2014). This is particularly relevant to this study that seeks to understand resilience from a PSC context which is expected to influence the findings.

Pragmatism has also been touted as a problem-solving philosophy as it constructs a credible model of human nature while accentuating the interaction between meaning and action (Farjoun et al. 2015). The underlying principles of this model help address contemporary issues such as rapid technological changes, globalisation, interdependencies dynamic disruptions and burdensome regulations by fostering the use of 'what works' tools in research (Child and Rodriquez, 2011). Pragmatism, thus, focuses on the research question and subsequently focuses on different approaches to obtain knowledge and information about the phenomenon under study (Tashakkori and Teddlie, 2010; Morgan, 2014). This implies that pragmatists are free to study what interests them in the way they deem suitable. This is particularly relevant to this study, where the research questions (see Table 4.1) determined the various approaches used to obtain knowledge.

Pragmatism, therefore, offers a middle position both philosophically and methodologically and this enables the selection of methodological mixes that are appropriate for answering different research questions

(Johnson and Onwuegbuzie, 2007). It is through the pragmatist philosophical position that this research takes advantage of such flexibilities during the research process as it does not require researchers to be committed to any of the traditional dualisms (Creswell, 2009).

4.3.2. Strategy of Inquiry

The strategy of inquiry provides guidelines regarding techniques to adopt when developing research designs for carrying out valid research (Easterby-Smith et al. 2012). Strategies of inquiry, often referred to as the research approach are types of designs or models that provide precise direction for procedures in research design. These strategies can be either qualitative, quantitative or mixed methods (Creswell, 2009).

In this study, the mixed-method strategy was deemed the most appropriate method to answer the underlying research questions, as identified in Table 4.1. The mixed-method approach involves using both qualitative and quantitative research strategies, techniques and concepts in a single study (Denzin, 2010; Teddlie and Tashakkori, 2009; Creswell and Plano-Clark, 2017). A recap of what qualitative and quantitative research approach entails will be presented below as it provides the foundation for which mixed-methods strategy is developed.

4.3.2.1. Qualitative Strategy of Inquiry

The qualitative strategy of inquiry entails the process of understanding a social phenomenon through the development of a complex, holistic picture, formed with words, reporting detailed views of research participants which are usually conducted in a natural setting (Arthur, 2012; Creswell and Plano-Clark, 2017). This implies that qualitative researchers study a phenomenon and try to make sense of these phenomena based on the meaning individuals attach to them.

The qualitative strategy of inquiry has been suggested as a practical approach for data collection that provides emerging themes, ideographic descriptions and a holistic perspective of the issue under study (Cassell and Symon, 2004). It also permits the researcher to interact with the research participants to feel the pulse of the phenomena under investigation and see the social reality as a subjective experience of the participants (Morgan, 1980). Qualitative methodology is used when the research strategy is inductive, where data are collected towards theoretical development and can be used for potential future hypothetical investigations (Creswell and Plano-Clark, 2017).

4.3.2.2. Quantitative Strategy of Inquiry

The quantitative strategy of inquiry is designed to test and establish the validity of an underlying theoretical proposition formulated using a scientifically adopted process (Saunders, 2012). It relies significantly upon laid down principles and measures that are tested hypothetically (Patton, 1990). Quantitative research methods, therefore, attempt to unveil the significance of data to a problem numerically, by quantifying the results from the study. The research strategy for quantitative methods is deductive as it entails theory testing rather than building. As such, data collected and analysed is directed towards testing an existing theory or its applicability in practice (Bryman, 2013).

Adopting the quantitative strategy of inquiry, thus entails collecting and analysing data as well as subjecting the data to various statistical tests in proving postulated conjectures (Collis and Hussey, 2013). It thus permits the researcher to postulate a hypothesis, which is tested and interpreted numerically. Social science researchers employ it because of its ability to predict the cause and effect of a given problem, reliability and generalisation (Cassell and Symon, 2004). Specific characteristics of quantitative research include i) the research relies on a wider range of sample size and as such it is easier for generalisations; ii) It assigns numerical data to variables and attempts to measure these variables quantitatively; iii) it is possible to distinguish the researcher from the research as researchers involvement is not required during

data collection; and iv) statistical inference and numerical comparison are used to analyse data collected (Bryman, 2013).

4.3.2.3. Mixed-methods Strategy of Inquiry

The use of the qualitative or quantitative strategy of inquiry alone has, however, been subject to various criticisms. For instance, qualitative researchers argue that the quantitative approach involves designs that disengage the researcher from the research participants and the field they are researching. In addition, the statistical correlations between variables may be defined arbitrarily by individuals undertaking the researcher(Gray, 2009; Berg, 2009; Bernard and Ryan, 2010). The mixed-method approach, therefore, overcomes the weaknesses associated with using a single method or data source and thus ensures methodological rigour (Johnson et al. 2007; Creswell, 2013).

Proponents of the mixed-method approach suggest that the combination of both methods in a single investigation produces consistency, as the high levels of internal validity of the quantitative approach and the external validity of the qualitative methods complement each other (Teddlie and Tashakkori, 2009). Also, studies that use mixed-methods are willing to gain the best understanding of the research problem and follow the pragmatist's approach (Tashakkori and Teddlie, 1998).

4.3.2.4. Designing Mixed-methods Strategy of Inquiry

There have however been debates on how best to design research strategies when combining both qualitative and quantitative methods in a single study (Johnson et al. 2007; Teddlie and Tashakkori, 2009; Golicic and Davis, 2012). Creswell (2013) explains that there are three significant research designs for mixed-methods study, namely:

i) **Convergent parallel mixed-method**: the design of a mixed-method study here involves conducting both qualitative and quantitative research at roughly the same time. The findings of the data are converged through comprehensive analysis, and both contribute towards the interpretation of the research.

ii) Exploratory sequential mixed-method: the design of this mixed-method study involves conducting research where the qualitative data is collected and analysed first, by exploring the views and experiences of participants. The findings of the qualitative research are used to develop the quantitative phase of research which is aimed at providing in detail explanation for the qualitative findings. It is termed sequential because the qualitative is followed by the quantitative method.

iii) **Explanatory sequential mixed-method**: In this design**,** research is conducted by first employing quantitative methods and then qualitative methods are used to provide answers that may not be readily obtainable by the quantitative design.

Golicic and Davis (2012) further categorise the mixed-method approach for supply chain research into four main designs, which considers the timing and weight of the methods used within the design. The various designs include:

- **Developmental:** where the initial study is used to inform the subsequent study; here, equal weight and timing are allocated to the data collection process.
- **Initiation:** like developmental mixed-methods. However, the timing and weights of methods differ, and priority is giving to the more critical method.
- **Complementarity:** the method used in researching a phenomenon is employed concurrently, where the findings from one phase complement the findings of the other**.**
- **Interpretation:** the findings from the second phase of the study are used to explain the first phase of the study.

The categorisation of the mixed-methods design presented above reflects that the decision to adopt an approach is dependent on the research aim, context and research question under investigation (Teddlie and Tashakkori, 2009). The priority each method will be given, as well as the choice of integration, is paramount (Yardley and Bishop, 2008).

In this study, the goal was to understand the vulnerabilities and resilience strategies in the PSC. Therefore, the exploratory mixed methods design was adopted, which involved the use of both qualitative and quantitative research inquiry. The qualitative data was first collected and then used to develop the tool for collecting the quantitative data (Creswell and Clark, 2017). The findings from both data were analysed to expand the insights into vulnerabilities and resilience strategies in the PSC.

The mixed-method approach adopted in this study was also considered a developmental design as the researcher employed equally weighted methods in a two-phase design; as the findings from one method (semi-structured interviews), informed the design and implementation of the following method (questionnaires). The data collected from the qualitative methods were analysed and interpreted to form questions for the quantitative methods. The findings were converged and discussed, as presented in Figure 4.2 below.

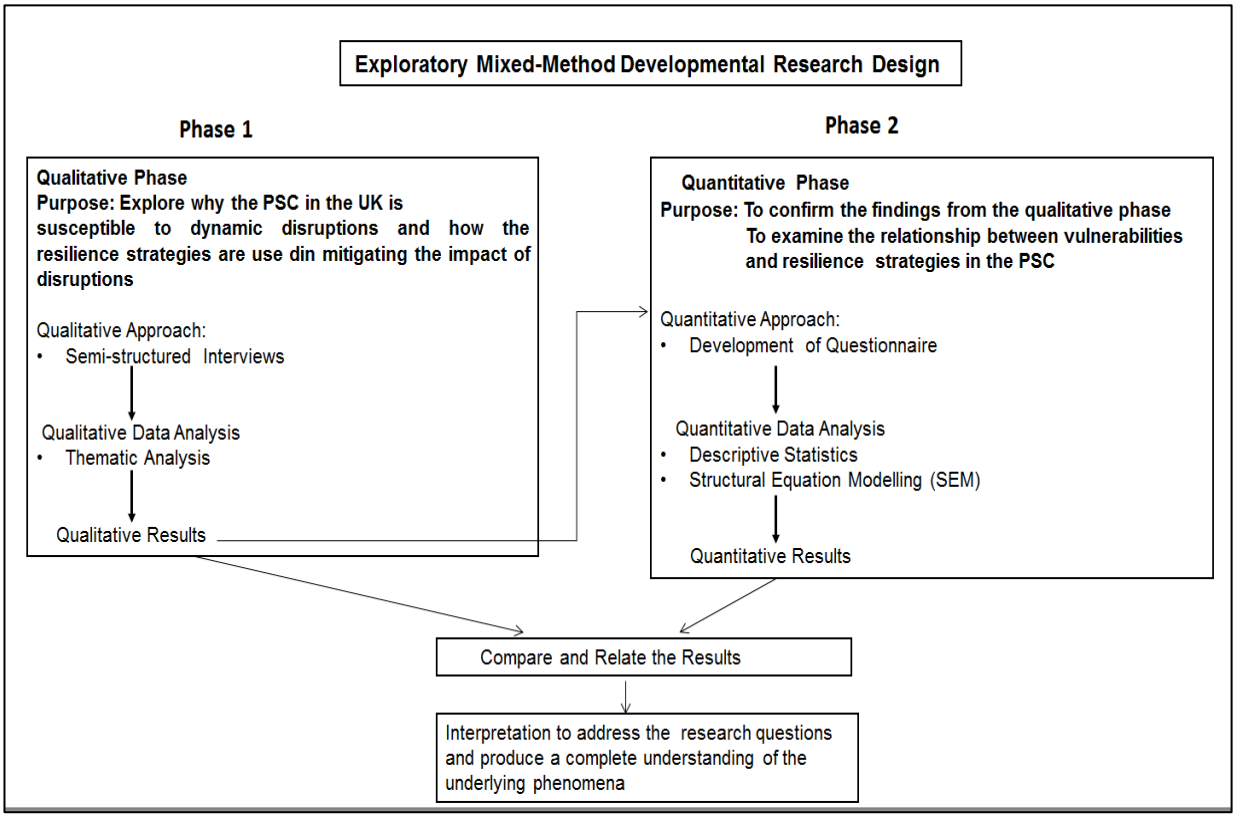

Figure 4.2 The Sequence of Activities of this Research Process
Source: Adapted from Creswell and Plano-Clark, (2017)

As illustrated in Figure 4.2 above, this research involved two diverse but interrelated phases of data collection and analysis classified as phase 1 and 2. The diagram shows that this research adopted an exploratory mixed-method and developmental design. The starting point was the qualitative phase (Phase 1), and the goal was to address the underlying research questions in this study. Data were collected from key actors in the PSC in the UK using semi-structured interviews and analysed using thematic analysis. These primary qualitative data, in conjunction with existing literature, were used to inform and develop the quantitative research instrument, as the variables were unknown. This exploratory research design has been supported by multiple worldviews, including pragmatism (Creswell and Plano-Clark, 2017).

An inductive approach was employed using semi-structured interviews to identify the underlying vulnerabilities in the PSC and the strategies supply chain actors employed in mitigating dynamic disruptions. Thus, the findings from the qualitative research informed the development of the questionnaire, which facilitated the gathering of quantitative data. Subsequently, the two data sets were integrated during the analysis stage leading to the discussion and interpretation. At the discussion stage, the results were compared for convergence, divergence, contradictions or relationships from the two data sources as recommended by Creswell and Plano-Clark, (2017). The next section provides a detailed discussion of the various phases involved in collecting and analysing the data used in this study.

4.3.3. Research Methods

The previous section discussed the mixed-method research design adopted in this study which involves a combination of qualitative and quantitative research methods. This section presents the tools and techniques used in collecting and analysing the data for both phases of the research.

4.3.3.1. Phase One: Qualitative Research Phase

This study aimed to understand why the PSC was susceptible to disruptions and how supply chain actors used resilience strategies to mitigate the impact of disruptions. This follows the review of literature which highlighted the limited

availability of empirical research on vulnerability and resilience strategies and specifically to understand resilience in the context of the PSC due to its unique characteristics. The aim was to gain insights by exploring the perception of actors at various levels of the PSC. This identified the need for a qualitative, exploratory study (Creswell and Poth, 2016). The following section discusses and justifies the methods used during the qualitative phase of the research, which included: the data collection, the recruitment strategy, as well as how the data was analysed and interpreted.

4.3.3.1.1. Data Collection: Semi-structured Interviews

There are different methods used to collect data in qualitative research. The most common are interviews, focus groups, observational methods and document analysis (Patton, 1990; Creswell, 2013). In qualitative research, interviews are considered the most appropriate tool in exploring new topics or areas classified as sensitive (e.g. vulnerabilities of the PSC) where detailed insights from participants are required (Holloway and Wheeler, 2013). For example, the study by Bogaert et al. (2015), who adopted an interview approach in collecting and analysing data to identify the significant causes of medicine shortages in European hospitals. In the same view, Atif et al. (2019) used a semi-structured interview protocol to explore the challenges and possible solution of access to medicine in the PSC in Pakistan.

Interviews are a form of data collection in qualitative research, which entail a discourse between a researcher and interview participants, to provide rich insights that can be employed for analysis (Bryman, 2013). Interviews provide exhaustive and comprehensive information required exploring the experiences, beliefs, views and/or motivations of individuals on the phenomenon under investigation (Rowley, 2012). These interviews can be conducted both face-to-face, over the telephone or via skype. There are three forms of interviews identified in the literature and have been classified based on their level of structure, namely: structured, semi-structured and unstructured interviews (Rowley, 2012).

Structured interviews consist of a well-structured list of questions which the participants are required to answer verbatim (Silverman, 2010). This list of questions is used on every participant with little or no distinction where the responses are required to be succinct. The advantage of using structured interviews is that they are often less time-consuming and easier to administer and facilitate.

In unstructured interviews, the goal of the researcher is to propel discussions around the theme of study. In the course of the discussions, questions are spontaneously generated, which allows room for more probing and further insights (Bryman, 2013). An unstructured interview may begin with an opening question like: - How would you describe your role in the PSC? The initial response then facilitates the discussion flow. This structure of the interview is beneficial when there is little knowledge about the subject matter, and it might generate more structured questions (Bryman, 2013). The shortfall is that it is usually time-consuming and the conducting of the interview here requires experience and skills (Roulston, 2010).

The next form of interviews is the semi-structured interviews which are the most common form of interviews used in qualitative research (Creswell, 2013). As the name implies, this interview follows a structure but in a more flexible manner, permitting the interviewer to drive the discussion on some responses as the case arises (Rowley et al. 2012). This interview structure is made up of several key questions which are based on existing literature to define as well as develop a better understanding of the context of the study. It also allows the interviewees to focus on and analyse a specific subject, which will generate new and valuable insights (Rowley, 2012). The interactions and discussions developed between the researcher and the interviewees provide avenues to extract more information about respondents' experiences (Kvale and Brinkmann, 2008).

This study aimed to explore the views of stakeholders regarding elements of resilience in the PSC. This study, therefore, employed the semi-structured interview approach to data collection, as it permitted the researcher, the avenue to ask questions to the phenomenon informed by literature as well as probe further for clarity. The process provided as much information as possible and

addressed the underlying goals of the study. The data collected was enhanced using the semi-structured interview (Bryman, 2013). Interviews were conducted, with supply chain actors at various levels of the PSC between June 10th, 2018 and August 9th, 2018.

4.3.3.1.1.1. Choosing Research Participants and Sampling Strategy

It was pertinent to approach research respondents who were knowledgeable about the phenomenon under investigation. Thus, the aim was to select respondents in charge of making decisions at various levels of the PSC, to provide a holistic view of disruptions, vulnerabilities and resilience strategies. It was envisaged that 16-24 interviews would be required to achieve data saturation (Hennink et al. 2017). Also, to obtain rich and diverse data, the aim was to include representation from each level of the PSC. Ultimately this was achieved with 23 research respondents.

Participants were recruited until data saturation was achieved (Morse, 1995). Another rationale for conducting interviews across the various levels of the PSC was to examine and determine the interrelatedness of vulnerabilities and resilience strategies across the PSC. The nature of the sample was based on the design of the UK PSC (see Chapter 3.2, Figure 3.1).

Based on the research objectives of this study, the participants were chosen using the following criteria.

Their level in the supply chain: This is made up various supply chain actors (partners - manufacturers, wholesalers, logistic service providers, secondary care and primary care pharmacists.

Their job role: This implies the responsibility in decision making with regards to the strategies related to disruption management in the PSC.

Purposive sampling and snowballing sampling strategies were employed to access the target population. Purposive samples are the most frequently used form of non-probability sampling in qualitative research (Miles and Huberman, 1994). Purposive sampling technique is a non-probability sampling technique which relies on the subjective judgment of the researcher in selecting

participants for research (Saunders, 2012; Maheshwari, 2017). They are typically used to choose a relatively small number of participants, such as those that are particularly informative (Neuman, 2005).

Snowballing sampling is commonly used when it is difficult to identify members of the desired population (Saunders, 2012). Snowball sampling is a sampling technique where research participants are volunteered to be part of the research rather than being chosen. Here, once contact has been made and data collected from an initial participant, she or he identifies several other participants from the same population and facilitates access. They, in turn, find further participants and so the sample snowballs (Saunders et al. 2009). Regularly, participants are most likely to volunteer other potential participants who are like themselves, resulting in a homogeneous sample (Lee, 1993).

The aim of using the purposive sampling technique was to ensure that the research participants met the criteria specifications set out in the research, which were their job specification and role. To this end, therefore, in recruiting research participants, information about the study was circulated at two European Research Network for Medicine Shortages (COST Action, 15105) meetings (January 2018 and April 2018). In attendance at these meetings were representatives of the European Association for Hospital Pharmacists (EAHP) UK chapter, the Royal Pharmaceutical Society (RPS) and the Association of British Pharmaceutical Industries (ABPI). Representatives at these meetings were provided with a brief description of the research, a name, an email address and phone number of a contact person to circulate among their colleagues. Interested participants replied through emails, and interviews scheduled.

However, some challenges were encountered during the data collection process because the population that met the criteria specified for the research participants were challenging to access. The snowball sampling technique was used to circumvent this. Thus, existing research participants identified prospective participants and provided the emails addresses of these prospective participants. This follows the recommendations by Saunders (2012), who explain that it was common to use two or more sampling techniques when using non-probability sampling.

4.3.3.1.1.2. Interview Process

This section presents an overview of the semi-structured interview process and design in this study. This encapsulates the planning of the interview, the delivery of the interviews and managing of the interview process. Before conducting the interviews with the participants, the necessary documents were sent to the participants at least one week ahead of the scheduled interview dates. These documents included: a letter which introduced the research aims and the agenda of the study; the participant information sheet with details of the study as well as how the information provided, confidentiality and anonymity would be maintained. A consent form was included for participants to sign if they were willing to participate (for a copy of the documents, see Appendix A). Pettigrew (1997) also suggests that the guiding principle to determine the date, location, and time of interviews should be agreed between the researcher and the interviewee. The researcher tried to accommodate the needs of the research participants. 80% of the interviews were conducted by telephone, and the remaining 20% were conducted 1-to-1 on the participants' premises. The interviews were conducted between 11th of June 2018 and 9th of September 2018.

4.3.3.1.1.3. Interview Protocol Design

As stated earlier, data were collected by conducting semi-structured interviews with key actors in the PSC in the UK. To ensure that the process of generating the data was structurally sound, the researcher developed an interview protocol. The interview protocol provided a means to enquire in detail about the activities surrounding why the PSC in the UK is prone to the impact of disruptions and how resilience strategies can be employed in mitigating the impact of these disruptions. The structure of the interview protocol was developed using various themes from supply resilience literature which has been highlighted in the literature review chapter of this study (see Chapter Two). Thus, the structure of themes in the guideline matched with the selection of vulnerabilities, disruption and resilience strategy questions. This thematic structure facilitated a positive interaction with participants and encouraged them to speak more openly about their perceptions and experiences (Kvale, 1996). The interview protocol also

enabled the interview process to ensure replication across the various supply chain partners, which further ensured reliability (Yin, 2013).

However, following recommendations by Pettigrew (1997), the interview protocol was tested on the first four participants who included a manufacturer, a hospital pharmacist, a regulatory body representative and a community pharmacist. The responses thus permitted necessary amendments to be carried out on the final interview protocol and was used in the main research (n=23). The main amendments were related to terminology. For instance, the term ‘dynamic disruptions’ may not be a term familiar to the participants and was rephrased as disruptions. Also, it was important not to classify disruptions to only include medicine shortages, as participants may have experienced other forms of disruptions. The questions were changed as necessary to generate the required information and minimise the risk of misunderstanding.

A standard interview guideline was developed, which comprised of four sections (see Appendix A), to cover disruptions, vulnerabilities and resilience strategies in the PSC in the UK. The first section focused on the overview of the study, its objectives and rationale. The second section focused on field procedures, ethical issues and covered aspects, such as tape recording and confidentiality. The third and the last section provided an outline for thematic areas of discussion. Even though the areas progressed in different ways during the interviews, the goal of the research remained consistent throughout the interviews, focusing on why PSC is susceptible to the impact of disruption and how resilience strategies can be used in mitigating these impacts.

4.3.3.1.2. Data Analysis: Thematic Analysis

There are various approaches to analysing qualitative data in research. These include discourse analysis, content analysis, grounded analysis, social network analysis, conversation analysis and thematic analysis. All these forms of analysis have a different philosophical stance which must be taken into consideration when analysing the data (Bryman, 2013). However, there is no universal analysis technique. The contention here is that the method adopted

for particular research largely depends on the data collected and the underlying objectives of the study (Saunders et al. 2015). The argument is based on the idea that as a result of the key components of analysing qualitative data, which includes organising, classifying, coding, interpreting, presenting and writing up the data may be a complex process (Rowley, 2012). Therefore, the research question and the set objective need to be considered when choosing an analytical tool with qualitative data with a focus on collecting data and trying to identify key themes.

Further, qualitative analysis methods can be divided into two camps. Within the first, there are those tied to or stemming from, a specific theoretical or epistemological position. For some of these, such as conversation analysis (Hutchby and Wooffitt, 1998) and interpretative phenomenological analysis (Smith and Osborn, 2007), there is relatively limited variability in how the method is applied, within that framework. For others, such as grounded theory (Glaser, 1992; Corbin and Strauss, 2014), discourse analysis and or narrative analysis (Murray, 2015), there are different manifestations of the method, from within the broad theoretical framework. Within the second camp of qualitative analysis methods, some methods are mostly independent of theory and epistemology. These methods can be applied across a range of theoretical and epistemological approaches. Although often (implicitly) framed as a realist/experiential method (Aronson, 1994; Roulston, 2010), thematic analysis is firmly in the second camp and is compatible with the pragmatist philosophy (Braun and Clarke, 2006).

Thematic analysis has been suggested as a flexible and useful tool in identifying, analysing and reporting patterns in qualitative data. It also has the potential of providing a rich, detailed and sophisticated account of data (Braun and Clark, 2006). Thematic analysis is considered a foundational method for analysing qualitative data because it provides a good overview and summary of a large body of data. Thematic analysis can be used to generate data when a research topic is an under-researched topic such as this referred to as ‘unexpected insights’ (Braun and Clarke, 2014). The analysis is informed, rather than being driven, by existing theory (Guest et al. 2013). In this study, therefore,

thematic analysis, as defined by Braun and Clarke (2014) was identified as the most appropriate approach for these data, as it allowed a flexible, data-driven analysis, rather than one rooted to a specific theoretical framework. As prior research in this particular participant group is limited, this approach allowed for analysis to be primarily inductive, reflecting the experiences of participants.

Themes are referred to as an essential segment or element of data (Boyatzis, 1998) that help organise data in groups of repeating ideas which allow the researcher to answer the research questions (Vaismoradi et al. 2016). There is, however, no consensus on the right way or wrong way in conducting thematic analysis (Saldana, 2015; Vaismoradi et al. 2016). This study thus follows Braun and Clarke's six-step method for theme development which includes i) Familiarisation; ii) Generation of initial codes; iii) Searching for themes; iv) Reviewing themes; v) Defining and naming themes, and vi) Producing the final report (Braun and Clarke, 2014). Similarities and contrasts between the individual interviews were noted. Themes were developed through a series of constant comparison of codes between transcripts.

Coding of qualitative data often referred to as the 'critical link' between collected data and its meaning (Charmaz, 2011) entails assigning short words or phrases to indicate salient points within the data (Saldana, 2015). The coding method adopted in a study is influenced by the nature of inquiry and objective of the research (Patton, 1990). Some researchers argue that one coding method is sufficient in developing connections that highlight findings (Dewalt and Dewalt, 2011). Other researchers suggest that using more than one coding method is desirable to facilitate accountability, depict the depth and breadth of the study (Leech and Onwuegbuzie, 2007).

The adoption of more than one coding method, therefore, entails the use of the first cycle and second cycle coding process. In this study, two forms of data coding were employed in a 'two cycled' coding process. The first cycle employed descriptive coding, while the second cycle used pattern coding. The descriptive coding which entails assigning vocabulary to the contents was adopted because it helped the researcher in the preliminary account of data content and as such

formed the backdrop against which the second cycle of coding occurred (Seldana, 2015).

Pattern coding also referred to as inferential coding, is used to identify emerging themes. In this process, most materials from the data are brought together to provide a more meaningful unit of analysis (Miles and Huberman, 1994). The pattern code also highlighted significant quotes from participants who served as stimuli in developing the survey instruments for the quantitative aspect of this study. Boyatzis (1998) explains that identifying themes in data analysis is an attempt at describing as well as organising aspects of the underlying phenomenon emerging from the data.

Although there are software packages available to analyse qualitative data, they did not fit the purpose of this study as they have been developed under various epistemologies (Coffey et al. 1996; Petty et al. 2012). In view of this, and to maintain control of the data, the thematic analysis of the data was done manually.

The interviews were initially coded, and the themes developed by the lead researcher. This was achieved through repeated readings of the transcripts to understand the data and identify fragments of the data that referred to various parts of the research questions. These themes were subsequently reviewed by three other experienced researchers in supply chain management and pharmacy and any areas of disagreement resolved through discussions. For further confirmation, an interdisciplinary research group (Operations management and Pharmacy) reviewed the output and validated the constructed themes. The use of multiple researchers in the development of themes aimed to reduce bias and enhance the validity of the research (Corbin and Strauss, 2014). These themes are presented and analysed in the following Analysis Chapter (Chapter Five).

The themes generated from the qualitative data were used to develop the questionnaire used to collect the data in the second phase of the research process (quantitative research). The next section, therefore, discusses the second phase of the research design, which is the quantitative phase.

4.3.3.2. Phase Two: Quantitative Research Process

The quantitative research phase aimed to confirm the findings of the qualitative research findings and answer the third research question, which was to assess the interactions between vulnerabilities and resilience strategies in the PSC. These aims were confirmatory and as such, required the use of quantitative techniques (Saunders, 2012; Creswell and Poth, 2016). This section thus discusses and justifies the various quantitative techniques used in the study which includes the reason for using a survey questionnaire, explanations as to how the questionnaire was designed, the sample characteristics and how the data were analysed.

4.3.3.2.1. Data Collection: Survey Questionnaire

The survey was developed following identified themes from the qualitative phase and guidance from existing literature (a summary of how the questionnaire was developed is provided in Appendix E), to achieve the underlying objectives. Data collected at this stage were used to describe and to measure the major factors that facilitated vulnerabilities and resilience strategies in the PSC in the UK.

A survey approach is a form of collecting data in quantitative research from a wider sample of respondents who represent a specific population. Here data are collected from respondents by asking respondents to record specific answers with regards to attitudes, behaviours and opinions on a subject (Ghauri and Gronhaug 2010). A survey can take diverse forms such as structured interviews, structured observations and questionnaires (Maylor and Blackmon, 2005). It is pertinent that a suitable form of survey is chosen to fit the objectives of the study (Bernard, 2013).

In this study, the questionnaire survey was used to collect the required quantitative data. The questionnaire was considered the most appropriate as it had the capacity of reaching a wider population as well as the ability to gather vast amounts of information within a limited amount of time (Blair et al. 2013; Allen, 2017). The information gathered was used to support the findings from

the qualitative data. The information gathered were regarding the factors that increase vulnerabilities and resilience strategies in the UK PSC and to measure the relationship among the identified themes.

4.3.3.2.1.1. Questionnaire Design

A questionnaire survey is made up of a list of questions which are often accompanied by a range of answers developed in a standardised manner which facilities ease in collecting and analysing the data (Matthew and Ross, 2010). The questionnaire as a data collection tool provides relevance and accuracy of variables of interests in a study (Sekaran and Bougie, 2016). The data was collected on a wider scope where the self-administered questionnaires, which had four major sections, were administered.

The first section of the questionnaire collected data about the demographic features of the research participants. The second section examined the experiences supply chain actors on the forms as well as the timing of disruptions prevalent to the PSC in the UK. The third section was based on supply chain vulnerabilities, while the concluding section was related to resilience strategies and possible recommendations. The survey was administered in the English language as English is the official language in the UK, and the majority of the target population can read and write in English.

In this study, the questionnaire design process was divided into a series of stages, which were guided by the goals of the study (Frazer and Lawley, 2000). This involved carefully articulating the research objectives, incorporating results from the qualitative research and existing related literature, comparing the questionnaire design with similar studies in literature, using multiple items to measure each construct as well as the pre-test of the preliminary version of the questionnaire before dissemination of the tool (Churchill and Peter, 1984).

A major constraint to the development of questionnaires is the phrasing and selection of the appropriate questions to achieve research objectives. Two forms of questions have been identified in the existing literature: - Closed-ended questions which require respondents to choose answers from a list of answers

provided, and open-ended questions where respondents are given the liberty to provide answers (Couper et al. 2001).

In this study, various response formats were incorporated into the survey to mitigate response bias. Closed-ended questions were mostly used throughout the survey. The context remained the same for all the respondents, and a minimal amount of thinking was required (Gendall and Hoek, 1990).

The responses were also scaled to measure the extent to which the respondents agreed or disagreed with the concepts (Alreck and Settle, 1995). The study employed the seven-point Likert scale for questions as validated by Joshi et al. (2015). The questions were categorised by topics and followed a logical sequence where the funnel approach was adopted. Therefore, the questions began with broad questions and then narrowed down to specific questions. The opening questions included: demography of the respondents followed by forms of disruptions experienced, then vulnerabilities. Resilience strategies and recommendations were asked last in the survey, as suggested by Churchill and Peter (1984).

4.3.3.2.1.2. Developing the Content of the Questionnaire

The questionnaires were developed based on the study's objectives. This was targeted at identifying vulnerabilities and resilience strategies in the PSC. Thus, the data generated were based on the opinion, beliefs and attitudes of the research participants in the role of procurement at various levels of the PSC in the UK. The questions developed were constructed on the principles of good question design, where the questions were kept brief, leading questions were avoided, positive undertones were used, and the questions could be applied to all respondents (Frazer and Lawley, 2000; Cooper and Schindler, 2001; Brace, 2018).

a. **The wording of the questions in the questionnaire**: The principles of questionnaire wording which recommends simple-worded questions were applied when drafting the wording for the questionnaire (Frazer and Lawley, 2000; Brace, 2018). As such, the wordings of the questions were kept as brief and as simple as possible. Ambiguous words avoided. Also,

terminologies identified from the semi-structured interviews were incorporated to mitigate issues associated with respondents' biasedness.

b. **Response Formatting:** The questions asked in the survey were related to disruptions, vulnerabilities and resilience strategies in the PSC in the UK. The targeted respondents had supply chain management roles in their respective firms and were assumed to have experienced a form of disruption in the course of performing their roles. As such, the respondents would be expected to respond to the questions without difficulty (Brace, 2018).

4.3.3.2.1.3. Pilot Study for the Questionnaire

It is essential to pilot an instrument to certify that respondents appreciate the questions posed (Bell, 2010). Therefore, before administering the questionnaire to a wider audience, a pilot study was conducted. It involved ten experts conversant with the PSC in the UK. The aim was to address any possible weaknesses of the questionnaire's formatting, wordings, ambiguity and contents so that amendments could be done to improve the questionnaire before the actual data collection process (Grossnickle and Raskin, 2001; Saunders et al. 2015). Also, it helped the researcher check if the instrument had any practical or contextual issues that may have likely affected the data collection process, such as opening the survey on different devices. The research participants from the interviews were asked to complete the questionnaire as they represented the population to whom the questionnaire was targeted as well as for member checking (Cunliffe, 2011).

These participants were asked to make notes on time spent in completing the questionnaire, instances of ambiguity, difficulties encountered and how these could be addressed. After the initial piloting of the questionnaire, several issues were highlighted including choice of terminologies (e.g. 'Drugs' in place of 'Medicines'; 'Secondary Care' in place of 'Hospital Pharmacists'), reordering of questions and timing. The length of time to complete the questionnaire was reduced by trimming down the number of questions and ensuring questions were relevant to the objective of the study (see appendix 4 for a sample of the pilot questionnaire). The final questionnaire, therefore, required approximately

10-15 minutes to complete. The total length of the questionnaire was equivalent to four pages of an A4 paper.

4.3.3.2.1.4. Sampling Techniques

Sampling techniques are used to gather the required information from a defined group of people (Saunders, 2012). Researchers select the sample that matches several criteria and best answers the research questions meeting the research aims and objectives (Matthews and Ross, 2014). Probability sampling and non-probability sampling are the two forms of sampling techniques. Probability sampling refers to the techniques where participants in a study are chosen at random. In non-probability sampling, the selection of samples is based on personal judgment or convenience, which means that the probability of members of the population is not random.

Non-probability sampling is both cost and time effective and is suitable when the target population for research is small. Further, in quantitative exploratory research, non-probability sampling has been advocated as efficient as the goal of the research is not hypothesis testing but exploratory (Saunders, 2012; Baker et al. 2013). Snowballing and purposive sampling techniques are types of non-probability sampling techniques used to achieve a sample size based on the researcher's judgment regarding individuals that could be potential participants required to answer the research questions (Saunders et al. 2015).

This research aimed to explore the experiences of supply chain actors about vulnerabilities and resilience strategies when dynamic disruptions occurred. At the quantitative phase of this study, the aim was to confirm the findings of the qualitative phase on a broader scale of research respondents and to explore the impact resilience strategies had in reducing vulnerabilities in the PSC.

To this end, non-probability sampling was considered appropriate as it was pertinent that respondents who were knowledgeable about the phenomenon being investigated completed the survey. Thus, the snowball sampling technique and purposive sampling technique were used to arrive at the sample size in the quantitative phase of the study. Since the emphasis of this study is on elements related to the PSC, the population that meet the participation

criteria contains very few members, who were challenging to access (Saunders, 2012). This implies that anyone who was identified as knowledgeable about the phenomenon being investigated was notified of the survey

The sample was derived from the UK. The UK was chosen mainly because of the ease of accessibility of the target group and in line with the objectives of the study.

4.3.3.2.1.5. Distribution of Questionnaire Survey

There are different ways a questionnaire survey can be distributed, including drop-off surveys, fax surveys, mail surveys and online surveys (Zikmund et al. 2012). Google form a web-type of questionnaire survey was used during the data collection phase of this research to increase the response rate and reduce the collection time (Groves et al. 2012). A brief explanation of the significance of the survey with a clear and succinct message was attached to the link of the survey.

Information about the survey was circulated on social media platforms such as LinkedIn and Twitter to raise awareness of the survey. A brief description of the survey's objectives and details of a contact person: email address and phone number were provided for any of the respondents who wished to participate in the survey. The link was sent to research respondents who responded to the call to participate in the survey. More specifically, when existing research respondents identified new PSC actors in charge of the decision-making process at various levels of the PSC, they were contacted and asked if they would be willing to participate in the study and the link to the survey sent to them.

Other information circulation professional groups were suggested by some of the research respondents to raise awareness about the survey. The underlying notion was that most of the targeted respondents belonged to at least one of these groups. These groups included the European Association for Hospital Pharmacists (EAHP) had accompanying messages on two issues of the EU Monitor (4th of December and the 18th of December 2018) with particular focus on the UK. The Royal Pharmaceutical Society (RPS) was also asked to circulate

information about the survey on the RPS blog, and the Association of British Pharmaceutical Industries (ABPI) circulated awareness through their monthly newsletter.

Follow-up calls and emails were sent to the gatekeepers of these societies as a reminder to increase the response rate to the questionnaires.

4.3.3.2.2. Data Analysis

Analysing data collected at the quantitative phase of this study was done in four stages. All the questions asked in the survey were closed-ended apart from the questions regarding the 'timing of the disruptions' and 'possible recommendations'. As such, there was a need to input the data into a numeric form for analysis. This involved coding of the data and descriptive statistics, using mean and frequencies of the data to ascertain the similarities and differences that existed in the respondents' opinion and attitudes in the survey. Assessing the reliability and validity of the data, and structural equation modelling (SEM) was used to explore the relationship between the variables.

The responses were coded as soon as the data collection process ended to ensure reliability (Hair et al. 2019). The process involved in coding the data is presented in Appendix C. Data were inputted into SPSS Version 25.0 Software as soon as the data collection period ended. In calculating the simple statistics of the data, the one-way tabulation and cross-tabulation were employed. Other simple statistics like frequencies of responses, averages and percentages were used to profile the sample of the respondents, establish the basic features of the respondents and any outliers. The sections following this describe the Cronbach Alpha and Heterotrait-monotrait Ratio tests, Kruskal-Wallis tests as well as the Structural Equation Modelling as tools used in analysing the quantitative data collected.

4.3.3.2.2.1. Cronbach Alpha and Heterotrait-monotrait Ratio

Validity and reliability are two essential, but vital tenets required in a quantitative study. The former refers to the degree that a construct is measured accurately while the latter is associated with the quality and accuracy of the research

instrument (Heale and Twycross, 2015). In this study, therefore, measures were taken to ensure the validity and reliability of the study using different assessment strategies. For the content validity of the measurements in ensuring internal consistency of the survey instrument, an extensive review of literature, summarising qualitative data findings and the Cronbach's alpha (α) are used (Heale and Twycross, 2015).

Cronbach's alpha is particularly relevant as the survey instrument contains more than two responses. Cronbach's alpha is the most common measure of internal consistency when multiple Likert questions are used in a survey (Vaske et al. 2017). It is easy to use, easy to interpret and available in most statistical analytical software. Here the average of all correlations in every permutation of split halves is determined, and the Cronbach α result is a number between 0 and 1. The closer the value is to 1, the higher the reliability. An acceptable level, however, is from 0.7 (Heale and Twycross, 2015). The values of the alpha may sometimes be sensitive to the number of items in the scale. When the scale is small, usually items below ten, the alpha coefficients are often low (Briggs and Cheek, 1986).

In cases like this, it may be more appropriate to report the mean inter-item correlations for the items where appropriate values should range between 0.2 and 0.4. Higher alpha coefficients (>0.7) indicate that the items within a scale are measuring what they should be while low scores reflect that the items may be measuring something else and may be removed.

The Heterotrait-monotrait ratio of correlations (HTMT) is a new method for assessing discriminant validity in partial least squares (PLS) structural equation modelling, which is one of the critical building blocks of model evaluation. The goal is to ensure that a reflective construct has the most robust relationships with its indicators (e.g., in comparison with than any other construct) in the PLS path model (Hair et al. 2019). Henseler (2017) also shows using a simulation study that these approaches do not reliably detect the lack of discriminant validity in common research situations. This author, therefore, proposes an

alternative approach, based on the multitrait-multimethod matrix, to assess discriminant validity.

4.3.3.2.2.2. Kruskal-Wallis test

Kruskal-Wallis test (Kruskal and Wallis, 1952) is used when the data is non-parametric to examine if differences exist among three or more independently sampled groups. Non-parametric data here entails that the data does not meet the required normality assumptions and as such, no prior assumptions are needed (McKnight and Najab, 2010). The Kruskal-Wallis test is used to examine non-normally distributed continuous variables. The Kruskal-Wallis test differs from the Analysis of Variance tests (ANOVA) which is a parametric test that is used for a normally distributed continuous variable. The Kruskal Wallis test is not, however, as powerful as the Analysis of Variance tests. The null hypothesis here is that the sample is from an identical population, while the alternate assumes that there are differences in the population (McKnight and Najab, 2010).

4.3.3.2.2.3. Structural Equation Modelling (SEM)

The role of the quantitative analysis was to confirm findings from the semi-structured interviews. Structural Equation Modelling (SEM) is a technique that has been widely used for instrument validation in research as well as to test theoretical models which involve suggested causal links among variables (Chau, 1997; Schumacker and Lomax 2016; Hair et al. 2019). It is defined as a class of methodological analysis that is aimed at representing the distribution of the data in smaller numbers of structural parameters defined by hypothesized underlying models.

Therefore, SEM is a tool suitable for analysing sets of variables that have structural associations, and it also possesses the flexibility of incorporating exploratory data analysis (Byrne, 2010). SEM accepts that the suggested links among variables can be denoted using sets of structural regression equations which can be presented pictorially (Byrne, 2010). It centres around two parts: validating the measurement model and fitting the structural model. The former is accomplished through confirmatory factor analysis, while the latter is

accomplished through path analysis with the latent variables (Haenlein and Kaplan, 2004; Statsoft, 2013; Hair et al. 2017).

A structural equation model, thus, consists of the measurement models, which connects the observed variables to the latent variables and the structural model that connects the latent variables through simultaneous equations. The SEM is accomplished using fit statistics. The fit statistics are used to accept or reject the assumed relationships between the latent and observed variables (measurement models) on the one hand, and the latent variables (structural model) in the study (Wong, 2013). This process then incorporates the benefits of multiple regression analysis in that it considers multiple factors, which may simultaneously influence a phenomenon and the benefits of path analysis that allows for the influence of mediating variables. Further, SEM deals with one of the inherent difficulties of multiple regression analysis, namely- measurement error arising from the multiple inter-correlations (Hair et al. 2019). It provides estimates of the strength of all the hypothesized relationships between the constructs in theoretical models, comparing, most importantly, the model to the empirical data.

Numerous statistical techniques propose links between dependent variables and single or multiple dependent variables (ANOVA, Regression). These techniques are however unsuitable when the goal of the researcher is to include more dependent variables with multiple independent variables as the researcher is often limited to adopting procedures such as multivariate regression, MANOVA and similar tests in trying to establish the links. These multivariate techniques do not permit the researcher to include more variables to the dependent variable side of the assumed model. The situation is further complicated if the data are ordinal variables that do not pass the normality assumptions tests (Kline, 2005; Hair et al. 2017).

SEM, therefore, provides the tool that is suitable for testing multivariate links among variables and allows for testing predictions, unlike the conventional regression techniques. It offers a more flexible method for testing indirect effects of an independent variable on a dependent variable. Further, traditional

statistical techniques require that parameters included in a model are measured without errors which in most cases are unattainable. The presence of measurement errors leads to biased estimates of the parameters being measured. By incorporating flexibility into its systems, the researcher can incorporate or adjust measurement parameters within the model as well as possible biases in the parameter estimates (Byrne, 2010). The fact that SEM can measure large unobservable constructs which makes it the most suitable in this research.

There are several variations to SEM which include: The Covariance-Based SEM which used with AMOS, LISREL and MPlus software packages and the Partial Least Squares (PLS) which centres on the analysis of variance with PLSGraph, Visual PLS and SmartPLS as the statistical software packages. The other techniques include the component-based SEM and the Generalized Structured Component Analysis (GSCA) and the Nonlinear Universal Structural Relational Modelling (NEUSREL) (Haenlein and Kaplan, 2004).

The Partial Least Squares Method to SEM (PLS-SEM) was used in this study because it does not require that the data have any prior assumptions; it is suitable if the sample size is small and there is very little theory available; if the principal goal of the analysis is predictability and specification of the right model cannot be guaranteed (Wong, 2013; Hair et al. 2017). PLS-SEM is also beneficial for data that have limited participants or data with skewed distribution and is mostly useful when studies are at the exploratory stage when no ad-hoc models have been previously designed (Wong, 2013). For this reason, this study adopted the PLS-SEM as the sample size for the data was 106 (Vinzi et al. 2010; Sideridis et al. 2014). The data collection process emerged from an exploratory study where little theoretical knowledge for the variables in the study was known, and the goal of the analysis was to achieve predictability (Wong, 2013). The data are not required to follow the normality assumptions requirement when using multiple regressions techniques (Berenson et al. 2012).

SEM is prone to measurement errors as a result of the use of multiple statistical techniques such as Confirmatory Factor Analysis, Path Coefficients and

correlation within one analysis (Hair et al. 2017). The disadvantage here is that while some techniques may show significant results, others may be insignificant. The problems of generalizability may also arise especially if the sample size is not large enough as well as issues of multicollinearity (Tarka, 2018). In this study, therefore, the model tested was based mainly on the findings from the exploratory stage of the research process and review of related literature. This analysis thus required a multivariate approach based on the number of constructs developed as well as hypothetical assumptions developed (Hair et al. 2017).

4.4. Quality of Research Design

Scholars have suggested that to ensure rigorous research, the quality of a research design be defined around four key terms to include internal validity, external validity, construct validity and statistical conclusion (Lewis, 1998; Yin, 2013; Hong et al. 2018). Construct validity aims to ascertain the accuracy of the operational measures used in the study. Internal validity of a research design seeks to establish the causal links and to distinguish them from spurious ones while external validity the ability to generalise the findings of a research.

This study used the Mixed-methods Appraisal Tool (MMAT) by Hong et al. (2018) as a checklist to ensure the quality of the research design. The MMAT suggests that the quality of the qualitative and quantitative components should be appraised individually to ensure that no critical threats to trustworthiness are present and ensure the quality of the research design A summary of the checklist is presented in Table 4.2 below.

Table 4.2 Quality of research design checklist based on (MMAT)

Phase of Research	**Methodological Quality Criteria Checklist**	**The Approach in this Thesis**
Qualitative phase	Was the approach appropriate to answer the research question?	The approach used in the qualitative phase was the qualitative descriptive as was appropriate to answer the research question as the aim

		was to gather the perceptions and experiences of PSC actors on issues of vulnerabilities and resilience strategies
	Are the qualitative data collection methods adequate to address the research question?	Semi-structured interviews were used to collect data as it allowed for flexibility in collecting the data as well as gaining insight into the phenomenon.
	Are the findings adequately derived from the data?	Data were coded, and themes developed from the data. The developed themes were checked by the supervisory team, and members of a research group made up of pharmacists and supply chain experts.
	Is the interpretation of results sufficiently substantiated by data?	Interpretation of results was substantiated by quotes to justify themes.
	Is there coherence between qualitative data sources, collection, analysis and interpretation?	Member checking was achieved by asking research respondents who participated in the interview to complete the survey for feedback and opinion.
Quantitative Phase	Is the sampling strategy relevant to address the research question?	The non-probability sampling strategy was used since the aim of the research was exploratory. A specific target population was required to complete the survey, and as such, the snowballing sampling was considered appropriate.
	Is the sample representative of the target population?	Attempts were made at achieving a representative target population through circulating information on social media platforms and professional groups.
	Is the risk of nonresponse bias low?	The risk of bias responses was high as may be expected with snowballing sampling.

	Is the statistical analysis appropriate to answer the research question?	The statistical analysis used include Cronbach's alpha, Kruskal Wallis tests and SEM and were appropriate in answering the research questions
Mixed-methods	Is there an adequate rationale for using a mixed-method?	The research questions identified in Table 4.1 provide an adequate rationale for using mixed-methods.
	Are the different components of the study effectively integrated to answer the research questions?	The mixed-methods approach adopted in this study was the developmental exploratory mixed-methods and as such, permitted effective integration of both the qualitative and quantitative phases.
	Are there divergences and inconsistencies between quantitative and qualitative results adequately addressed?	There are no divergencies and inconsistencies between quantitative and qualitative results.
	Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?	All the different components have adhered to the quality criteria of each method

The information in Table 4.2. above shows that the mixed-method research design was used to achieve both internal consistency and external validity for conclusion in this study (Creswell and Plano-Clark, 2017). The argument of achieving generalisation even though the sampling techniques are non-random as in the case of Yin (2013) was identified. Describing the study's setting adequately, documenting and validating the responses from the respondents was done to ensure transparency of the findings and to ensure validity

Further, to achieve construct validity in this study, various activities occurred. These include the development of the interview protocol based on existing literature and the piloting of the interview and survey protocol with research respondents who occupied relevant key decision-making posts in their firms. The development of the questionnaire using the findings from the interviews and existing literature; the use of multiple firms at each level of the supply chain as significant sources of data and the use of methodological triangulation were also

yardsticks for validity using the mixed-method approach. The mixed-method approach used in this study further enhances the methodological triangulation of data and guards against observer bias as well as provides rigour (Denzin, 2012).

4.5. Ethical Considerations

Before the data collection, ethical concerns were addressed, and as such, all ethical considerations were check listed and identified below.

4.5.1. Nature of the Research

This research did not involve the study of humans, although it required asking questions from human subjects about processes and procedures. The nature of the research did not expose participants to adverse risks.

4.5.2. Type of Questions

No experimentation was involved in this study, and the questions did not ask respondents anything that was of a uniquely personal or sensitive nature or if exposed might subject them to any sort of adverse action such as loss of employment or enrolment at the educational institution.

4.5.3. Freedom of Participants

Participants were given with the option to exit the research at any point they chose, and by proceeding with the survey, they were giving consent to having their responses included in the results.

4.5.4. Confidentiality of Data

Participants were assured of confidentiality and privacy through limited access to and sharing of any of the information collected. Access to the raw data was limited to the researcher and the supervisory team. The name and specific company where research participants worked, for example, was not requested, making it virtually impossible to trace a given response to an individual. Where data could lead to identification, procedural measures were employed. Confidentiality of participants was ensured by separating demographic data from interview transcripts. Any quotations used in study outputs were anonymised.

4.5.5. Ethical Approval Process

This study was guided by the University of Bradford code of practice where the proposal together with the participant information sheet (provide participants with information about the research) and the consent form (enable participants to make voluntary and informed consent) was assessed and approved by the university ethics committee. Ethics approval was provided as required by the University of Bradford research ethics committee. After that, the participant information sheets and consent forms were sent to potential participants before data collection to enable them to make informed decisions regarding participation.

4.6. Methodological Limitations

Methodological limitations are the features that affected the research design. Retrospectively, the limitations of this research were factors beyond the control of the researcher These limitations imposed restrictions on the study. The methodological limitations observed in this study will be discussed in the sub-sections below.

4.6.1. Use of Telephone Interviews

Phase one of the mixed-method study involved interviewing actors across various levels of the PSC in the UK. The potential participants were located all across the UK. Travelling to various locations would have been expensive and as such telephone interview was the primary source of data collection at the qualitative phase of the study. The shortcoming to the use of this mode of data collection was the loss of personal contact as well as a reduction in social cues during the data generation process. The use of telephone interviews inhibited the researcher from observing body language and behaviour when conducting the interviews. The use of visual cues could have provided vital insight and non-verbal cues from the perception of research respondents (Opdenakker, 2006).

4.6.2. Recruitment Strategy

One major challenge encountered in conducting this study was related to accessing the required data. This study involved interviewing actors at various stages of the PSC, and as such, recruiting and conducting the interview was challenging. Since professionals working within the PSC have a relatively heavy workload, several potential participants were reluctant to be involved in this research. The data was collected during the agitation created by BREXIT. This affected the willingness of potential participants because of the uncertainties. Also, the data collection phase was during the rollout of GDPR (General Data Protection Regulation), and as such, it was difficult to access potential participants through the regular channels. For instance, before the implementation of GDPR, it was possible to send an introductory email to the head of the Royal Pharmaceutical Society (RPS) who would then circulate the email to everyone on the mailing list and was no longer possible. Research participants who fitted the criteria and were willing to participate were previously easier to access, than the communication method ultimately used, which was the use of newsletters and blogs that participants seldomly read.

4.6.3. Time Constraints

This study was conducted in two phases, and it involved the completion of one phase before proceeding to the next phase. The time involved in conducting the entire research was limited and as such posed restrictions of the time available for recruiting to the survey and the ability to increase the number of survey participants further.

4.6.4. Sampling Strategy

The study used snowballing and purposive sampling strategies. The downsides to these methods of sampling is that it included only members of specific networks as such representativeness may not be guaranteed especially at the quantitative phase of the research (Bowling, 1997). Also, the researcher had little control over the sampling method, and this may lead to sampling bias.

4.7. Summary

In this chapter, the methodology chosen to achieve this study's objectives was discussed. The chapter justifies the pragmatists' paradigm as the most suitable paradigm to address the research questions. The research design adopted was an exploratory developmental mixed-method design which involved the use of both qualitative and quantitative approaches within a single study. The first phase of the study was the qualitative phase where data was collected using semi-structured interviews from key actors of the PSC and analyzed using thematic analysis. The next stage was the quantitative phase, and data was collected using a questionnaire from a broader audience of key actors in the PSC and the data analysis techniques discussed and justified.

The next chapter, therefore, presents the findings from the qualitative phase of the research process and the first level of analysis. This is the qualitative stage of the research process where the data were analysed using templates in thematic analysis and the findings used to develop the category structure for the quantitative aspect of the study in chapter six.

Chapter Five: Findings from Semi-structured Interviews

5.1. Introduction

The purpose of this study was to explore why the PSC (PSC) in the UK is susceptible to dynamic disruptions and examine how resilience strategies have been employed in reducing the impact of these disruptions. The mixed-method approach (qualitative and quantitative techniques) was identified as suitable to achieve the research objectives based on the underlying research questions for the study are exploratory (see chapter 4).

Research questions

RQ1: Why is the PSC in the UK susceptible to the impact of dynamic disruptions?

- What are the drivers of vulnerability in the PSC?
- How do these drivers expose the supply chain to the impact of dynamic disruptions?

RQ2: How are resilience strategies used to mitigate the impact of dynamic disruptions in the PSC?

- What strategies do supply chain actors adopt to build resilience against dynamic disruptions?
- What are the outcomes of implementing these strategies?

RQ3: What impact do resilience strategies have on vulnerabilities in the PSC?

This chapter, therefore, presents the findings from the semi-structured interviews, which forms the first stage of the mixed-method process of data collection. The findings from the semi-structured interviews are categorised under the main themes, and subthemes (see section 5.2) that emerged from the data and will be presented in tables, figures and texts. The chapter begins by describing the research participants followed by the taxonomy of the various findings' classifications derived from the data (section 5.3). The chapter ends

with concluding remarks in section 5.4, where the output from the first stage of the study is used to develop questionnaires for the quantitative data collection, which is the second stage of the study.

5.2. Features of Interview Participants

Interviews were conducted with actors at various levels of the PSC between June 10th, 2018 and August 9th, 2018. It is pertinent to seek research respondents who are knowledgeable about the phenomenon being investigated. Thus, key research respondents in charge of making decisions at various levels of the PSC were carefully selected to provide a holistic perspective of operations considering disruptions, vulnerabilities and resilience strategies. It was envisaged that 16-24 interviews would be required to achieve data saturation (Hennink et al. 2017). Also, to obtain rich and diverse data, the aim was to include representation from each level of the PSC. Ultimately this was achieved with 23 research respondents.

Participants were thus recruited until data saturation was achieved; the point at which no new information or themes was observed in the data (Morse 1995). Another rationale for conducting interviews across the various levels of the PSC was also to examine and determine the interrelatedness of vulnerabilities and resilience strategies across the PSC. The nature of the sample was also based on the design of the PSC in the UK (see Chapter 3.2, Figure 3.1).

The research participants interviewed represented each level of the supply chain. Based on the study's research objectives, the participants were drawn using the following criteria.

Their level in the supply chain: This comprises of the various supply chain stakeholders (partners - manufacturers, wholesalers, logistic service providers, secondary care and primary care pharmacists.

Their job role: This included their responsibility for decision making with regards to the strategies related to disruption management in the PSC.

Table 5.1 below, presents research participants characteristics and the codes assigned to them for analysing the data from the interviews. The coding was to ensure that their identity was protected and adhere to confidentiality. Thus, five manufacturers, one pre-wholesaler, two logistic service providers, five hospital pharmacists, six community pharmacists, one pharmacist working in a GP practice and 3 participants representing various regulatory bodies participated in the study.

Table 5.1 Characteristics of Interview Participants

Participant Type	Number of Interviews	Participant Type Identifier	Participants Roles	Years of Experience
Manufacturers	5	MFC	Director Packaging and Sales	4
		MFC	Global business Product Development	5
		MFC	Head of Supply Chain operations	15
		MFC	Head of Supply Chain Operations	9
		MFC	Head of Supply Chain and Procurement	20
Pre- Wholesalers	1	PWS	Operations Manager for Procurement	20
Wholesalers and Logistic Service Providers	2	LSP LSP	Operations Manager Operations Manager	20 3
Community Pharmacists	6	COMM	Superintendent Pharmacists	18
		COMM	Superintendent Pharmacists	44
		COMM	Superintendent Pharmacists	15
		COMM	Head of Buying /Group Pharm	17
		COMM	Superintendent Pharmacists	16
		COMM	Superintendent Pharmacists	5
Hospital Pharmacists	5	HOSP	Procurement Specialists	25
		HOSP	Regional Procurement Specialists Officer/	31.5
		HOSP	Regional Procurement Specialists Officer	17
		HOSP	Regional Procurement Specialists Officer	20
		HOSP	Regional Procurement Specialists Officer	37
Other Pharmacists	1	GP	GP Practice	12
Regulatory Bodies	3	REG	Director for Supply chain	15
		REG	Economic Director Primary and Secondary care	7
		REG	Principal Pharmacists	1.5

5.3. Presentation of Findings

The interview protocol focused on understanding supply chain resilience using medicine shortages as a disruption while exploring vulnerability drivers and antecedents of resilience strategies informed by pertinent literature. The nature of the interview questions asked was based on:

- Description of how firms within the PSC handled disruptions when they occurred.
- Why these disruptions occurred
- How managers in these firms handled the disruptions
- Reasons why these firms felt the impact of the disruption if at all they did and possible solutions to resolve the impact of these disruptions.

The interview protocol had 20 questions in total (see Appendix A for interview protocol) and lasted for an average of 30 minutes. The themes that emerged from the data collected have been listed in this section, i.e. 5.3. The data from the semi-structured interviews were analysed following the process identified by Braun and Clarke (2006) for thematic analysis (as discussed in section 4.5). As the study sought to determine the nature of vulnerabilities in the PSC, two dimensions from the analysis emerged to include:

•Internal Drivers —that is, relational activities in the PSC which are within the control of supply chain partners and stem from their asymmetric relationship, to include supply chain power and supply chain conflicts.

•External Drivers —that is structural activities beyond the internal control of supply chain partners within the PSC in the UK and emanate from the complexity of the supply chain to include regulations as well as economic, technological and political issues.

The study also explored the resilience strategies employed in curbing the impact of dynamic disruptions when they occurred. The analysis revealed that two forms of resilience strategies were used in restricting the impact of identified dynamic disruptions. These were classified as either reactive strategies - which helped supply chain actors to recover from the disruption and/or resistance

strategies- that enabled the supply chain actors to resist the impact of the disruption.

Based on these categorizations, 5 major themes and 11 subthemes emerged. The activities of the supply chain actors were categorised to form the sub-themes, and these sub-themes were further categorised to form the main themes.

Related literature provided the framework that the researcher used in naming and organising the data. These themes and sub-themes are presented in Table 5.2 below and will be discussed in detail in the sections following this.

Table 5.2 Themes and Sub-Themes Generated from the Qualitative Analysis

No	Factors	Sub-Themes	Themes
1	• Quotas and Allocations • Rationing	Control of Drug Flow	Supply Chain Power
2	• Behavioural Uncertainty • Market Reputation	Control of Information Flow	
3	• Price Manipulation	Control of Price	
4	• Misalignment of Supply Chain Goals • Asymmetric Relationships • Trust	Partner Satisfaction	Supply Chain Conflict
5	• Brexit • Parallel Trade • Mergers and Acquisitions	Economic/Political	Supply Chain Complexity
6	• Ethical Framework • Pricing Reimbursement	Regulations	
7	• Product Lead Time • Product Life Cycle • Product Characteristics	Product Characteristics and Production Process	
8	• Volume/Form Flexibility • Supplier Flexibility	Flexibility	Recovery Strategies
9	• Product Visibility • Information Visibility	Visibility	
10	• Joint Decision Making • Information Timing • Information Quality	Joint Decision Making	
11	• Technology • Safety Stock • Strategic Alliance	Resource Sharing	Resistance Strategies

Source: Researcher's findings (2019)

5.3.1. Supply Chain Power

Frequently highlighted in the interviews was the role power played among supply chain partners. In the study, therefore, power was a defining parameter of exchange in the PSC. The data showed the extent to which supply chain partners wielded their power and as such, identified the presence of power asymmetry. More specifically, the issue of power could be seen emanating from the manufacturer. This was either as a result of the nature of the manufacturer (in most instances, there were limited manufacturers or sole manufacturers) and/ or the manufacturers' product which placed manufacturers in a more powerful transactional dynamic. In view of this, the manufacturer determined the tone of the relationship in the PSC. Particular attention was drawn to three instances that occurred among supply chain partners which depicted the presence of power: 1) Control of drug flow through the quota system (allocation) by manufacturers. 2) Control of information and 3) Price control.

5.3.1.1. Control of Drug Flow

The analysis from the data showed that supply chain partners controlled the flow of drug along the supply chain: 1) to protect revenue stream and 2) to ensure patients' treatment continuity.

5.3.1.1.1. To protect the revenue stream

A Manufacturer (MAN3) explained that it was important to control the number of medicines the downstream supply chain partners received through the quota system (allocation). This was because some downstream (wholesalers and or community pharmacists) were perceived to sell excess drugs abroad for profit and as such manufacturers could face revenue losses. MAN1, further stated that because the profit from the sale of these drugs abroad did not reach the coffers of the manufacturers, it had become imperative to control how drugs were distributed to other supply chain partners, hence the introduction of the quotas. Justification for this was provided by MAN2, who stated that:

> *"If the pharmacists are selling a product to a competitor in Germany, the pharmacists take the profit and not the manufacturer…... All I will suggest the pharmaceutical society and*

the General Pharmaceutical Council should take stronger measures against pharmacists that are exporting products" (MAN2).

A response from a logistic service provider (LSP1) reiterated that in situations where they believed that supply chain partners were either stockpiling the drugs or selling the drugs abroad for a profit, they rationed these partners' allocation to zero until they had received scanned copies of patients' prescription. This was to ensure that only patients on the treatment received their drugs as well as to limit the chances of supply chain partners having excess to sell abroad for profit. In these instances, pharmacists and or wholesalers received products only when manufacturers had gained access to scanned patients' prescription.

Another research participant (MAN4) however explained that the control of drug flow occurred depending on the type of medicine that the disruption had impacted on. Therefore, if the prescriptions were a long-term treatment, for example, where the patient had to pick up three months of a six months' worth of prescription, then the drug would be monitored to ensure that all the stock did not go to a single patient. This action could get even out stock distribution until they had returned to normal operations.

5.3.1.1.2. To ensure patients' treatment continuity

The control of drug flow along the supply chain also extended to the regulatory bodies, as REG3 also reiterated that, they imposed restrictions on supply chain partners in trying to manage products in the event of a disruption. This was to ensure that patients remained on medications throughout the disruption. As explained in the statement below:

"We have in the UK two licensed holders for morphine, and it would not run out until September, the other one cannot meet demand 100% so our management plan obviously with lots of consultation for July and August is primary care. We restricted the wholesaler route for primary care so we could manage it more". (REG3)

The above statement thus revealed that regulatory bodies used their position of power to control product flow to smooth out drug distribution throughout the period of the disruption. Stock allocations were however carried out after careful

investigations that showed that the number of products available was not enough to meet demand. This implies that drug control often is in place to manage the supply of the products based on forecasted demand.

> *"If we have low stock, the first strategy is to investigate if we don't think we can react in time to bring in additional stock, we would need to put in allocation for the stock to ensure that all of our stock doesn't go to one consumer or a few consumers and make sure that we adopt everybody". (MAN3)*

The responses also indicated that drug control is referred to as fixed allocations/rationing for secondary care pharmacists, put in place by the Department of Health and Social Care (DHSC), the Commercial Medicine Unit (CMU), and quotas by the manufacturers for primary care pharmacist.

The findings also indicated that drug flow control differed depending on the type of manufacturer since not all manufacturers had the power to control how drugs moved along the supply chain. This implied that the branded and generic manufacturers had different goals. The branded manufacturers had power and more incentive to control how supply chain partners distributed their drugs due to the absence of competition in the market. For generic manufacturers, whose aim was to increase market share, quotas were less likely to be imposed, as the incentive to do so is relatively low with little or no profit gained.

> *"We have the quotas system imposed by the solo suppliers because of people like Pfizer and Glaxo amongst others; all like to impose quotas". (COMM2)*

These assertions were, however, countered by a pharmacist (GP) working at a GP practice; by explaining that most generic manufacturers would impose restrictions to avoid panic buying in the event of a disruption. GP stated that:

> *"Oh, I think a lot of pharmacies stockpile because when they think there is going to be a shortage. They will order extra, which makes them less available to everyone else…That's why there is the quota system, but the quota system doesn't always work does it". (GP)*

The pharmacists who are at the downstream end of the supply chain confirmed the existence of the quota system. The community pharmacists explained that they had to scan all the prescription for certain drugs before the drug was

released to them. This was to ensure that the community pharmacists did not receive more drugs than they required. They continued by stating that they were not guaranteed the supply of the drugs even after scanning the anonymized prescription slips, especially if the drugs requested exceeded the scanned prescriptions. In this case, they had to call the manufacturer to increase the quotas allocated to them. A community pharmacist, COMM1 believed that the quotas were just a form of control by manufacturers when distributing their drugs which made medicines unavailable to the downstream sector. Another respondent, COMM3, classified quotas as artificial shortages caused by manufacturers which made it difficult for them to manage and pre-plan activities in the event of disruption as provided in the exemplary statement below:

> *"Oh, there are also disruptions which I think it is almost artificial disruption around supply chain shortages are things around quotas within the marketplace…. This makes it difficult to pre-plan and manage shortages*". (COMM3)

The introductions of quotas and rationing, thus, depict how manufacturers of pharmaceutical products, controlled drug flow, by influencing the way supply chain partners distributed their products.

The findings also indicated that by controlling drug flow in the supply chain; the intentions notwithstanding, made it difficult for downstream supply chain partners to manage low stock and prepare for disruptions. This is because they were uncertain if it was an actual disruption or an imposed quota. COMM1 expressed this uncertainty in the statement below

> *"Quotas are quite difficult because it makes it quite difficult to predict because you think you are doing the right thing"* (COMM1).

5.3.1.2. Control of Information Flow

The responses from the interviews showed that supply chain partners wielded power through the type of information shared, the quality of information, as well as the timing of the information shared. The data revealed that manufacturers controlled the nature of the information they shared with their supply chain partners during a disruption: (1) to protect their reputation/market share, and (2)

because they were uncertain about the behavioural response of other supply chain actors as a result of receiving information.

5.3.1.2.1. Protecting Reputation

The findings from the interviews revealed that supply chain partners chose not to share timely information if they were having problems with the manufacturing /supply of their products, to preserve their reputation. This was particularly for brand manufacturers who had a reputation to protect and as such, feared to destroy this reputation. This is evidenced by MAN4 who explained that, when their manufacturing site failed an FDA inspection in the US and had to shut down, it took them six weeks to inform their supply chain partners because they thought they could handle the situation. Therefore, they tried to manage the information that got out and protect their reputation in the marketplace. However, when the firm saw it could not manage the global demand, it had to inform its supply chain partners. This implied that if a firm's reputation was damaged as a result of its inability to supply products to its supply chain partners, it might lead to loss of income as well. This is further reiterated in the statement below.

> *"Some manufacturers do not necessarily want the market to know that they are going to go short in supply …it's a reputational thing as well". (LSP1)*

Another interview participant (MAN1) also explained that when a disruption occurred, its firm controlled the information it shared about the disruption with its supply chain partners and tried to manage the situation. They engaged in this action because they feared they would lose their customers. MAN3 stated that it was a difficult conversation to have with the GP, as this meant that the GPs had to stop prescribing their products if they could not continue patients on their treatments on that drug. This meant that the loss of sales, in the long run, affected the financial performance of their firm.

> *"It was a difficult conversation to have, and some GPs said they were going to switch all their patients to alternative products. The good news for us is that even on occasions where all that happened, the patient tried all the products and requested to come back to our product". (MAN3)*

However, some respondents believed reputation protection was mostly by generic manufacturers who had a reputation to protect in the market and so were not keen on sharing information when they had a problem.

MAN2, on the other hand, stated that sharing information was vital in maintaining brand image, explaining that when their firm experienced a disruption in the supply chain, sharing of all necessary information relating to the disruption was essential as it helped maintain customer loyalty as evidenced in the statement below:

> *"Obviously we had to communicate to the customer to tell them what the situation was and luckily it was a product, not all the hospitals used…. Moreover, our customers stayed loyal to our products and started using them again. So, if we had not managed the situation very well, they would have moved on to other manufacturers". (MAN2)*

The above statement indicated that even after sharing the information of impending disruptions to the supply of drugs to their supply chain partners, their customer base had not changed, and their firm still maintained its profit margin.

5.3.1.2.2. Behavioural Uncertainty of Supply Chain Actors

The data from the interviews revealed that supply chain partners exhibited power on other supply chain members through the control of information to avoid diverse reactions from these members. For instance, HOSP2 explained that they usually experienced various actions by supply chain partners if there was a disruption and partners could not supply goods. On the one hand, some manufacturers would ask to salvage the situation by agreeing to supply the goods and seek to be reimbursed at the going NHS rate. On another end of the spectrum, some manufacturers would agree to supply the goods at an exorbitant cost, thus seeking to make an abnormal profit as suggested in the statement below:

> *"Manufacturers; will go and approach individual hospitals and now say we have got this product; the contracted one I hear you can't get this product; we will sell it to you at this price". (HOSP2)*

Another instance depicting supply chain actors' behavioural uncertainty is related to the issue of panic buying. HOSP3 elaborates that, as a manager in a managerial capacity, they would panic buy based on information received on impending disruption. HOSPI also explained that managers might create panic buying if they received news of disruptions to buffer stock. HOSP3 echoed that the action of supply chain partners could result in a domino effect where close substitutes become unavailable, explaining that when supply chain partners receive information about disruption, they begin panic buying and buy products they do not need, which causes a stampede. Supply chain partners may go to the extent of stockpiling alternative drugs and as such put pressure on competitors. As explained by HOSP4, who states that:

> *"When people know about it is when you can't buy it, and the word goes around, and people say oh that's something that we need. And people start panic buying". (HOSP4)*
>
> *"As a manager of someone in a managerial capacity, you can create drug shortages by panic buying. If you hear that there is a shortage is likely to occur, the first instance some people will do is the need to get plenty of that product when it is still available; then demand goes up …One of the dilemmas you are trying to manage is how much information can you give people". (HOSP3)*

Another response from the interviews, REG1, stated that to avoid activities such as stockpiling by some supply chain members which may cause further disruptions, when their firms received news of disruption, they would choose not to share. HOSP3 identified lack of sharing information as a form of opportunism, resulting in profiteering as well as the undermining of the contractual process. COMM1 reiterated these actions by explaining that some wholesalers would hoard the products to make an abnormal profit if they got news of a product going in short supply or any other disruption. They explained that if wholesalers get information about a shortage earlier than other supply chain partners, these activities further strain the supply chain and complicate disruptions. LSP1 also said that some of the information shared may be out of date as at the time this information reached their intended users, which was usually as a result of poor information sharing facilities and triggered poor demand signals. In view of this, information shared to supply chain partners was controlled. REG2 further

explained that late access to information made it difficult to respond to the disruption as well as find alternative products on time which included, regulators, being able to fast forward license variation or other and applications that may cause a delay in medicine shortage management. Figure 5.1 provides a summary of how power is displayed through the control of information.

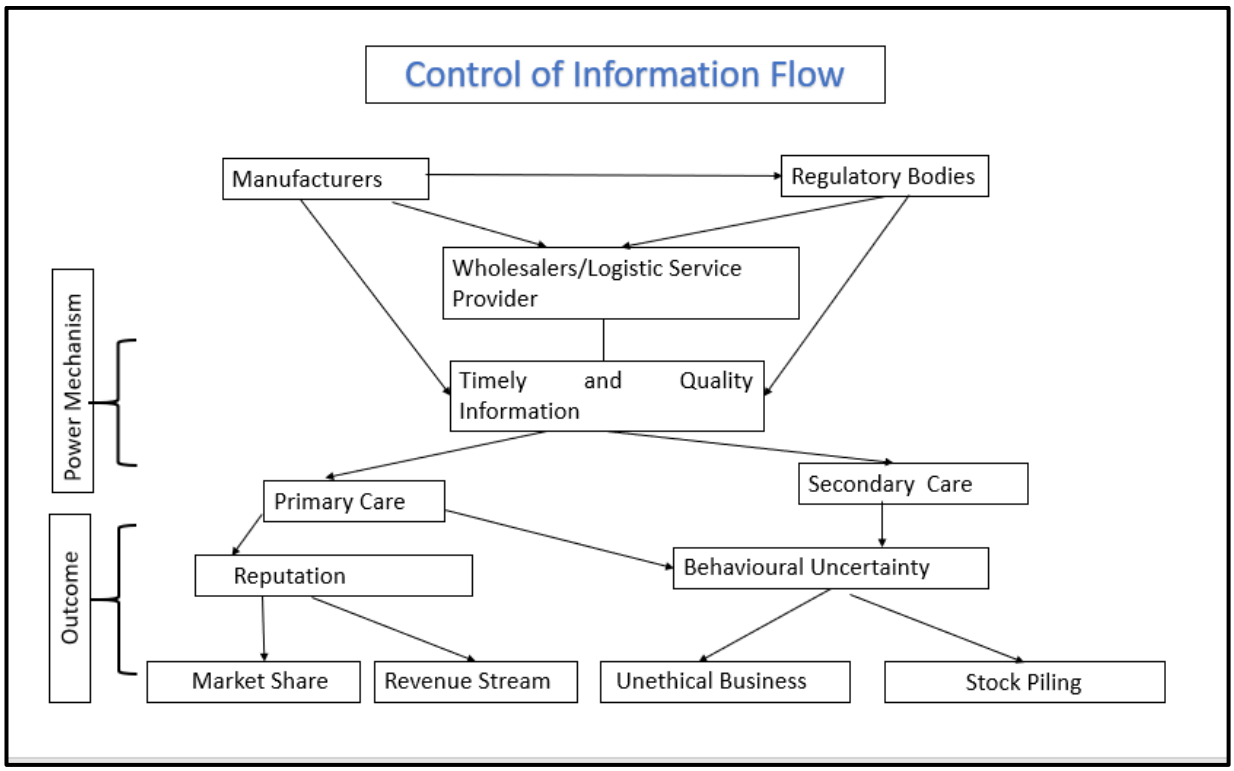

Figure 5.1 Control of Information Flow

5.3.1.3. Price Control

The responses from the interviews also provided the issue of price control as a form of power in the PSC, which is usually manifested through price manipulations. For instance, community pharmacists explained that some supply chain partners, especially the ones that had their presence at various levels of the PSC (such as wholesaling and retailing) manipulate prices to sell for their gain. This is because if the prices go up, they get remunerated more. In some instances, supply chain partners may create artificial demand to control the prices. The actions below illustrate reality:

> *"A drug used to be on the market selling for maybe £3 to £4, I can't remember exactly. Amacol bought the license for this drug, removed it from the market for about six months and sort of created havoc, re-released it back onto the market with an inflated*

price of about £20. And that's the other aspect, so we have got that manipulation". (MAN2)

The above statement demonstrates how supply chain partners display power through the control of prices. A summary of power as a vulnerability is presented in Figure 5.2 below.

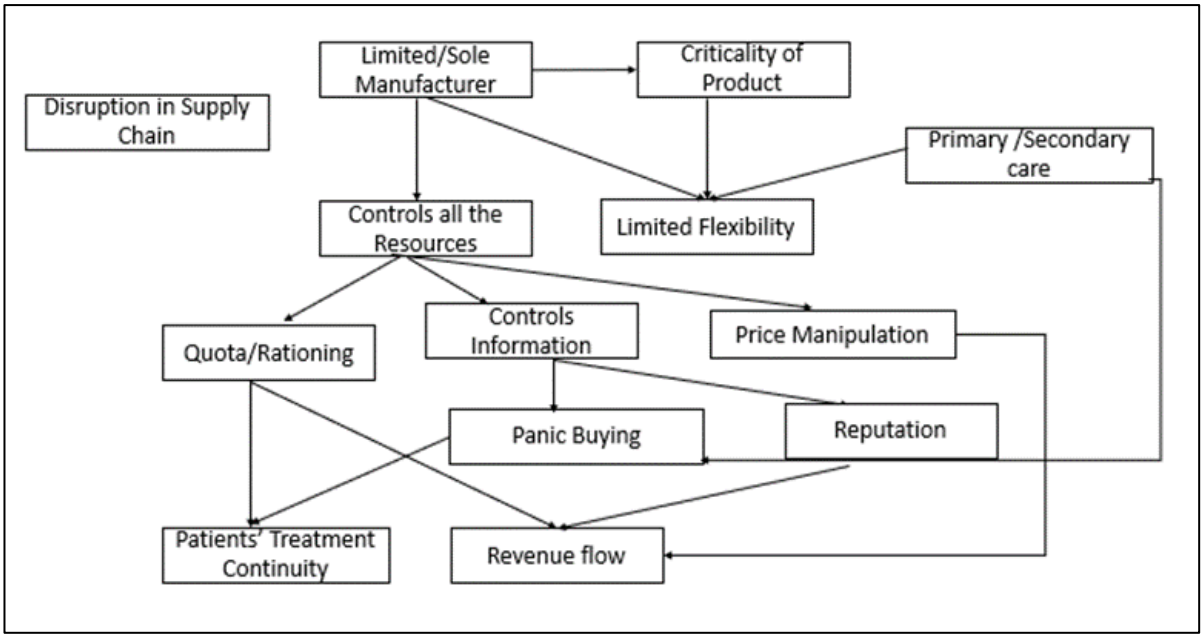

Figure 5.2 Power as a vulnerability in the PSC

In analysing the findings from the data; therefore, it is worthy to note that there is the presence of power asymmetry in the PSC, which increases the level of vulnerability. Also, patients' treatment continuity, as well as revenue flow, were the two major reasons why supply chain actors engaged in power dynamism.

5.3.2. Supply Chain Conflict

The second major theme that emerged from the data analysis was the presence of supply chain conflict. The responses from the interviews thus revealed that the absence of trust, misalignment of goals and asymmetric relationships between supply chain actors were the breeding ground for conflicts in the supply chain. The sections following this provide insights into how these dimensions occur in the PSC.

5.3.2.1. Misalignment of supply chain goals

The data collected from the interviews identified the tendering system versus profit-oriented goals and service-oriented goals versus profit-oriented goals, which depicts the misaligned supply chain goals. Regarding the tendering system in the PSC in the UK, there is a conflict of interests amongst supply chain partners. For instance, REG3 explained that the goal of the NHS was to supply drugs to patients at the minimum price possible and as such embarked-on pricing schemes that met these goals. In most cases, the NHS offered contracts to two and not more than three suppliers on a regional basis. This was further reiterated by MAN1 in the statement below:

> *"Because I know the NHS often award based on price and get the cheapest supplier"*. (MAN1).

MAN3 also explained that they could not compete favourably with generic manufacturers for lower prices and as such, when they lost the bid, they sought alternative markets and sometimes ceased production. This implies that the tender system drives other suppliers who do not win the contracts as a result of their inability to supply at the required NHS prices out of the market. Therefore, when a disruption occurred, suppliers were unable to meet local demand on time since they had been pushed out of the market. Further, MAN1 also complained that in the NHS procurement practices, the NHS did not consider the reliability of suppliers in meeting demand but usually sought the lowest prices irrespective of suppliers' failure to fulfil their contracts in previous periods.

> *"The NHS does not consider supply chain reliability of the supplier. I think the NHS needs to get better at collecting information on past performances of suppliers." (MAN1)*

REG3 and HOSP2 in responding to the issues on the NHS tendering process, explained that it was against the procurement laws to consider the past performances of suppliers. More specifically, REG3 elucidated that if they were to consider the past performances of suppliers before awarding contracts, there might be no suppliers left in the end as there were usually limited pharmaceutical suppliers.

Another instance of goal misalignment was the profit-oriented goal of the manufacturer, as REG3 stated that.

> *"Medicine is not a commodity; it's not something consumers can do without. Some of our manufacturers don't just get how important the medicine they make is, it's not just business". (REG3)*

The above statement denotes that some manufacturers may not understand the criticality of the products they provide and as such were in the pharmaceutical business not for serving the patients but as a business venture. The implies that although the role of actors in the PSC was to save lives; some actors were just in it for the profit, this transcends just being in business to make money but also involves saving people's lives.

Also, the interviews highlighted that the role of community pharmacists focused on service, being involved with patients within the community; profit was not the main goal of their existence. COMM3 further highlighted pharmacy type and scale in the statement below:

> *"There is a debate as to understanding the role of pharmacy… additional service to patients or make profit… certainly the more money you take from the pharmacy…. community pharmacy is not about making money whereas for the multiples it's about profit not about service". COMM3*

Some respondents also complained about supply chain partners hoarding products for price gain and profiteering, especially when they failed to meet their forecasted sale. This thus depicted that some supply chain partners did not understand the criticality of the product and as such, portrayed divergence of goals. COMM1 however, explained that the reason for the misalignment of goals was because supply chain actors were acting as per their firms' individual business strategy, pressures and needs as explained in the statement below.

> "*Because all these are individual businesses, and all reacting to their own individual strings and pressures and needs at that time." COMM1.*

The responses from the interview also indicated those goal misalignments existed between the pharmacists and the GP. The issue here is that pharmacists may want to keep inventory as low as possible to reduce costs, while the GP may prescribe drugs based on incentives, they may be receiving

from supply chain partners. For instance, the pharmacists at a GP practice gave a recent example of Quetiapine with the brand name Seroquel which is expensive to procure, and when suggestions for cheaper generics are brought up as the available alternative, the GPs were hesitant to change the product. The pharmacists here are left with the choice of either footing the bill for the alternative expensive brand drugs or sending the patient to other pharmacists who may have the brand readily available. In most cases, the latter occurs, and this may create a false demand signal, thus increasing incidences of disruptions.

5.3.2.2. Asymmetric Relationships

Another indicator of supply chain conflict was the presence of asymmetric relationships amongst supply chain partners, and this affected the level of partners' satisfaction among supply chain actors. Asymmetric relationships here emanate from the amount of control the manufacturer and the regulatory bodies have over material and information in the supply chain, as explained in 5.3.1.1 and 5.3.1.2. These dominant activities breed asymmetric relationships that lead to conflict and partner dissatisfaction as well as making the supply chain vulnerable to the impact of disruption. The statement by a community pharmacist (COMM2) below highlights aspects of this type of dissatisfaction:

> *"Drug shortages occur because somebody else in the chain is making a profit by locking these items, or increasing prices, or stopping them from coming into the country*". (COMM2)

The exertion of certain business practices from the dominant partner hampers communication flow as well as the ability to respond adequately when a disruption occurs as the supplier exploits its position as a dominant partner. On the other end of the supply chain, are the supply chain partners with lower dominance powers, but these supply chain partners have been accused of profiteering at the expense of the manufacturers. There were also comments about the absence of measures to curb profiteering from the export of products, and pharmacists were blamed for the existence of these vulnerabilities. These activities generated conflict among supply chain partners as well as lowered trust and commitment. COMM1, for instance, stated that the GPHC (as a regulatory body) was more concerned about how pharmacies dealt with inspectors, instead of the public. He argued that the goal of pharmacies

exceeded dealing with inspectors, where the pharmacy was more about dealing with the public and the services it offered. Other research respondents complained about the absence of complete transparency and hoped that actors within the supply chain would remember what their role was; unfortunately, that was not a reality.

The presence of an asymmetric relationship also highlighted issues related to the blame and dissatisfaction of supply chain actors. For instance, the findings from the interviews revealed that manufacturers were dissatisfied with transactional issues where prices of pharmaceutical products were considered too low and as such, manufacturers were dissatisfied and sought other markets.

5.3.2.3. Absence of Trust

The responses from the interviews revealed issues on lack of trust as a criterion that bred conflict in the PSC. Trust issues thus emanated from the inability of supply chain actors to audit the behaviours of their supply chain partners or in some instances, evaluate the quality of resources brought to the supply chain. For instance, LSP1 explained that they did not trust the activities of their supply chain actors, so unless pharmacists produced genuine anonymised prescriptions, they did not supply products to them. The action of scanning prescriptions by pharmacists allays the fears of manufacturers with regards to the activities of the pharmacists about their product.

Another incidence of a trust issue was the introduction of the Direct to Customer Model (DTC) introduced by manufacturers. DTC here entails bypassing intermediaries and supplying medicine directly to patients. This action signals the absence of trust as manufacturers do not trust that their supply chain partners possess the expertise necessary in distributing their products effectively.

> *"For instance, the direct to the patient model where the manufacturer supplies directly to the patient is not practical as it tends to cause more issues if something goes wrong, there is no resilience." (COMM1)*

COMM1 further explained that the introduction of DTC model, however, creates conflicts and increases the complexities of the PSC. Thus, by bypassing intermediaries and using hospital prescriptions to serve patients, these patients

lack the service they require. Also, if there is a disruption, there is no resilience within the system, and it doesn't ensure business continuity. The responses from the interviews further revealed that issues of behavioural uncertainties among supply chain partners either increased or decreased the level of trust among supply chain partners

5.3.3. Supply Chain Complexity

The responses from the interviews identified complexities within the supply chain as a theme which exposes the PSC to the diverse impact of disruption. In this study, supply chain complexities are categorized as external drivers of vulnerability as the supply chain actors may have little or no control over these actions. Antecedents of supply chain complexity found in this study included product/process characteristics, regulations and economic and political issues. These antecedents will be explained in the sections that follow.

5.3.3.1. Product Characteristics and Production Process

Product and production processes were also dimensions highlighted from the interview responses as an element of supply chain vulnerability that increased the impact of disruptions on the supply chain. Elements of product and production processes included the life cycle of pharmaceutical products, the production lead times as well as the composition of the product.

5.3.3.1.1. Production lead time

The responses from the interviews identified the manufacturing lead time as a major feature of pharmaceutical products that increases the impact of disruptions. The study identified that the lead times for pharmaceutical products are longer and differ significantly from other products. MAN4, for instance, explained that the pharmaceutical products his company manufactured included drugs aimed at curing diabetes and heart failure, which were specifically manufactured based on a patient's prescription and previous demand. He further explained that because of the speciality of these products, the planning involved in manufacturing these drugs, especially to meet the set standards on time is quite complex. Another research respondent further explained that due to the complexities involved in manufacturing pharmaceuticals, in the event of a disruption, it would take about eight to twelve weeks for a competitor to respond to the demand in the marketplace and some cases years.

> *"The drugs we predominantly sell are not the type of drugs like other products. It must be like diabetes, heart failure …… We manufacture based on patient prescription numbers which are not quite straight forward. I would say the manufacturing of pharmaceuticals is quite a long process. It is a complex release process. Certain things need to take place. It's not a quick process"*. (MAN4)

Further, MAN1 gave an instance in the case of vaccines, explaining that it would be difficult to cover the gap of a competitor in the case of disruption as vaccines require about three years of planning and to produce more vaccines. Another respondent COMM1 also explained that the inability of the manufacturer to create products quickly enough to meet demand in the event of disruption created a backlog and as such, increased the impact of disruptions when they occurred.

5.3.3.1.2. Product Life Cycle

Some manufacturers also expressed the uncertainty associated with forecasting the demand for new products in the market. The reasons included difficulty in gauging the end-users' perception, ambiguity around NHS's decision to fund the new drug, or in some instance approval by the NHS or NICE to using the products. This uncertainty had a large impact on their decision to supply to the UK market, thus making the PSC vulnerable. Manufacturers also explained that decision making was difficult when the products reach the end of their life cycle or when they came off patents, thereby permitting competition. They were unsure if the GPs and the NHS would continue to prescribe the drugs or seek cheaper alternatives. Given this, the manufacturers preferred to market products at the end of their life cycle to more profitable markets.

Other findings from the interviews related to product characteristics were the lack of available alternatives. The responses from the interviews identified that for pharmaceutical products to be effective, they had to be taken in the right dosage and strength. This, therefore, suggests that the absence of alternative products for a pharmaceutical was another reason why the impact of a disruption in the PSC could be felt as stated by HOSP3 below:

> "*The difference between medicines and other products, if you don't have baked beans you can go without, you can't do that with medicines. You must find an alternative. This, in turn, affects the supply of goods in the marketplace. It is much more obvious with*

pharmaceuticals because there are strict scarce alternatives". (HOSP3).

Further complexity of the pharmaceutical product may relate to the storage and distribution process. For instance, REG3 elucidated that some pharmaceutical products may be recalled if they have been left too long on a runway or the temperature control of the product changed slightly making it unsafe to be prescribed to the patient. This action leads to the inability of supply to meet demand and as such leads to a shortage.

5.3.3.2. Economic and Political Issues

Economic and political issues were also some of the themes that emerged from the interview responses.

5.3.3.2.1. Political Issues (BREXIT)

With regards to political issues, for instance, several respondents expressed their fears about BREXIT and how it would affect drug supply and distribution in the UK. A manufacturer (MAN3) stated that if regulatory bodies reassured supply chain partners that BREXIT would not affect drug supply, then they would be able to plan better and manage drug supply in the UK. However, with the uncertainty of BREXIT looming around the corner, manufacturers, as well as other supply chain partners, had resorted to stockpiling as well as diversifying business strategies outside of the EU which would have an impact on the supply chain. REG3 elucidated that these actions would further complicate the PSC in the UK, making it vulnerable to other underlying issues. MAN2 also explained that a political issue like BREXIT had a major impact on the PSC in the UK. This was especially if underlying systemic problems were not properly dealt with pre–BREXIT. In the event of BREXIT, the supply chain would suffer. An example is the uncoordinated information system of the PSC, which makes it rather difficult for supply chain actors to forecast demand, as explained in the exemplary statement below:

"Let say BREXIT… because the wholesalers play a major part in the supply chain. If at the moment they are importing products from other countries and we are not aware of that, if we are not able to do that pre-Brexit, then we will find that demand for

products in the UK will increase and we might not have forecasted the market".(MAN2)

5.3.3.2.2. Mergers and Acquisitions

The results from the interviews also highlighted that mergers and acquisitions among supply chain members heightened the impact of supply chain disruptions. One community pharmacist, COMM4 believed that when big pharma firms' products came off patent and no longer controlled the market share, they merged with smaller supply chain partners to remain relevant. The argument against these actions is that there is less competition, less variance and as such disruptive events hit the supply chain harder.

> *"In the last few years, a lot of big manufactures have merged so there is less variance, less competition, so if there is manufacturing problem that hits the supply chain a little harder". (COMM1)*

Responses from MAN1 explained that mergers and acquisition in the PSC in most cases were carried out to strengthen both the upstream and downstream sector of the PSC.

5.3.3.2.3. Parallel Trade

The responses from the interviews also identified parallel trade as one of the reasons for vulnerabilities within the PSC in the UK. The research participants explained that although trading of pharmaceutical products within the European Union is legal, it had a huge impact on the supply of medicines within the PSC in the UK. For instance, PWS, a research respondent explained that parallel export was rampant during the financial crises in 2008 and that the supply chain had not fully recovered from those activities. The underlying cause is that the nation has shifted from being a parallel import country to a parallel export country as a result of the fluctuations in exchange rates. As such, supply chain partners tend to take advantage of the weakening British pound against the Euro to make profits. Although parallel trade and the whole movement of stock across

the border are not illegal, these activities confuse demand signals and may cause chaos if not managed adequately.

MAN4 echoed this in the statement below:

> *"Other problems will be related to parallel trade, using an example where there is a product which is an eye care product and 10% of the sales of the product are the UK taxed which we distribute, 90% are products that are imported into the UK. The parallel importers for whatever reason had problems with getting hold of the products and so suddenly we were faced with an increase in demand of 10 times what the normal demand was. On an average, we would have 1.5 to 2 months of stock, so very quickly we ran out of stock for that product, and there was a gap between 6 to 8 weeks before we were in a position to supply". (MAN4)*

The balance between supply and demand, which is closely linked to globalisation is another issue that increases supply chain vulnerabilities as well as economic issues. The respondents highlighted that as a result of globalisation, manufacturing firms have wider markets but have not developed or increased supply strategies to match the demand

> *"I think it's a combination of all these things of the globalised supply market. Manufacturers are rationalizing the number of manufacturing sites that they have. All of these is making the supply chain very fragile, and it will be difficult to address if anything goes wrong*." (HOSP3)

Another economic issue identified as a driver of supply chain vulnerability within the PSC was the pricing structure as identified in the statement below by REG3

> *"The other factor, in reality, is price because prices have been pushed down so much that the industry has had to find a way of reducing costs at all points along the supply chain". (REG3)*

The above statement highlights that prices of drugs matched against supply chain security increased vulnerability. REG3 explained that because supply chain actors demand cheaper products, manufacturers, in seeking ways to reduce costs of production, rent manufacturing schedules at various manufacturing plants. While these may be cost-effective, MAN2 explains that there is no visibility between the manufacturer and its manufacturing plant since

the location of where the manufacturing plant being rented is different from the headquarters of the pharmaceutical firm. As such, there may be a gap in communication when there are incidences like news of a disruption. REG3 argued that it is that lack of governance between the manufacturer and its manufacturing plant that makes the supply chain extremely vulnerable.

MAN1 further elucidated that to increase security in the supply chain as well as be more cost-effective, it has become pertinent for manufacturers to reduce the number of manufacturing plants globally. This enhances visibility as well as establishing product flow control. Other supply chain partners, however, argue that these actions increase vulnerability because, in the event of disruptions at a manufacturing plant, there may be no backup plant to restore supply chain activities.

5.3.3.3. Regulations

The responses from the interviews identified regulations as an emerging theme relative to the vulnerabilities of the PSC. For instance, MAN3 explained that because their firm failed to meet certain regulatory requirements, they could not supply their products. The impact of this regulatory requirement was adverse as this firm was the sole manufacturer of the product.

> *"We had a situation which lasted about nine months, and this was because of the GMP failing in one of the Roche factories in the US and the regulatory bodies decided that we were not able to release product onto the market until we had resolved the issue."(MAN3)*

HOSP3 also indicated that it was not about the regulations but the constant changes of the regulatory requirements for the manufacture of pharmaceutical products as elucidated in the statement below:

> *"For instance, a lot of drug shortages around Europe have been caused by the constant change in regulatory bodies. The FDA is going to manufacturers saying the standards have changed. For manufacturers to meet up with these requirements, they must disrupt their manufacturing process" (HOSP3)*.

The presence of some of the regulations in place was also seen to inhibit supply chain flexibility which may also intensify the impact of disruptive activities. A scrutiny of the rules set in place for reimbursement of drugs sold on the NHS

price list was identified as cumbersome, as some pharmacists explained that they are required first to supply products to the patients before they could be reimbursed. These processes, in most instances, make pharmacists run their businesses at a loss, with complications involved in reconciling their books. As a result, some of the pharmacists chose to stock their pharmacies with essentials products which they considered as 'fast liners' that were termed 'more profitable'. The activities of the pharmacists, in this case, may indicate that the regulations affected their managerial decisions to be more resilient and as such, hampered drug flow. One pharmacist working in a GP practice stated:

> *"The trouble is, for instance, if this is June; they don't normally accrue till the end of June. So, you have dispensed all through June those prescriptions let's say Lamotrigine. Sometimes you must go all through your prescriptions, take them out and send them in July, so you get the higher price otherwise they will charge you at the old price. So, it's very difficult for us, more work for us". (GP)*

Another instance of regulation closely linked with reimbursement has to do with drug availability and prescriptions, which causes false demand signals. According to COMM3, the underlying regulation requires the pharmacists to provide the patient with all the drugs on the prescription. If a drug on the patient's prescription is unavailable, the pharmacists may need to refer the patient to another pharmacy to receive the prescription, thus losing a customer as well as a possible profit stream.

To avoid these losses of whatever kind, the pharmacists may ask the patient to come back at a stipulated time, while he tries to source the drug or ask the GP to prescribe an alternative treatment. If these options are absent, then the patient may have to seek the drugs elsewhere, as explained by COMM1. The movement of a patient from one pharmacy to another in search of the prescribed drug created a false demand signal which may lead to panic in the market. Another instance described in the statement below by COMM4 entailed difficulty in managing the drug supply when other supply chain partners on the same level did not have access to the products.

> "*And again, in the same way, we had probably bought enough levothyroxine ……, actually what happens then is that we get their*

patients and our usage goes up. It becomes more difficult to manage that as well." (COMM4)

The research respondent here implied that the false demand signals were created because, if other supply chain partners were not as prepared for disruption as they ought to be, because of the underlying regulations, the more resilient firms experienced customer management crises which may lead to further complications thus weakening the supply chain. Also, the findings indicated that government taxes, as part of its regulatory framework, further weakened the PSC in the UK. COMM1 explained that in recent years the government had taken pharmacy contract worth over £170 million from community pharmacies. Therefore, to remain viable in business, community pharmacies tend to hold less stock to release capital as well as ensure cash flow to cater for overhead expenditures.

The responses from the interviews also indicated that supply chain partners did not clearly understand the roles of the available regulatory bodies when disruptions occurred. For instance, when research respondents were asked about the role of regulatory bodies in the event of a disruption, COMM3 referred to the General Pharmaceutical Council (GPC), the GP referred to the Pharmaceutical Service Negotiating Committee (PSNC) as a regulatory body that assisted, MAN1 stated that they reported to, as a well as depended on the Department of Health and Social Care (DHSC). A logistic service provider (LSP1) explained that*:*

"The (Medicines and Healthcare Regulatory Agencies) MHRA plays a role in regulating us in ensuring that we meet the quality standards we need especially manufacturers. I don't think they get involved in the supply chain; I mean the flow of goods. The Department of Health (DoH) does get involved in the supply of goods". (LSP1)

The absence of a centralized regulatory body to cater for PSC disruptions such as information flow, in an industry that is heavily regulated makes the supply chain vulnerable to the impact of disruptions. This is because supply chain partners will have to rely on any available information from whatever source in the event of disruptions in order to develop coping mechanisms*.*

Further, the interviews revealed that the regulations guiding the supply of drugs, especially within secondary care, had lapses which supply chain partners had taken advantage. HOSP4 explained that, if a generic manufacturer was contracted but could not supply the drugs within 14 days, they had to report the incident and be penalised. This being the case, before another alternative was sought, supply chain partners had to wait for 14 days before the hospital, for instance, could purchase the medicine from another supplier. The issue here is that with this regulation in place, suppliers may be reluctant to share information of disruptions before the 14 days expired. Also, procurement teams were not permitted to consider the past performances of the suppliers in terms of the national contracting process, as stated by HOSP4 and REG3.

HOSP3 explained that this regulation was in line with the principle of competitive tendering and capitalism, where the more suppliers you have in the market, the more competitive the prices will be. The underlying idea here is that there are limited suppliers of pharmaceutical products, therefore if past performance such as their inability to supply products were considered, there might be one or no supplier to supply goods to the PSC in the UK, and the prices may be high. Some of the respondents, however, argued for the presence of regulations in the production and distribution of pharmaceutical products. The contention here is that regulations are required to increase safety and ensure the efficacy of the medicines that are being distributed. However, the procedures taken in ensuring these regulations are adhered to is where the problems arise.

> *"I think it's true that we have more and more regulation. …regulation is important, and it's needed. Clearly, people want to be sure that medicines are of a certain standard and it is going to work wherever they are supplied to across the world erm how you do that is important and doing that in a way that doesn't lessen safety standards and efficacy standards in any way".(REG2)*

5.3.4. Resilience Strategies

Two forms of resilience strategies also emerged from the data and were classified as either recovery capabilities (reactive strategies) or resistance

strategies (proactive capabilities) and will be explained in the sections following this.

5.3.4.1. Recovery Strategies

The data revealed that some of the measures that actors within the PSC employed in mitigating the impact of disruptions were strategies that helped them return to normal operations; hence the term 'recovery'. These strategies are explained in detail below

5.3.4.1.1. Flexibility

Regarding flexibility, the data indicated that two forms of flexibility were used in recovering from a dynamic disruption. These were medication form/volume flexibility and supplier /logistic flexibility. For form/volume flexibility, the respondents explained that to recover from the impact of a disruptive activity the use of products that had similar strengths, or a suitable clinical alternative at the right dosage or trying to make do with available combinations were the available options to continue patients' treatment. This strategy was particularly relevant depending on the product the disruption had affected.

The findings indicated that it was essential to find available alternatives to maintain the financial performance of their firm. For instance, in secondary care, if a supply chain partner was unable to satisfy the demand of its customers within two weeks, then the impact would be loss of sales and an end to the contract claim. COMM1 provided an example of seeking for alternatives for levothyroxine and phenytoin at the strength through using multiple tablets to achieve the right dose or to manage drug flow as well as ensure that patients' treatment continued correctly.

> *"So, what happened with that was that you might have decided 100mg may have gone out of stock originally, so you double up with 50mg and everyone was doing that. It took a good three or four weeks for things to settle down because people were trying to make do with whatever ". (COMM1)*

HOSP3 also explained that an alternative might be to use different forms of the product. Therefore, instead of volume alternatives with regards to the strength of the drug, flexibility could be in formulations such as liquids instead of tablets and non-sustained release rather than a sustained-release preparation.

> *"A coping strategy might be to use syrup instead of a tablet, or strength of tablet rather than the strength that is out of stock or a non-sustained release rather than a sustained release. For example, we had a long-standing problem with diamorphine injection we had to get people to switch to morphine". (HOSP3)*

To this end, several reservations were raised about product flexibility as an effective recovery strategy *as* the tendering process by the NHS, the brand versus generic issues as well as the ability to find suitable alternative may hamper flexibility. The NHS pricing principle in awarding contracts, as explained by MAN4 made some brand manufacturers exit the market or stop production of the line of medicines entirely. In the same vein, when about five generic manufacturers bid for the contract and only one or two wins, they may also decide to leave the market. So, the problem is that the NHS has a huge reliance on a few companies, thus reducing its resilience strategies impact. As explained in the statement below:

> *"If the NHS has a huge reliance on a few generic companies, they may run into problems because generally, they are manufacturing lots of products they don't really specialize in any particular. The NHS is in a weak position, and sometimes they come back to the brand manufacturers, and there is no way we can meet their demand because ourselves we have basically disappeared". (MAN4)*

The findings also indicated that flexibility was challenging depending on whether the affected medicine was generic or branded. If the products were generic, it might be easier to find alternatives within the market. However, issues may arise if the product was branded, which implies that there were no clinical alternatives. Similarly, the impact may be felt more in the hospitals as they were based on tenders in comparison to primary care (pharmacists) who had more flexibility when sourcing for alternatives. The research respondents also explained that to ensure that patients continued their treatment when disruptions occurred, sourcing for substitutes with the right dosage and strength was difficult. However, it was hard to find alternative products in the right dosage as well as strength.

The process of, therefore, sourcing for alternatives in most cases created chaos, stress on supply chain partners and further complexities, which heightens the impact of a disruption. For instance, HOSP4 explained the issue with diamorphine injection that was short in supply for a long period. In seeking alternatives, patients had to switch to morphine; however, there are different strengths of morphine, so the dosage had to be calculated to get the right strength for each patient - in some cases different clinical alternatives or different presentations. Community pharmacists, however, complained that getting alternatives for some of the pharmaceutical products was quite difficult, as explained in the statement below.

> *"With things like levothyroxine and phenytoin you have to start doing things around multiple tablets to get the right dose or strength, the problem with the levothyroxine is that there is not enough time to find alternatives"*. *(COMM3)*

The argument here is that the alternatives may not be as efficient as the originally prescribed drug and may cause what they termed as the 'crackdown effect' or 'domino effect'. One community pharmacists (COMM4) also explained this by saying that, sometimes when tablets were swapped to capsules, the alternative drug supply chain ay feel the pressure. Thus, when they thought they were turning to another product as a form of flexibility, they may have been creating instances where the other products became unavailable. Thus, managing this disruption implied taking the supply of other drugs that had already been forecasted for. It was also difficult to find alternatives for medicines that were not often prescribed, and sometimes the timing required to find alternatives were limited.

For supplier flexibility, the respondents explained that they sometimes had to go out of the supply chain to source for their products to ensure patients treatment continuity. For community pharmacists, they sometimes engaged the services of 'short liners'- who are specialist wholesalers with limited stock but are scattered across the country. The issue associated with this form of flexibility is that it is often costly, and as such, some supply chain actors may be reluctant in employing this mitigation strategy.

> *"I occasionally have to buy from the main short-line. If I get something, I pay over tariffs to make sure I have supplied for my patients. I lose money for that, and I hope we recover from it in the end. .. Professionally, I try to maintain supply for my patients, and it costs me money to do so". (COMM5)*

Other respondents explain that these short liners are owned by the three major wholesalers who often used these channels to dispose of excess stock, and as such, the prices are unstable. The short liners also took advantage of disruptive events to make an excess profit. Therefore, if they noticed a surge in demand, they increased their prices to make an abnormal profit. It should be noted that these forms of flexibility adopted as recovery strategies were often used at downstream end in the PSC.

5.3.4.1.2. Visibility

The findings from the interview also identified product and information visibility as forms of visibility that supply chain actors used in mitigating the impact of disruption.

Product Visibility

For product visibility, a pharmacist working in a GP practice explained that when they placed an order for a drug from their respective wholesalers, they could see through their information system which wholesaler had the drug, the quantity available and when it would be supplied. Other respondents indicated that information regarding impending shortages as well as details of current distribution management was also made available on different websites like the PSNC and National Pharmacists Association (NPA). This helped them to plan accordingly.

> *"We have an online ordering system. Which is actually quite good because they actually tell us if it's red it means it's out of stock and blue if they have got stock." (GP)*

The shortfall, however, was that sometimes even if they could view the amount of stock available and all the information regarding the stock, some manufacturers still refused to supply.

> *"The only information we get from the pharmaceutical services negotiation committee (PSNC) website…. They have put everything in place, for example, they tell you which product is affected and why and they say to you when you can contact alliance. I have done that; it still doesn't help because they don't*

supply the medicines. We have to keep phoning every day in trying to get stock." (GP)

Information Visibility

The interview responses indicated that information visibility increased supply chain actors' ability to withstand the impact of disruptive activities that may occur in the PSC. The dimensions of information visibility included the timing of the information, the quality of information and channels through which the information is visible. The channels for sharing information as highlighted by the interview responses included stock bulletins that are sent out to customers every week, attending stakeholders' conferences to inform them of ongoing situations as well as a centralized information system. A manufacturer, MAN3, explained that it was necessary to share information with its competitors if they were experiencing difficulties in supplying goods. This action was pertinent, especially if the disruption was going to last a long time to prepare competitors for spiked demand during that period.

> "*Obviously we had to communicate to the customer to tell them what the situation was especially if the disruption was going to last longer". (MAN3)*

However, how the information was shared, as well as the information that flowed behind, was critical. For instance, if a supply chain partner advised that a product was going to become unavailable, the information shared was expected to contain the causes of the unavailability, timing for the shortage as well as information about alternative substitutes. This implies that if a supply chain partner informed other members of the supply chain that there were going to be disruptions, information follow-up included the length of the disruption and possible solutions with other supply chain partners.

The responses from the interviewees also revealed that the quality of information was a necessary strategy for the supply chain to remain resilient in the event of a disruption. HOSP3 explained that the major dilemma in being resilient was to understand how much information you share with supply chain partners.

"Provide the right information for nurses and doctors for them to understand what the issues are and how best they can overcome them". (HOSP3)

COMM3 also explained that the greatest threats to handling supply chain disruptions were the lack of relevant and timely information. He explained that the wholesalers might not inform them about a disruption until they had an issue and called up. This form of information sharing hurts supply chain partners as well as creating counterproductive strategies. The findings from the study also revealed that because manufacturers are not allowed to talk to each other as it crosses commercial lines, an honest central broker is required to improve lines of communication and to facilitate the dialogue.

5.3.4.1.3. Joint Decision Making

The findings from the data showed that through joint decision making, the impact of drug shortages is mitigated or that supply chain partners could recover from the impact quickly. For instance, MAN4 explained that they had meetings with stakeholders/ other supply chain partners where they advised them of the problems the manufacturing firm faced and asked for their support in ensuring that they changed the prescribing habit of the GPs. MAN3 further reiterated that, when there was a disruptive event, the first step was to investigate the cause of the disruption and then hold a local discussion with stakeholders across the firm to come up with appropriate strategies necessary in dealing with the situation at hand.

"We would have a local meeting to discuss the situation, a local meeting within the stakeholders across our business, so our regulatory colleagues, our quality colleagues, supply chain and also our communication with colleagues as well". (MAN3)

Further, one of the regulators explained that their role was to take action in recovering from a shortage through having discussions with other regulatory bodies and suppliers. This was to see if they could identify the causes of the disruption and if competitors could ramp up their productions and move products to areas of scarcity. PWS illustrated that the process of the decision making differed with respect to secondary or primary care. For secondary care, the joint decision-making process involved the Commercials Medicine Unit (CMU) and the Department of Health and Social Care (DHSC). Here conversations were

had within each organisation to determine how to recover from the disruption, either through sourcing for product alternatives, importing from abroad or manufacturing within the NHS manufacturing plant. He, however, stated that the joint decision making was successful through relationships built over the years. These actions thus highlight the role of joint decision making between stakeholders as a strategy in recovering from a disruption.

> *"We help the department of health by identifying where there may be shortages and then see if members do have the ability to ramp up production, move production from other products and supply where there may be a shortage". (REG2)*

The findings from the data thus indicated that flexibility, visibility and joint decision making were the strategies that actors in the PSC employed in trying to recover from disruptions. However, these strategies had several shortfalls which included costs and time required for the supply chain to return to normal operations.

5.3.4.2. Resistance Strategies

The respondents revealed strategies that some supply chain actors had in place, which provided the capacity to resist the impact of dynamic disruptions. These included resource sharing through a strategic alliance, information sharing, safety stock sharing and the use of technology.

5.3.4.2.1. Resource Sharing

The respondents indicated that resource sharing was an appropriate mitigation strategy in resisting the impact of dynamic disruptions. Sharing of resources here were internally generated, externally acquired or shared among supply chain partners. These resources were financial, human, technological or material. For instance, a research respondent indicated that they spent about 1100 hours of staff time which was worth £146,000 of staff salary directly assessing disruptions for the whole of the supply chain. Thus, if there was an impending danger, these staff had their 'hands-on-deck' to understand the sources, impact and possible solutions.

5.3.4.2.1.1. Strategic Alliance

The findings also showed that to share resources with supply chain partners effectively, strategic alliances had to be formed. These strategic alliances were

vertically aligned, where manufacturers formed alliances with wholesalers and pharmacists or vice versa. The findings from the interviews indicated that forming relationships with alternative supply chain actors in the case of a disruption, to meet patients demand was imminent. For instance, COMM3, an independent community pharmacist, complained about the absence of information when a disruption occurred and as such, failed to pre-plan. Group pharmacists or pharmacists that had formed strategic alliances were still supplying products to patients because they had prior knowledge of disruptive events as well as direct supply from wholesalers. COMM4 further confirmed that their buying power was more reliable as a result of their alliance with more prominent companies, as explained in the statement below.

> *"Because of our alliance with bigger firms, our buying is better. The company we buy from tend to build bulk order in advance; a lot of smaller independents struggle for stock we recover more quickly because we tend to hold on to stock longer than other people would have." (COMM4)*

A logistic service provider (LSP1) further explained that because they worked in close partnership with their strategic partners, they were able to resist the disruption and continue operations normally. This was because the manufacturers informed them about the pending disruptions well ahead of time and they jointly worked out solutions in advance on how to resist the pending unfavourable events.

MAN3 further explained that in terms of strategic alliance, they had provided a live-stock inventory platform all the way through the supply chain to their supply chain partners where they had strategic alliances. This facilitated understanding of up to date stock issues within 24 hours for supply chain partners. By sharing these resources with its supply chain partners, the necessary information on how much stock was available at various levels of the PSC. Given this, better resistance strategies were developed with these technological resources made available to supply chain partners.

5.3.4.2.1.2. Technology

Some supply chain actors explained that technology was critical in resisting supply chain disruptions. MAN4, for instance, explained that they used technology to capture the trends in demand, to note if there was a surge in

demand and possible reasons why these trends occurred. Other supply chain actors explained that the absence of a centralized information technology system like the ones in the US-led to their inability to become resilient in the event of a disruption. For instance, MAN2 called for the use of aspects of artificial intelligence such as big data and the Internet of Things (IoT) to capture trends in drug distribution and changes in demand for products. The need for a central resource was also referred to by HOSP3:

> *"It's not effective for each trust to be doing the same thing. NHS trust is spending time. It should be done centrally. Some sort of central resource like they have in the US is a good example. Foster information sharing. It's about developing a centralized resource to help manage the shortage which people can find. You could share the information that will be a low cost of it".* (HOSP3).

5.3.4.2.2.3. Safety/Buffer Stock

Stockpiling which involved supply chain partners storing up stock to be used on a later date emerged as a resistance capability but was only feasible through resource sharing and sometimes strategic alliance. The volume of safety stock ranged from two weeks' worth of stock to about three months' worth. The research respondents explained that keeping safety stock was also based on historical demand, and this provided the capacity to resist the impact of disruption if the demand nodes were projected accurately. The responses provided an example of safety stock as resistance capability with issues closely related to BREXIT. Here pharmacists were required to stock medicines before the March 29^{th,} 2019 (the planned day for the UK to leave the EU) in case there would be situations where drugs movements would be delayed or prevented through the UK borders.

While this approach seems straight forward, some respondents explained that most hospitals kept safety stock for up to three weeks at a time. However, increasing this safety stock by just an extra week would mean an extra 33% worth of demand. This would imply that manufacturers would have to increase their safety stock and thus increase manufacturing capacity, which may further increase vulnerabilities in the supply chain.

> *“From a manufacturer point of view, we always aim to have enough stock in the UK to meet the UK demand and usually you try and have a safety stock which will last a few months. We also have a safety stock based on historical demand. We build at least three months of safety stock.” (PWS)*

Other misgivings of stockpiling included the fact that it caused chaos in the marketplace since the manufacturing and supply of pharmaceutical products were based on past consumptions and forecasted demand. Similarly, because of the nature of some pharmaceutical products, the keeping of buffer stocks may not be feasible, and it may lead to waste. Financial capacity was also an issue to consider when stockpiling, as some respondents indicated that it costs a lot to create safety stock and if they had the financial opportunity to buy up more products to mitigate disruptions. Some respondents, however, explained that even when they had the financial capacity and everything was in place, manufacturers refused to allow them to buy enough stock to meet the meet demand.

> *“We have an example somewhere where a hospital bought 150 packs of a product but normally sold 1 and 2 products a month. When you have something like that happen, that could potentially wipe out stock in the UK within a period”. (LSP1)*

Figure 5.3 below provides a summary of the resilience strategies that supply chain actors used in the PSC.

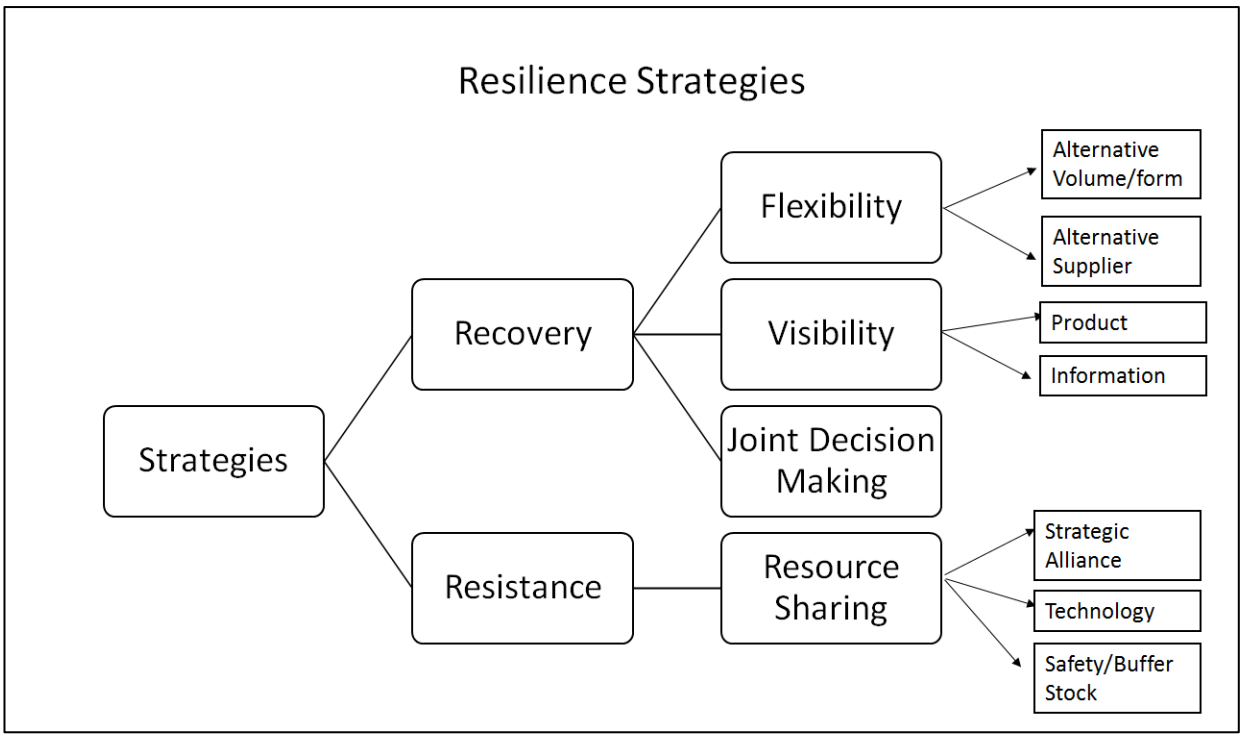

Figure 5.3 Resilience Strategies in the PSC

The findings indicate that although some of the strategies provided supply chain actors with the capacity to recover and return operations, the strategies adopted had shortfalls and may provide reasons as to why the impact of dynamic disruptions are on the increase in recent times.

5.4. Summary of Findings

In this chapter, the findings from the qualitative data generation phase were presented. It involved conducting semi-structured interviews with 23 participants who were identified as actors at various levels across the PSC. The goal was to answer the research questions (RQ1 and RQ2 as specified in section 5.1) which sought to explore why the PSC in the UK is susceptible to the impact of disruptions and how resilience strategies had been employed in mitigating the impact of dynamic disruptions. The data generated identified 5 major themes and 11 sub-themes. For supply chain vulnerability drivers, the study found that there are internal and external drivers. The internal drivers consist of elements of supply chain power and supply chain conflict while the external drivers were made up of supply chain complexities. For supply chain resilience, two forms of resilience strategies were identified: recovery and resistance capabilities.

The activities, sub-themes and themes that emerged from this Chapter were used to develop a questionnaire to generate quantitative data. The quantitative data were required to confirm the findings of the qualitative data to ensure triangulation and more reliable findings. In view of this, the next chapter presents the findings from the questionnaires, which was administered to 106 key actors of the PSC.

Chapter Six: Findings from the Survey Questionnaire

6.1. Introduction

In this study, the goal was to explore why the PSC is susceptible to dynamic disruptions and examine how resilience strategies can be employed to reduce the impact of these disruptions. The questions posed were:

RQ1: Why is the PSC in the UK susceptible to dynamic disruptions?

- What are the drivers of vulnerability in the PSC?
- How do these drivers expose the supply chain to the impact of dynamic disruptions?

RQ2: How are resilience strategies used to mitigate the impact of dynamic disruptions in the PSC?

- What strategies do supply chain actors adopt to build resilience against dynamic disruptions?
- What are the outcomes of implementing these strategies?

RQ3: What impact do resilience strategies have on vulnerabilities in the PSC?

A mixed-method approach using both qualitative and quantitative techniques was deemed appropriate was used to answer these questions, as discussed in Chapter Four. The findings for the qualitative phase of this research process were presented in Chapter Five, where factors, sub-themes and themes were developed for further analysis and confirmation. The factors, sub-themes and themes from the previous chapter were developed into items on the questionnaire, and in this chapter, the data generated from the questionnaire are analysed and the findings presented in tables, figures and text.

The chapter begins by describing the supply chain actors who participated in the study (6.2). The sections following include; the descriptive statistics of the data which detail the response rate to the questionnaire (6.3); to validate the responses across supply chain actors, the Kruskal Wallis test was used (6.4) and the reliability and validity of the data were measured using the Cronbach's alpha (6.5); The relationship between the identified factors, sub-themes and

themes were also tested using Structural Equation Modelling (SEM) (6.6) and the chapter is concluded in 6.7 where actions for discussions are addressed.

6.2. Respondents' Profile

In the quantitative phase of the research, data were collected from 106 respondents using a questionnaire. As presented in Figure 6.1, there were five categories of respondents. Although the highest rate was from secondary care/hospital pharmacists (54%), all categories of supply chain actors were represented in the sample.

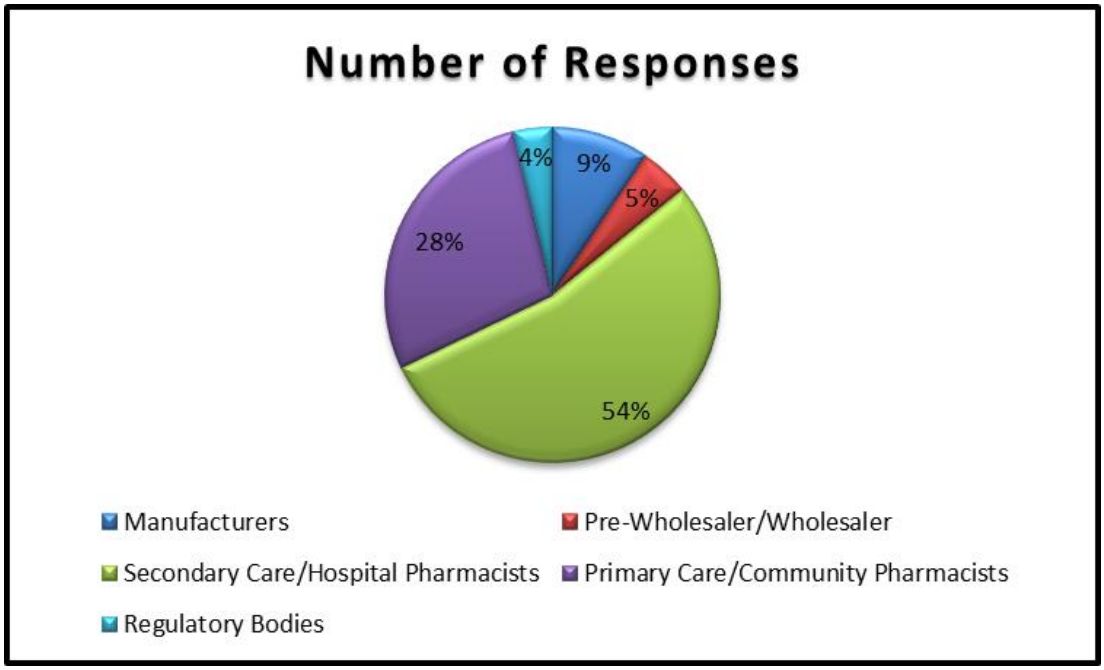

Figure 6.1 Number of Responses

Table 6.1 below shows that 32.1% of the respondents held between 21-30 years of experience in this industry, 26.4% subsequently had 11-20 years of experience, 23.4 % had between 1-10 years of experience and 17.1% had over 30 years of experience. This indicates that more than 75% of the respondents had over 10 years' experience in this industry. In line with the nomenclature of supply chain actors, as presented in Chapter Five, the responses from trade associations were merged with regulatory bodies and equipment manufacturers merged with medicine manufacturers. It should also be noted that the disparity in the number of responses across the various supply chain actors was

expected since there are fewer manufacturers and regulators than primary and secondary care pharmacists.

Table 6.1 Profile of respondents

Respondents' Features	Category	Number of Responses	Frequency in Percentages (%)
Supply Chain Actors	Manufacturers	10	9.4
	Pre-Wholesaler/Wholesaler	5	4.7
	Secondary Care/Hospital Pharmacists	57	53.8
	Primary Care/Community Pharmacists	30	28.3
	Regulatory Bodies	4	3.8
Years of Experience	1-10 years	25	23.6
	11-20 years	28	26.4
	21-30 years	34	32.1
	31 and above	19	17.9

6.3. Presentation of Findings

The respondents were asked to complete a questionnaire which consisted of 35 question items. Initially, respondents were asked about the causes of supply chain disruption and how quickly they were informed about them by other supply chain actors. Other questions covered the themes that emerged from the qualitative phase of the study, namely: - power, conflict, complexity, recovery and resistance strategies. The responses from the survey are reported in the following sections.

6.3.1. Supply Chain Disruption

With regards to supply chain disruptions, respondents were required to indicate the types of disruption that had occurred most frequently in the supply chain during their years of experience. The responses are presented in Table 6.2 below.

Table 6.2 In your experience, what is the most common form of disruptive activity in your supply chain?

Supply Chain Disruption	Number of Responses	Frequency in Percentages (%)
Natural Disaster	4	3.77
Counterfeiting	0	0
Medicine Shortages	98	92.45
Theft	2	1.89
Union Strikes	0	0
Others	2	1.89

The table above indicates that at 92.45%, medicine shortages were by far the most common cause of supply chain disruption. No respondent identified counterfeiting or union strike as a disruption affecting the PSC.

6.3.2. Information Timing and Flow

For timing of information following a disruption and the information flow during the disruption phase, respondents were asked at what point they received information about disruptions and how often information updates were provided following the initial alert.

Table 6.3 When is information about a disruptive activity in the supply chain shared with you?

Timing of Information following a disruption	Number of Responses	Frequency in Percentages (%)
Within 24 hours	1	0.95
Within 48 hours	7	6.60
Within 3 days	17	16.04
Within 5 days	7	6.60
Within 7 days	40	37.74
Others	34	32.07

The responses in Table 6.3 above showed that most of the respondents, i.e. 40 (37.74%) of the 106 respondents, received an initial information alert about

disruption within 7 days; 34 (32.07%) indicated others. This implies that supply chain actors received information about disruptions more than a week after the disruption had occurred and only 1 of the 106 respondents indicated that they received initial information about disruption within 24 hours following the disruption. These findings support the assertions that the release of information about disruptions was not timely.

Following the initial alerts about a disruption, 66% of the respondents indicated that they received information when there were alternative products available, 22.6% indicated that they received information about the disruption after initial notification every 24 hours and every 48 hours, 6% of the respondents reported they received information every 3 days, 2.8% reported weekly and 1.9% monthly.

6.3.3. Supply Chain Power

Supply chain power emerged as a major theme from the qualitative phase of this research where three constructs: - information control, drug control and price control were used as indicators of supply chain power. Thus, to measure the three constructs signalling the presence of supply chain power, six statements (items) 9-14 were used in the questionnaire and respondents' level of agreement measured using a Likert scale**.** Two of these statements represented information control (IC1 and IC2), as indicated by behavioural uncertainty and firm reputation; two statements represented drug control (DC1 and DC2) and two statements for price control (PC1, PC2) as presented in Table 6.4 below.

Table 6.4 Supply chain power

Variables	Statements	S/ Agree	SW/ Agree	N/Nor	SW/ Disagree	S/ Disagree	IDW	NA
IC1	We do not have confidence in our supply chain partners actions	11 (10.4)	32 (30.2)	23 (21.7)	37 (34.9)	0 (0)	3 (2.8)	0 (0)
IC2	Our supply chain partners encounter significant disruptions frequently	34 (32.1)	31 (29.2)	18 (17)	16 (15)	1 (0.09)	2 (1.9)	2 (1.9)
DC1	We do not agree with supply chain partners on critical issues like the distribution of our products	17 (16.0)	26 (24.5)	32 (30.2)	24 (22.6)	0 (0)	2 (1.9)	5 (4.7)
DC2	Our supply chain partners prevent us from doing what we want to do	15 (14.2)	31 (29.2)	24 (22.6)	30 (28.3)	0 (0)	4 (3.8)	2 (1.9)
PC1	Information regarding product prices is not readily available within our supply chain	22 (20.8)	44 (41.5)	13 (12.3)	20 (18.9)	0 (0)	3 (2.8)	4 (3.8)
PC2	There is no transparency in the pricing of goods within the supply chain	27 (25.5)	23 (21.7)	18 (17)	30 (28.3)	0 (0)	4 (3.8)	4 (3.8)

- **IC-Information Control DC-Drug Control PC- Price Control**
- **S/Agree-Strongly Agree, SW/ Agree-Somewhat Agree, N/Nor-Neither agree nor disagree, Somewhat Disagree- SW/Disagree IDW-I do not know, NA -Not applicable**
- **Values in brackets ( ) indicate frequencies in percentages**

From Table 6.4 above, IC1, which measured behavioural uncertainty with the question '*we do not have confidence in our supply chain partners actions'* showed that respondents' opinion was fairly evenly split. While *37* (34.9%) of the 106 respondents somewhat disagreed about the lack of confidence with supply chain partners, 30 (32%) of respondents somewhat agree, and 23 (21.7%) of respondents were neutral. This implies that overall respondents were neutral about confidence in supply chain partners' actions. However, for IC2, which measured reputation, there was a stronger agreement that supply chain partners encountered significant disruptions; with 61.3% of the 106 respondents agreeing to varying degrees. This is consistent with the findings from the qualitative phase of the research process.

To measure the drug control (DC1) respondents were asked *if they agreed with their supply chain partners on critical issues like the distribution of products*. Out of the 106 responses, 43% agreed while and 30% were neutral in their opinion. However, for DC2, when asked if their supply chain partners prevented them from doing what they wanted to do*,* the opinion of responses indicated that most of them agreed as indicated at 43.4%.

Respondents were asked about 'information regarding the prices of the product (PC1) as well as the transparency of products prices within the supply chain' (PC2), to measure price control (PC1, PC2) as a construct of supply chain power. For PC1, 66% of the 106 respondents agreed that information regarding prices was not readily available, and 47.2% expressed agreement about the absence of transparency of pricing within the supply chain. The finding for price control (PC1, PC2) thus indicates that the respondents largely agreed to the presence of price control as a measure of supply chain power within the PSC. The responses presented in Table 6.4 above depicts that the respondents confirm the presence of supply chain power through its constructs of - information control (IC2), price control (PC1, PC2) and drug control (DC1, DC2). The exception, however, is IC1 where the responses reflect that they do not agree to the presence of information control.

6.3.3.1. Understanding Responses of Supply Chain Power across Supply Chain Actors

In this section, the responses from the respondents are further analysed according to specific types of supply chain actors. The responses will be presented based on the highest frequencies of response for each category of supply chain actors in Table 6.5 below. For information control (IC1, IC2), the responses indicate that the highest frequency of agreement with these statements was by primary care and secondary care respondents with 'somewhat agree' at 6 and 'strongly agree' at 7 for these group. This implies that actors at the patient-facing end of the supply chain experienced the presence of information control within the supply chain. Responses from wholesalers, regulatory bodies and manufacturers indicated lower levels of agreement with these statements. These findings thus indicate that primary and secondary care

respondents were more likely to experience the presence of information control and thus depicts that control emanates from manufacturers to primary care.

Table 6.5 Most frequent responses for supply chain power across supply chain actors

Variables	Statements	Agree	Disagree	Neutral
IC1	We do not have confidence in our supply chain partners actions	Primary care Secondary care	Manufacturers Regulators Wholesalers	
IC2	Our supply chain partners encounter significant disruptions frequently	Primary care Secondary care	Manufacturers Wholesalers	Regulators
DC1	We do not agree with supply chain partners on critical issues like the distribution of our products	Primary care	Wholesalers	Manufacturers Wholesalers Secondary care
DC2	Our supply chain partners prevent us from doing what we want to do	Primary care Secondary care	Wholesalers Manufacturers	Regulators
PC1	Information regarding product prices is not readily available within our supply chain	Manufacturers Wholesalers Primary care Secondary care	Regulators	
PC2	There is no transparency in the pricing of goods within the supply chain	Manufacturers Primary care	Regulators Secondary care	Wholesalers

- **IC-Information Control DC-Drug Control PC- Price Control**

For drug control question items (DC1, DC2), the highest level of agreement indicated by the frequency was from primary care respondents with a value of 6 ‘somewhat agree’ to the presence of drug control within the PSC. The wholesalers somewhat disagreed to the presence of drug control while manufacturers and regulatory bodies neither agreed nor disagreed. For price control (PC1), all the supply chain actors apart from regulatory bodies somewhat agreed that there was price control when asked about readily available information regarding product prices within the supply chain. In PC2, however, manufacturers and primary care providers support the presence of price control,

indicating the absence of transparency in the pricing of goods. This implies that they are the two main supply chain actors that are largely controlled by pricing. These findings support the emerging theme of power as a vulnerability driver within the PSC, where control is largely felt by primary care providers.

6.3.4. Supply Chain Conflict

Supply chain conflict is also a theme that emerged from the qualitative phase of the research where three constructs- supply chain partners' satisfaction (SCPS1 and SCPS2), goal misalignment (GM1, GM2 and GM3), and the absence of trust, indicated the presence of supply chain conflicts. In the questionnaire, therefore, six statements were used to measure the three constructs of supply chain conflicts. Two of the statements represented supply chain partners satisfaction (SCPS1 and SCPS2), three statements represented goal misalignment (GM1, GM2 and GM3), and there was one question to measure the absence of trust. The findings are presented in Table 6.6 below.

Table 6.6 Supply chain conflict frequencies of responses

Variable	Statements	S/Agree	SW/ Agree	N/Nor	SW/ Disagree	S/ Disagree	IDW	NA
SCPS1	There is no feeling of fairness with our supply chain partners	26 (24.5)	28 (26.4)	19 (17.9)	21 (19.8)	2 (0.19)	6 (5.66)	4 (3.8)
SCPS2	Generally, we are not satisfied with our overall relationship with our supply chain partner	11 (10.4)	25 (23.6)	20 (18.9)	44 (41.5)	3 (2.83)	2 (1.9)	1 (0.9)
GM1	Our supply chain partners do not consider how their actions will affect us	38 (35.8)	35 (33.)	11 (10.4)	20 (18.9)	0 (0)	2 (1.9)	0 (0)
GM2	Our supply chain partners do not understand the market demand	14 (13.2)	19 (17.9)	29 (27.4)	25 (23.6)	0 (0)	12 (11.3)	7 (6.6)
GM3	Our firm does not understand the market demand	4 (3.8)	8 (7.5)	28 (26.4)	38 (35.8)	0 (0)	11 (10.4)	17 (16)
Absence of Trust	We do not trust our supply chain partners	8 (7.5)	24 (22.6)	28 (26.4)	43 (40.6)	0 (0)	2 (1.9)	1 (0.9)

- **SCPS- Supply Chain Partner Satisfaction GM- Goal Misalignment**
- **S/Agree-Strongly Agree, SW/ Agree-Somewhat Agree, N/Nor-Neither agree nor disagree, Somewhat Disagree- SW/Disagree, Strongly Disagree-S/Disagree IDW-I do not know, NA -Not applicable**
- **Values in brackets ( ) indicate frequencies in percentages**

For supply chain partners' satisfaction (SCPS1), the findings show that when the respondents were asked to indicate their preference about the feeling of fairness with supply chain partners, 50.9% of the 106 respondents expressed their agreement at various levels whereas 20% disagreed to varying extents. This indicates that the majority considered there was a lack of fairness amongst supply chain partners. However, when the respondents were asked 'if they were generally not satisfied with the overall relationship among their supply chain partners' (SCPS2), the views were divergent where 44.3% of the 106 respondents somewhat disagreed, and 34% expressed their agreement about being dissatisfied with their relationship. The findings thus depict mixed results about the satisfaction of their supply chain partners.

For goal misalignment (GM1) for the statement, '*our supply chain partners do not consider how their actions will affect us'* the highest frequency of responses was strongly agree which implied that the majority of the respondents, 68.8% of the 106 respondents, supported the presence of goal misalignment and 35(33%) somewhat agreed. When asked to indicate their preference for the statement (GM2) '*our supply chain partners do not understand the market demand',* the overall balance of responses tended towards disagreement of the statement. The responses thus imply uncertainty about supply chain partners' understanding of market demand. With regards to the statement '*our firm does not understand the market demand'* (GM3), most of the respondents disagreed with the statement.

With regards to the absence of trust, 43(40.6%) of the responses indicated that they rather disagreed about the absence of trust among supply chain partners, 28 (26.4%) were inconclusive in their opinion while 24 (22.6%) rather agreed that they did not trust their supply chain partners. This implies that even though the majority of the respondents indicated that trust existed among their supply chain partners, the issue of trust still lingers and may be an avenue of conflict within the supply chain. The output is consistent with the findings of the qualitative study, which showed that the presence of goal misalignment and

supply chain partners' dissatisfaction was an indicator of supply chain conflicts which increased vulnerabilities.

6.3.4.1. Understanding Responses of Supply Chain Conflict across Supply Chain Actors

In Table 6.7, the responses with the highest frequency are presented according to supply chain actors. For the supply chain, partners' satisfaction with regards to the absence of fairness, (SCPS1) primary care respondents strongly agreed that there was an absence of fairness amongst supply chain actors while regulatory bodies and secondary care respondents somewhat agreed. Manufacturers and wholesalers neither agreed nor disagreed to the presence of dissatisfaction.

Table 6.7 Most frequent responses for supply chain conflicts across supply chain actors

Variable	Statements	Agree	Disagree	Neutral
SCPS1	There is no feeling of fairness with our supply chain partners	Primary care Regulator		Manufacturers Wholesalers Secondary care
SCPS2	Generally, we are not satisfied with our overall relationship with our supply chain partner	Primary care	Manufacturers Wholesalers Regulators Secondary care	
GM1	Our supply chain partners do not consider how their actions will affect us	Manufacturers Regulators Primary care Secondary care	Wholesalers	
GM2	Our supply chain partners do not understand the market demand		Manufacturers Regulators	Primary care Secondary care Wholesalers
GM3	Our firm does not understand the market demand		Manufacturers Wholesalers Regulators	Primary care Secondary care
Absence of Trust	We do not trust our supply chain partners	Primary care	Manufacturers Wholesalers Regulators	Secondary care

SCPS- Supply Chain Partner Satisfaction GM- Goal Misalignment

For SCPS1, the analysis thus shows that primary care and regulatory bodies' respondents are dissatisfied in the PSC. Secondary care was neutral. In SCPS2, only primary care respondents supported dissatisfaction in the overall relationship with supply chain partners while all other supply chain actors

somewhat disagreed. This indicates that all other supply chain respondents (manufacturers, hospital pharmacists, wholesalers and regulatory bodies) are generally satisfied with their supply chain partners.

For goal misalignment (GM1) *'our supply chain partners do not consider how their actions will affect us'* the most frequent response from all supply chain actors supported these statements with exceptions from the wholesalers. A Possible explanation for this may be that the wholesaler respondents who completed the survey were part of strategic alliances and as such may not be impacted by supply chain partners' actions. For GM2 *'our supply chain partners do not understand the market demand'* and GM3 *our firm does not understand the market demand'* the most frequent response from supply chain actors was that they disagreed or were neutral about supply chain partners and their firms' understanding the market. This implies that goal misalignment as a source of conflict stems from supply chain partners' inconsiderate actions rather than supply chains partners understanding of market demand. This indicates that the major decisions supply chain actors take in mitigating the impact of disruptions in the supply chain are a major source of conflict. The output here corroborates the findings of the interviews.

With regards to the absence of trust, the most frequent response from the supply chain actors signified that they trusted their supply chain actors apart from primary care respondents who indicated the highest mistrust for their supply chain partners. This is closely followed by secondary care respondents who were neutral in their response to mistrust. A possible explanation could be attributed to the presence of quota systems as well as price manipulations as experienced by supply chain actors. The analysis thus confirms the presence of conflict among supply chain actors.

6.3.5. Supply Chain Complexity

Supply chain complexity also emerged as a theme from the qualitative phase of this research as presented in Chapter Five, where four constructs were used to indicate the presence of complexity: regulatory factors, economic/political factors, production factors and process factors. Therefore, to measure supply

complexity in the questionnaires, nine items were employed, and the findings from these will be presented in the following sections. Three statements from the survey were used to assess the extent of regulatory activities in the supply chain (REG1, REG2, and REG3). Two statements were used to measure economic and political factors (EC1, EC2). In measuring production and process complexity, three items from the questionnaires were used. The statements here are based on the production of pharmaceutical products and the process involved in handling the products (PRC1, PRC2, PRC3, and PRC4).

Table 6.8 Supply chain complexities

Variable	Statements	S/Agree	SW/ Agree	N/Nor	SW/ Disagree	S/ Disagree	IDW	NA
REG1	Our operations and products are subject to stringent government regulations	46 (43.3)	35 (33.)	10 (9.4)	9 (8.5)	0 (0)	5 (4.7)	7 (6.6)
REG2	We depend on the use of regulated or restricted materials	22 (20.8)	33 (31.1)	25 (23.6)	15 (14.2)	0 (0)	6 (5.7)	5 (4.7)
REG3	Regulation and pricing disbursement complicates transactions	26 (24.5)	32 (30.2)	28 (26.4)	7 (6.6)	1 (0.9)	2 (1.9)	10 (9.4)
EC1	We are uncertain about economic and political issues	38 (35.8)	22 (20.8)	26 (24.5)	0 (0)	0 (0)	17 (16.0)	3 (2.8)
EC2	We are part of a global distribution network	21 (19.8)	23 (21.7)	17 (16.7)	4 (3.8)	0 (0)	5 (4.7)	36 (34)
PRC1	Our products require strict storage or handling controls to maintain their purity and/or integrity that may cause delay	35 (33)	41 (38.7)	8 (7.5)	10 (9.4)	1 (0.9)	1 (0.9)	10 (9.4)
PRC2	Production of our products is very complex	11 (10.4)	39 (36.8)	14 (13.2)	13 (12.3)	0 (0)	2 (1.9)	27 (25.5)
PRC3	The lead times for manufacturing of our products are shorter	26 (24.5)	32 (30.2)	28 (26.4)	7 (6.6)	0 (0)	2 (1.9)	11 (10.4)
PRC4	The demand for our product is unstable	32 (30.2)	37 (34.9)	10 (9.4)	6 (5.7)	0 (0)	0 (0)	21 (19.8)

- **REG-Regulatory factors EC-Economic and political factors PRC-Production/product complexity**
- **S/Agree-Strongly Agree, SW / Agree-Somewhat Agree, N/Nor-Neither neither agree nor disagree, Somewhat Disagree- SW/Disagree, S/Disagree- Strongly Disagree, IDW-I do not know, NA -Not applicable**
- **Values in brackets ( ) indicate frequencies in percentages**

For regulatory factors as a construct for supply chain complexity, when respondents were asked to indicate their preference for the statement (REG1), 'Our *operations and products are subject to stringent government regulations',* 46(43.3%) of the 106 respondents strongly agreed to the presence of stringent government regulations on pharmaceutical products. Other responses included 35(33%) who somewhat agreed and 10(9.4%) who were uncertain about the presence of stringent regulations. These findings denoted that majority of the respondents agree to the presence of government regulation as an indicator of complexity which supports the finding of the qualitative research.

For the statement in (REG2), '*we depend on the use of regulations or restricted materials',* 33 (31.1%) of the 106 responses specified that they somewhat agreed to the dependence on restricted materials, 25 (23.6%) were neutral while 22 (20.8%) strongly agreed. These findings indicate that restrictions and regulations on materials used in the PSC were a factor that increased complexity. The regulations on pricing as well as disbursement were also measured as a yardstick for regulatory complexity (REG3), and the responses indicate that 32(30.2%) of the respondents rather agreed, 28(26.4%) were indifferent and 26 (24.5%) strongly agreed. The findings thus support the notion that regulations in both product and prices are factors which contribute to complexity in the PSC.

Economic and political factors were also identified as increasing complexity in the PSC. These factors include issues like globalisation, BREXIT, parallel trade and exchange rates as identified in the qualitative phase of this research. Thus, to measure economic and political factors, two items were used in the questionnaire (EC1 and EC2). The results show that for EC1, 38 (35.8%) of the 106 respondents strongly agreed that they were *uncertain about political and economic issues*, 26 (24.5%) neither agreed nor disagreed and 22 (20.8%) somewhat agreed. However, about 17 of the 106 respondents did not know if political and economic issues were affecting supply chain disruptions. For EC2, 36 of the respondents indicated 'not applicable' when asked if they were part of a global distribution network signifying that a third of the respondents did not consider globalisation as an issue within the PSC. That notwithstanding, 23

(21.7%) somewhat agreed, and 21(19.8%) strongly agreed about globalisation, and as such, it further increases complexities in the supply chain.

Product and production process are other constructs for supply chain complexity. With regards to PRC1 with the statement '*our products require strict storage or handling controls to maintain their purity and/or integrity that may cause delay',* the responses indicated that 41 (38.7%) of the 106 respondents rather agreed, 35 (33%) strongly agreed, and 11 (10. 4) indicated not applicable. The findings imply that the process involved in storing and handling pharmaceutical products increases complexities within the supply chain. For PRC2, *Production of our products is very complex*, while 39 (36.8%) of the 106 respondents rather agreed to the complexity of the production process of pharmaceutical products, 27(25.5%) of the responses indicated not applicable.

The possible reason for the high 'not applicable' responses could emanate from primary care respondents and secondary care respondents who may not necessarily have close links to the production processes. With regards to the statement in PRC3, '*The lead times for manufacturing of our products are shorter'* 32 (30.2%) of the 106 respondents rather agreed, 26 (24.5%) of the respondents strongly agreed, and 28 (26.4%) of the respondents were uncertain about the implications of lead times on the production process. The responses for (PRC4) *Demand for our product are unstable* indicated that 37(34.9%) of the 106 respondents rather agreed, 32 (30.2%) strongly agreed, and 21 (19.8%) specified not applicable. These findings corroborate the qualitative phase of the research that indicates that the products, as well as production process, are factors that contribute to the complexities in the supply chain and as such makes it vulnerable to disruptions.

6.3.5.1. Understanding Responses of Supply Chain Complexities across Supply Chain Actors

Table 6.9 below presents the most frequent responses of supply chain actors for complexity within the supply chain. The analysis also reveals that the perceived level of complexity in the supply chain differed at various levels in the supply chain.

Table 6.9 Most frequent responses for supply chain complexities across supply chain actors

Variable	Statements	Agree	Disagree	Neutral
REG1	Our operations and products are subject to stringent government regulations	Manufacturers Wholesalers Regulators Secondary care Primary care		
REG2	We depend on the use of regulated or restricted materials	Manufacturers Wholesalers Secondary care Primary care	Regulators	
REG3	Regulation and pricing disbursement complicates transactions	Manufacturers Wholesalers		Secondary care Primary care Regulators
EC1	We are uncertain about economic and political issues	Manufacturers Regulators Secondary care Primary care		Wholesalers
EC2	We are part of a global distribution network	Manufacturers Wholesalers Regulators		Secondary care Primary care
PRC1	Our products require strict storage or handling controls to maintain their purity and/or integrity that may cause delay	Manufacturers Wholesalers Regulators Secondary care Primary care		
PRC2	Production of our products is very complex	Manufacturers Wholesalers Regulators Primary care		Secondary care (NA)
PRC3	The lead times for manufacturing of our products are shorter	Manufacturers Wholesalers Regulators Secondary care Primary care		
PRC4	The demand for our product is unstable	Manufacturers Wholesalers Regulators Secondary care Primary care		

- **REG-Regulatory factors, EC-Economic and political factors, PRC-Production and product complexity**

For REG1, the analysis indicates that all supply chain actors strongly agreed to the presence of stringent government regulations within the PSC. However, for REG2, the regulatory bodies strongly agreed to the use of restricted materials as a source of complexity, manufacturers rather agreed, and all other supply chain actors were neutral. A possible reason could be that manufacturers

encountered the regulations during production and as such may not necessarily feel the brunt. For REG3, primary care respondents strongly agreed that pricing and disbursement policies complicated transactions and thus adds complexity to the PSC. Regulatory bodies, however, indicated that somewhat disagree while other supply chain actors indicated somewhat agreed.

For PRC1, PRC2 and PRC3 most of the supply chain actors strongly agreed that production process, as well as the nature of the pharmaceutical product, adds complexity to the supply chain thus making it difficult to withstand the impact of disruptions when they occur. The exception to these statements was secondary care respondents where the majority of the respondents indicated not applicable when asked about complexity emanating from storage and purity of the product. With regards to economic and political factors as represented by (EC1, EC2), the output shows that most of the supply chain actors agreed to economic and political uncertainty as a factor that may complicate the PSC apart from secondary care respondent where responses specified not applicable. Primary care respondents, however, neither agreed nor disagreed to the globalisation as a form of complexity. This may be as a result of the fact that they are not directly involved with the manufacturing process and so globalisation may not directly have an impact in their decision making.

6.3.6. Supply Chain Recovery and Resistance Strategies

The analysis from the qualitative phase of this research identified two types of strategies that helped operations within the PSC to return to normal after a disruption. These strategies were classified as recovery and resistance strategies. For recovery strategies, the constructs included flexibility, visibility and joint decision making and for resistance strategies, the constructs were internal and external resource sharing. Thus to represent these constructs in the questionnaire, two statements were used for flexibility (FL1, FL2), two statements were used to measure visibility (VS1, VS2), two statements were used to measure joint decision making (JDM1, JDM2) and three statements were used to measure resource sharing (RS1, RS2, RS3). The findings are presented in Table 6.10 below.

Table 6. 10 Recovery and resistance strategies

Variables	Statements	S/Agree	SW/ Agree	N/Nor	SWD	SDA	IDW	NA
FL1	There is access to alternative supply chain partners	43 (40.6)	46 (43.4)	3 (2.8)	8 (8.5)	2 (1.9)	0 (0)	5 (4.7)
FL2	There is access to alternative products	44 (41.5)	43 (40.6)	4 (3.8)	9 (8.5)	0 (0)	1 (0.9)	5 (4.7)
VS1	We have access to tracking information throughout the supply chain	32 (30.2)	42 (39.6)	8 (7.5)	20 (18.9)	1 (0.9)	2 (1.9)	2 (1.9)
VS2	We have access to tracking materials throughout the supply chain	27 (25.5)	36 (34.0)	12 (11.3)	15 (14.2)	0 (0)	6 (5.7)	10 (9.4)
JDM1	We have joint decisions with our supply chain partners when working out solutions	29 (27.4)	35 (33)	15 (14.2)	16 (15.1)	1 (0.9)	6 (5.7)	5 (4.7)
JDM2	Joint employee training with other supply chain partners	17 (16)	19 (17.9)	29 (27.4)	17 (16)	0 (0)	9 (8.5)	15 (14.2)
RS1	Our supply chain partners share their resources with us	26 (24.5)	44 (41.5)	18 (17)	6 (5.7)	1 (0.9)	2 (1.9)	10 (9.4)
RS2	We share resources with our supply chain partners	19 (17.9)	38 (35.8)	13 (12.3)	18 (17)	0 (0)	6 (5.7)	12 (11.3)
RS3	We share resources internally	27 (25.5)	42 (39.6)	6 (5.6)	20 (18.9)	1 (0.9)	6 (5.7)	4 (3.8)

- Flexibility-FL, Visibility-VS, Joint Decision Making –JDM, Resource Sharing-RS
- S/Agree-Strongly Agree, SW / Agree-Somewhat Agree, N/Nor-Neither neither agree nor disagree, SWD-Somewhat Disagree, Strongly Disagree-SDA, IDW-I do not know, NA -Not applicable
- Values in brackets ( ) indicate frequencies in percentages

For FL1 where respondents were asked to specify how they were able to recover from a disruption in the statement '*there is access to alternative supply chain partners'*, 84% of the respondents expressed their agreement to their ability to access alternative supply chain partners in the event of disruption was essential. Also, for FL2, 82.1% responded that access to alternative products helped them recover from disruption. The findings infer that in the event of a disruption, access to alternative suppliers and or products helped the supply chain recover from disruptions.

In measuring supply chain visibility, two items from the survey were used (VS1, VS2). The analysis indicated that the majority 42(39.6%) of the 106 respondents somewhat agreed and 32 (30.2%) strongly agreed that the ability to track information throughout the supply chain thus increased their ability to recover when a disruption occurred. However, 20 (18.9%) of the respondents did not agree with the statement indicating that visibility did not promote recover strategy. The outliers may emanate from primary care respondents who complained about the absence of information in the supply chain. For VS2, 26 (34.0%) of the respondents somewhat agreed that their ability to track materials throughout the supply chain helped recover when disruptions occurred, 27 (25.5%) strongly agreed, and 15 (14.2%) somewhat disagreed. The findings thus show that even though the majority of the respondents specified visibility as a form of the recovery strategy, other respondents rather disagreed.

For joint decision making (JDM1) '*We have joint decisions with our supply chain partners when working out solutions',* 64% of the 106 respondents agreed to various degrees that joint decision with supply chain partners helped reduce the impact of disruptions. However, for JDM2, when asked about joint employee training with other supply chain partners, opinion was split. 27.4% of the respondents neither agreed nor disagreed to joint employee training while 33.9% either strongly agreed or somewhat agreed. This analysis corroborates the findings from the qualitative phase of flexibility, visibility and joint decision making as recovery strategies that supply chain actors employs in mitigating the impact of dynamic disruptions.

The analysis for RS1 showed that majority of the respondents 70 (66%) either strongly or somewhat agreed that supply chain partners shared resources with them, and 18 (17%) were neutral. For RS2 38 (35.8%) of the responses rather agreed that sharing of resources with supply chain partners was a critical form of resistance strategy, 19 (17.9%) strongly agreed, 18 (17%) rather disagreed and 13 (12.3%) were rather neutral. With regards to the statement RS3 '*we share resource internally*', 42 (39.6%) of the respondents rather agreed, 27 (25.5%) of the respondents strongly agreed, and 20 (18.9%) of the respondents rather disagreed. The findings thus show that the sharing of resources is a resistance strategy.

6.3.6.1. Understanding Responses of Recovery and Resistance Strategies across Supply Chain Actors

In Table 6.11, the responses with the highest frequency for recovery and resistance strategies across supply chain actors are presented. For flexibility (FL1, FL2), all supply chain actors somewhat agreed or strongly agreed to flexibility about access to alternative partners and products. With regards to visibility (VS1, VS2) all supply chain actors agreed to their ability to track information and materials throughout the supply chain except primary care that could not track materials throughout the supply chain but had access to tracking information. For JDM1, supply chain actors apart from primary care agreed that joint decision making with supply chain partners when working out solutions helped reduce the impact of disruption. For JDM2 only regulators agreed to joint employee training with other supply chain actors, wholesalers disagreed, and the other supply chain actors were neutral. All supply chain actors agreed that sharing resources internally and when supply chain partners shared resources helped reduce the impact of disruption. However, primary care and wholesalers' respondents disagreed to this statement. This finding corroborates to the qualitative study of this research.

Table 6. 11 Most frequent recovery strategies and resistance strategies

Variables	Statements	Agree	Disagree	Neutral
FL1	There is access to alternative supply chain partners	Manufacturers Wholesalers Regulators Primary care Secondary care		
FL2	There is access to alternative products	Manufacturers Wholesalers Regulators Primary care Secondary care		
VS1	We have access to tracking information throughout the supply chain	Manufacturers Wholesalers Regulators Primary care Secondary care		
VS2	We have access to tracking materials throughout the supply chain	Manufacturers Wholesalers Regulators Secondary care	Primary care	
JDM1	We have joint decisions with our supply chain partners when working out solutions	Manufacturers Wholesalers Regulators Secondary care		Primary care
JDM2	Joint employee training with other supply chain partners	Regulators	Wholesalers	Manufacturers Primary care Secondary care
RS1	Our supply chain partners share their resources with us	Manufacturers Wholesalers Regulators Primary care Secondary care		
RS2	We share resources with our supply chain partners	Manufacturers Regulators Secondary care	Primary care	Wholesaler
RS3	We share resources internally	Manufacturers Wholesalers Regulators Primary care Secondary care		

This section has summarized the quantitative findings and provided further evidence to confirm the identified themes from the qualitative study. The survey uncovered similarities and differences between the views and experiences of the different actors in the PSC. The next section, therefore, reports the confirmation of the variances identified in this section using the Kruskal Wallis tests.

6.4. Analysis of Variance between Supply Chain Actors Using Kruskal Wallis Tests

In this section, the results of the Kruskal Wallis tests (McCrum-Gardner, 2008) are reported. The Kruskal Wallis test was to ascertain if differences existed, among the opinions of the supply chain actors that participated in the survey. For instance, if manufacturers disagreed to the presence of power and pharmacists agreed indicates a difference in opinion and as such depicts how power flowed. The aim of using the Kruskal Wallis test was, therefore, to confirm the findings of the qualitative data as well as understand the interactions between supply chain actors (see Chapter 4 for explanations). The results are presented in the tables below.

The values in the tables are the mean ranks produced by the Kruskal Wallis tests where responses are ranked based on the weighted average. The higher the mean values, the higher the ranking. P-values of less than 0.05 denoted that statistically significant differences exist between the responses among supply chain actors. Values highlighted in bold are the highest mean ranking values.

Table 6.12 Kruskal-Wallis test for supply chain power

Supply Chain Actors	Information control IC1	Information control IC2	Drug Control DC1	Drug Control DC2	Price Control PC1	Price Control PC2
Manufacturer	37.25	31.65	44.75	38.80	34	28.85
Wholesaler	37.80	41.60	40.80	37	**63.40**	47
Regulatory bodies	22.00	44.75	47.75	55.38	40	52.00
Secondary care	53.92	**62.76**	52.38	52.90	54.74	50.27
Primary care	**64.93**	47.75	**61.43**	**62.03**	57.80	**69.13**
Kruskal – Wallis Test-Statistics	13.559 (.009)***	14.602 (.006)***	4.116 (.391)	6.476 (.166)	6.578 (.160)	15.912 (.003)***

***** denotes the level of significance at 1%.**

The Kruskal Wallis test for supply chain power is presented in Table 6.12. The results show that there is a statistically significant difference of opinions about supply chain power with regards to information control and pricing control. For information control, '*we do not have confidence in our supply chain partners' actions (IC1), and our supply chain partners encounter significant disruptions frequently' (IC2).* The lower end of the supply chain (secondary care and primary care) identified the presence of control with higher mean ranking values (64.93; 62.76). For *price control (PC2), 'there is no transparency in the pricing of goods within the supply chain',* primary care respondents indicated the presence of power with highly ranked mean values at 69.13 while wholesalers identified the absence of pricing information (PC1) as the source of power with mean value 63.40. With regards to drug control; '*we do not agree with supply chain partners on critical issues like the distribution of our products (DC1), and Our supply chain partners prevent us from doing what we want to do'* (DC2) the primary care respondents' had the highest agreement although the difference was not statistically significant.

Table 6.13 Kruskal-Wallis test for supply chain conflict

Variables/Supply Chain Actors	GM1	GM2	GM3	SCPS1	SCPS2	Absence of Trust
Manufacturer	46.95	33.17	50.15	60.80	34.25	44.75
Wholesaler	38.30	46.30	41.50	28.10	41.80	37.30
Regulatory bodies	69.25	39.25	41.38	44.75	41	25
Secondary care	50.60	56.53	53.38	51.09	53.82	51.51
Primary care	61.63	55.20	58.47	59.60	62.92	66.70
Kruskal –Wallis Test-Statistics	(5.860) .210	6.063 (.194)	2.630 (.757)	6.326 (.276)	10.041 (.074)*	12.633 (.013)**

- **SCPS- Supply Chain Partner Satisfaction GM- Goal Misalignment**
- ***,**,*** denotes the level of significance at 1%, 5% and 10% respectively**

Table 6.13 presents the variance in responses between supply chain actors for supply chain conflict. The Kruskal Wallis test-statistics indicate that significant differences exist among supply chain actors with regards to the perception of trust as well as satisfaction with relationships with supply chain partners. Primary care respondents had the highest mean values for both at (62.92,

66.70) denoting a lack of satisfaction and trust. This indicates that because they do not trust their supply chain partners, they may not be satisfied with their actions. Another higher-ranking mean value that was interesting to note is the response of regulatory bodies to goal misalignment; our supply chain partners do not consider how their actions will affect us (GM1) at 69.25 although this was not statistically significant. The Kruskal Wallis test in Table 6.14 above showed that there were significant differences with regards to supply chain actors' perception of supply chain complexities.

Table 6.14 Kruskal-Wallis test for supply chain complexity

Variables/ Supply Chain Actors	REG1	REG2	REG3	PRC1	PRC2	PRC3	PRC4	EC1	EC2
Manufacturer	51.20	32.75	55.95	70.00	64.05	57.40	60.05	58.60	77.75
Wholesaler	56.20	61.90	47.90	66.20	60.60	58.40	69.80	40	64.70
Regulatory bodies	54.25	50.38	79.00	60.50	82.25	58.13	90.50	87.50	79.50
Secondary care	51.44	53.95	56.09	45.19	49.86	51.95	46.91	48.98	44.58
Primary care	54.58	58.58	45.30	60.73	51.88	53.72	56.18	58.10	57.03
Kruskal –Wallis Test-Statistics	3.437 (.633)	6.353 (.273)	5.884 (.318)	11.225 (.047)*	6.451 (.265)	9.708 (.084)*	11.396 (0.44)	8.674 (.123)	16.055 (0.007)***

- **REG-Regulatory factors EC-Economic and political factors PRC-Production/product complexity**
- ***,**,*** denotes the level of significance at 1%, 5% and 10% respectively**

For product complexity which required strict storage or handling controls that may cause a delay (PRC1), manufacturers had the highest mean values indicating that manufacturers are more favourable to the notion that disruptions occur as a result of production complexities. Regulatory bodies considered that being part of a global distribution network was the major propellant of complexity with mean values at 79.50 for EC2. In Table 6.15, the Kruskal –Wallis test revealed that manufacturers employed more of joint decision making (JDM1) as a form of recovery strategy in comparison to the other supply chain actors.

Table 6.15 Kruskal-Wallis test for recovery and resistance strategies

Supply Chain Actors	FL1	FL2	VS1	VS2	JDM1	JDM2	RS1	RS2	RS3
Manufacturers	35.95	38.15	65.80	71.70	69.60	74	54	52.85	44.95
Wholesalers	61.10	67.20	68.30	62.90	51.10	39.40	32.30	30.40	52.90
Regulatory bodies	73.63	73.88	62.75	61.50	57.88	81.75	67.25	75.63	61.00
Secondary care	50.07	51.46	51.94	51.54	54.32	49.82	54.61	54.90	57.61
Primary care	61.92	57.48	48.67	47.47	46.38	52.23	52.93	51.95	47.65
Kruskal –Wallis Test-Statistics	7.661 (.176)	10.147 (.071)*	4.841 (.436)	7.121 (.212)	6.289 (.279)	11.286 (.046)**	3.952 (.556)	5.648 (.342)	4.416 (.491)

- **Flexibility-FL, Visibility-VS, Joint Decision Making –JDM, Resource Sharing-RS**
- ***,**,*** denotes the level of significance at 1%, 5% and 10% respectively**

JDM2, which reflects joint training regulators had the highest mean rank value at 81.75. There were no statistically significant differences in VS1 and VS2, indicating that a consensus among supply chain actors. For RSI, RS2, RS3, there were no statistical differences in the responses among supply chain actors; this denotes that all forms of resource sharing were critical to supply chain resistance in the event of a disruption.

Resource Sharing (RS) was also indicated as the major resistance capability in the PSC for the interview phase. The underlying idea here is that with the presence of these resources, supply chain actors can have the capacity to resist the impact of a disruption. These resources were either shared internally or externally. Manufacturers, secondary and primary care indicated that they were able to resist disruptions more when other supply chain partners shared resources. However, regulatory bodies had the highest mean values for (RS1, RS2, RS3) at 67.25, 75.63 and 61.00, respectively. This indicates that by sharing their resources, through information, infrastructure and training, regulatory bodies can withstand the impact of disruption when they occur.

The analysis of variance using Kruskal-Wallis tests confirmed that there were statistically significant differences in the responses and views among actors in the PSC. For instance, with regards to supply chain power, the Kruskal Wallis test showed a statistically significant difference among the opinions of supply chain actors. These corroborate the findings of the responses among supply chain actors in section 6.3 and depicts interactions between supply chain actors. The next section presents the reliability and validity of the items used in the questionnaire using the Cronbach Alpha and the composite reliability tests.

6.5. Checking the Reliability and Validity of item Scales

This section aimed to ensure that the data gathered from the survey were valid and reliable. The Cronbach alpha and the Composite Reliability tests were carried out on the survey tool to determine the reliability and validity of the survey tool.

The Cronbach alpha test was used to determine the internal consistency of the variables in the questionnaire, and this has been explained in detail in section 4.3 (more specifically in section 4.3.3.2.2.1). The preferable value for the Cronbach alpha test is 0.7 and above (Bland and Altman, 1997; Vaske et al. 2017). Some authors, however, accept Cronbach alpha values within the 0.5 and 0.7 thresholds (Kline, 2007).

As presented in Table 6.16, most of the items used in measuring the constructs had Cronbach alpha values greater than 0.7, while the overall Cronbach alpha score stood at 0.84. The exception to this was the supply chain complexity internal theme which had a value 0.509 and will be accepted in this study (Kline, 2007). This implies that the internal consistency within the items of the scale is valid and reliable.

The composite reliability also tests if the model estimated to measure variables in a study is a good fit. Thus, values higher 0.7 indicate that a model is a good fit (Nunnally, 1994). In Table 6.16 below, the composite reliability values are all higher than 0.7, which suggest that the model used in this study to measure the

relationship between supply chain vulnerability and resilience strategies is a good fit.

Table 6.16 Reliability and validity tests

Constructs	Number of Items in the Scale	Cronbach Alpha	Composite Reliability
Supply Chain Power	6	0.776	0.847
Supply Chain Conflicts	6	0.677	0.791
Supply Chain Complexity (Internal)	5	0.509	0.777
Supply Chain Complexity (External)	4	0.816	0.710
Recovery Strategies	6	0.806	0.860
Resistance Strategies	3	0.830	0.898

The discriminant validity test was also used to confirm that the structural paths identified in this study are valid. In this study, the Heterotrait-Monotrait (HTMT) criterion was used as it has a higher chance of detecting the absence of discriminant validity (Henseler, 2017). When values are below 0.95, it indicated that the items measured their intended constructs rather than on the unintended constructs, which demonstrates that the constructs were relatively distinct and well operationalized. The output for the HTMT tests is reported as a matrix in Table 6.17 below. All the correlation values are below 0.95 apart from the link between power and conflict, which is greater than 1.099, which suggests a close relationship between the two constructs. The absence of values in some of the box indicates a perfect correlation. This confirmed the identified structural paths in the study.

Table 6.17 The Heterotrait-Monotrait ratio of correlations (HTMT)

Variables	Complexity (External)	Complexity (Internal)	Recovery Strategy	Resistance Strategy	Conflict	Power
Complexity (External)						
Complexity (Internal)	0.894					
Recovery Strategy	0.686	0.578				
Resistance Strategy	0.523	0.419	0.906			
Conflict	0.750	0.388	0.479	0.523		
Power	0.748	0.200	0.390	0.134	1.099	

6.6. Exploratory Factor Analysis

The goal of the exploratory factor analysis was to explore if there were relationships between the identified constructs in the study. Given this, this section starts by assessing the correlation between the variables. The Spearman's rank correlation was used following the non-normality assumptions of ordinal variables. The correlation of all the variables used in this study is shown in Appendix D. The study found that there were significant correlations between variables. Some of them were positive, while some were negative at a=0.01 significance level. The correlation between drug control (DC1, DC2) and information control (IC1) at 0.769 and 0.797 were the two values above 0.75 in the study. This signifies that most variables in the study can be measured distinctively within the same construct (Sekaran, 2000).

Table 6.18 Kaiser-Meyer-Olkin (KMO)

Themes	Degree of freedom	KMO	Significance
Supply chain power (SCP)	15	0.755	0.000*
Supply chain conflict (SCC)	15	0.692	0.000*
Supply chain complexity (SCCP) External	10	0.563	0.000*
Supply chain complexity (SCCP) Internal	6	0.706	0.000*
Recovery strategies	15	0.662	0.000*
Resistance strategies	3	0.721	0.000*

**p <0.005*

To further authenticate the constructs developed in this study, the Kaiser-Meyer-Olkin (KMO) statistics were used (Abdrbo et al. 2011). This is a measure of the sampling adequacy that reflects the ratio of variance in the constructs that may be caused by underlying factors. Therefore, the closer the KMO value is to 1, the higher the adequacy of the variables in the data. Values below 0.5 depict that factor analysis may not be useful. Table 6.18 above showed that all the KMO values were above 0.5, indicating that the constructs are suitable for factor analysis.

Table 6.19 Exploratory Factor Analysis (EFA)

Constructs	Rank of Factors	% of explained variance
Supply chain power (SCP)	1	69.93
Supply chain conflict (SCC)	1	64.277
Supply chain complexity (SCCP)	2	95.561
Recovery strategies	1	76.086
Resistance strategies	1	74.549

The findings for the exploratory factor analysis (EFA) are reported in Table 6.19 above. The aim of this study was exploratory, and as such, the study does not report the findings from the principal component analysis. The factors derived from exploratory factor analysis and the percentage of variance explained by each factor were reported. Factors in each construct captured more than 60% of the total variance. For supply chain complexity, the Eigenvalue indicated two factors, and as such, the variables denoting complexity.

6.7. Structural Equation Modelling

The goal of the Structural Equation Modelling is to explore if there are relationships between the identified constructs (variables, concepts of supply chain resilience) in the study. In the qualitative phase of the study, 30 themes and 6 major themes were identified. In developing the structural equation modelling phase, the study relied entirely on the outcomes of the partial least

squares analysis in estimating the models (PLS) (Hair et al. 2017). The path coefficient values presented in this study were assessed using SEM with Maximum Likelihood Estimation and bootstrapping with 5000 iterations. In view of this, six sets of measurement models were estimated in this study with their findings presented in the subsequent tables. The measurement models included an examination of the link between the major resilience concepts (vulnerabilities and resilience strategies), as shown in Figure 6.2.

Figure 6.2 in analysing the structural equation model in this study, the structural model examined the relationship between the latent variables, while the measurement models assessed the links between the observed variables and the latent variables. The analysis was presented from left to right assessing the impact of resilience strategies on vulnerabilities.

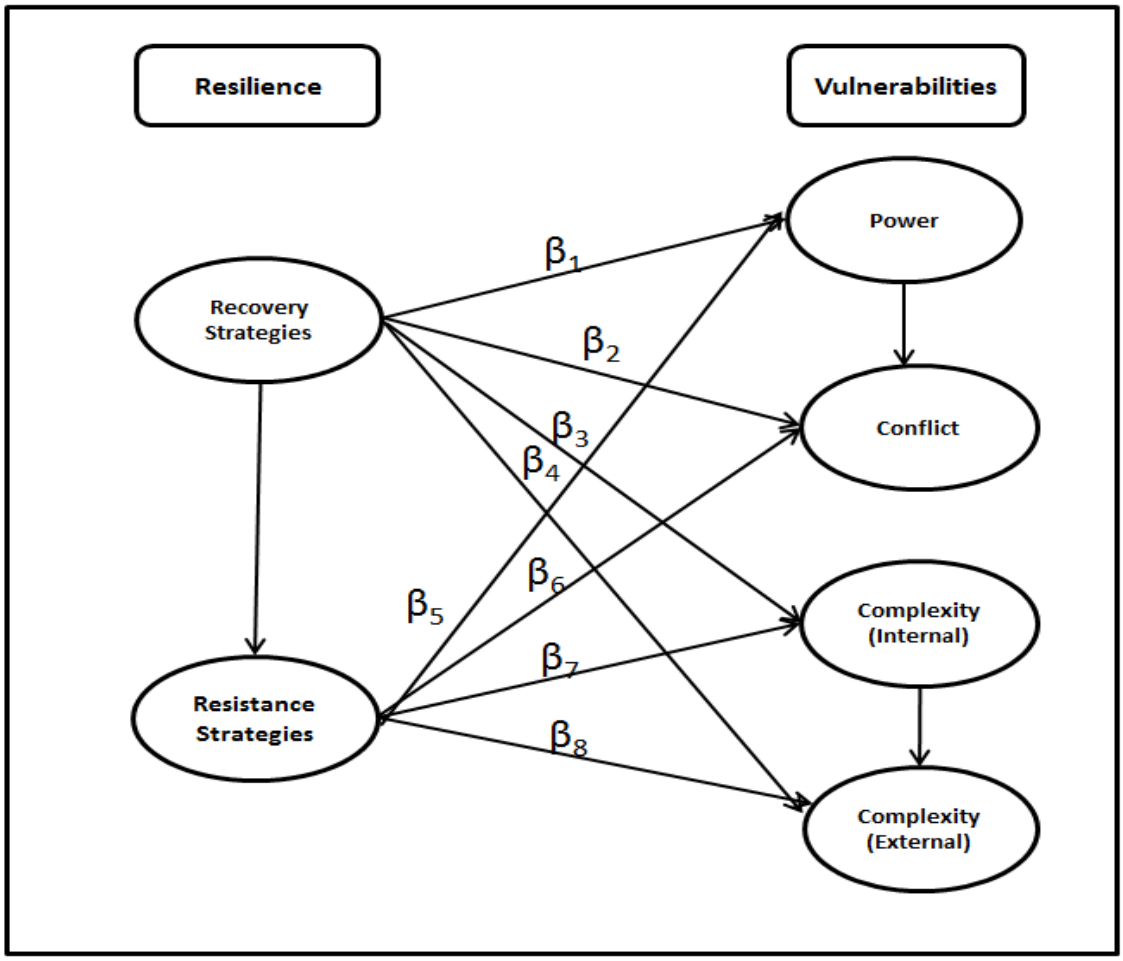

Figure 6.2 Vulnerability Drivers and Resilience Strategies (Expected)
β_1 - β_8 represent the path coefficients to be estimated

6.7.1. Resilience Strategies and Supply Chain Power

In Table 6.20, the link between supply chain power and resilience strategies is presented.

Table 6.20 Measurement models power and recovery strategies

Linkages	Variables	Loading	T Statistics	P value
Power	IC1	0.890	0	0.000***
	IC2	0.694	5.10	0.000***
	DC1	0.745	7.99	0.000***
	DC2	0.901	11.03	0.000***
	PC1	0.083	0.37	0.713
	PC2	0.769	7.94	0.000***
Recovery Strategies	FL1	0.691	8.53	0.000***
	FL2	0.649	8.38	0.000***
	VS1	0.803	5.11	0.000***
	VS2	0.682	2.81	0.005***
	JDM1	0.750	2.83	0.000
	JDM2	0.682	1.53	0.126
Resistance Strategies	RSI	0.848	0	0.000
	RS2	0.867	7.40	0.000
	RS3	0.874	7.26	0.000
Structural Model Recovery→ Power		0.190		
Structural Model Resistance→ Power		-0.004		
Goodness of Fit (Likelihood ratio)		540.607 (0.000)***		

***** denotes significance at 1%**

For the structural model, the beta coefficient has a positive value of β=0.190 for recovery strategies and (β=-0.004). This suggests that the recovery strategies adopted by supply chain actors in the PSC propel power and the resistance strategy reduced supply chain power**.** For supply chain power as an emerging theme, the table showed that four of the six observed variables had path coefficient values that are higher than 0.5 and p values >0.05. This indicated that the measurement models used to define power within the supply chain were good indicators of power. Information control (IC1) denoted that about 60% of the variable was a predictor of supply chain power. For the measurement model, all the values for the measurement variables were positive and statistically

significant apart from PC1 and JDM2. This implies that the variables measured the constructs for which they are assigned.

6.7.2. Resilience Strategies and Supply Chain Conflict

Table 6.21 presents the structural model between conflict and resilience strategies.

Table 6. 21 Measurement models conflict and resilience strategies

Linkages	Variables	Loading	T Statistics	P value
Conflict	GM1	0.666	-1.46	0.145
	GM2	0.694	0.52	0.602
	GM3	0.187	3.44	0.001***
	SCPS1	0.270		0.000***
	SCPS2	0.843	0.44	0.663
	Absence of Trust	0.896		
Recovery Strategies	FL1	0.691	8.53	0.000***
	FL2	0.649	8.38	0.000***
	VS1	0.803	5.11	0.000***
	VS2	0.682	2.81	0.005***
	JDM1	0.750		
	JDM2	0.682	1.53	0.126
Resistance Strategies	RSI	0.848		
	RS2	0.867	7.40	0.000
	RS3	0.874	7.26	0.000
Structural Model Recovery → Conflict		0.143	0.21	0.837
Structural Model Resistance ← Conflict		-0.165	7.30	0.000***
Goodness of Fit (Likelihood ratio) 1050.243 (0.000)***				

***** denotes significance at 1%**

The structural model depicts a positive relationship between conflict and recovery strategies (β=0.143), while the relationship between resistance strategies is negative (β=-0.165). Thus, if the level of recovery strategies increases by 1%, supply chain conflict also increases by 14%. Similarly, if resistance strategies increase by 1%, the level of conflict will drop by 0.16%.

The findings imply that resistance strategies aid in mitigating the level of supply chain conflict; however, recovery strategies increased conflict.

6.7.3. External Complexity and Resilience Strategies

The measurement model and the structural model for external complexities and resilience strategies are presented in Table 6.22 below. The analysis shows that all the variables for external complexities load well, indicating the items selected for measuring the constructs are well suited. The highest coefficient can be seen with EC2 at 0.789, which denotes that it has a higher impact on measuring external complexity. For the path model, the output shows positive links between both recovery and resistant strategies ((β=0.422; 0.031) on external complexities. The findings imply that the resilience strategies adopted by actors in the supply chain increase the level of external complexities.

Table 6.22 Measurement models for external complexity and resilience strategies

Linkages	Variables	Loading	T Statistics	P value
External Complexity	EC1	0.442	1.46	0.145
	EC2	0.789	0.52	0.602
	REG1	0.452	3.44	0.001***
	REG2	0.582	1.69	0.000***
	REG3	0.579	0.44	0.663
Recovery Strategies	FL1	0.691	8.53	0.000***
	FL2	0.649	8.38	0.000***
	VS1	0.803	5.11	0.000***
	VS2	0.682	2.81	0.005***
	JDM1	0.750	1.79	0.667
	JDM2	0.682	1.53	0.126
Resistance Strategies	RSI	0.848	7.45	0.000***
	RS2	0.867	7.40	0.000***
	RS3	0.874	7.26	0.000***
Structural Model Recovery → External Complexity		0.422	0.21	0.837
Structural Model Resistance ←External Complexity		-0.054	7.30	0.000***

6.7.4. Internal Complexity and Resilience Strategies

The findings indicate a positive link between recovery strategies and internal complexity at about 42%, which implies that recovery strategies increase the internal complexities of the PSC. The output also reflects that resistance strategies employed reduced internal complexities at 5% depicting that if resistance strategies which included internal and external training are increased, internal complexities reduce.

The path coefficient between recovery and resilience strategies indicates that recovery strategies largely influence resistance strategies by 76%, indicating a connection between the two resilience strategies. Supply chain power also increased supply chain conflict by 86%. This implies that higher supply chain power increases conflicts with the PSC. The study also examined the link between internal complexity and external complexity and found a positive increase of 0.548. This implies that the higher the level of internal complexity, the higher, the level of external complexity.

In Figure 6.3 below presents the relationship between all vulnerabilities and resilience strategies as identified themes in the previous chapter. The output reveals mixed-effects where almost all variables used in explaining the relationship between vulnerabilities and resilience strategies have significant values at 5%.

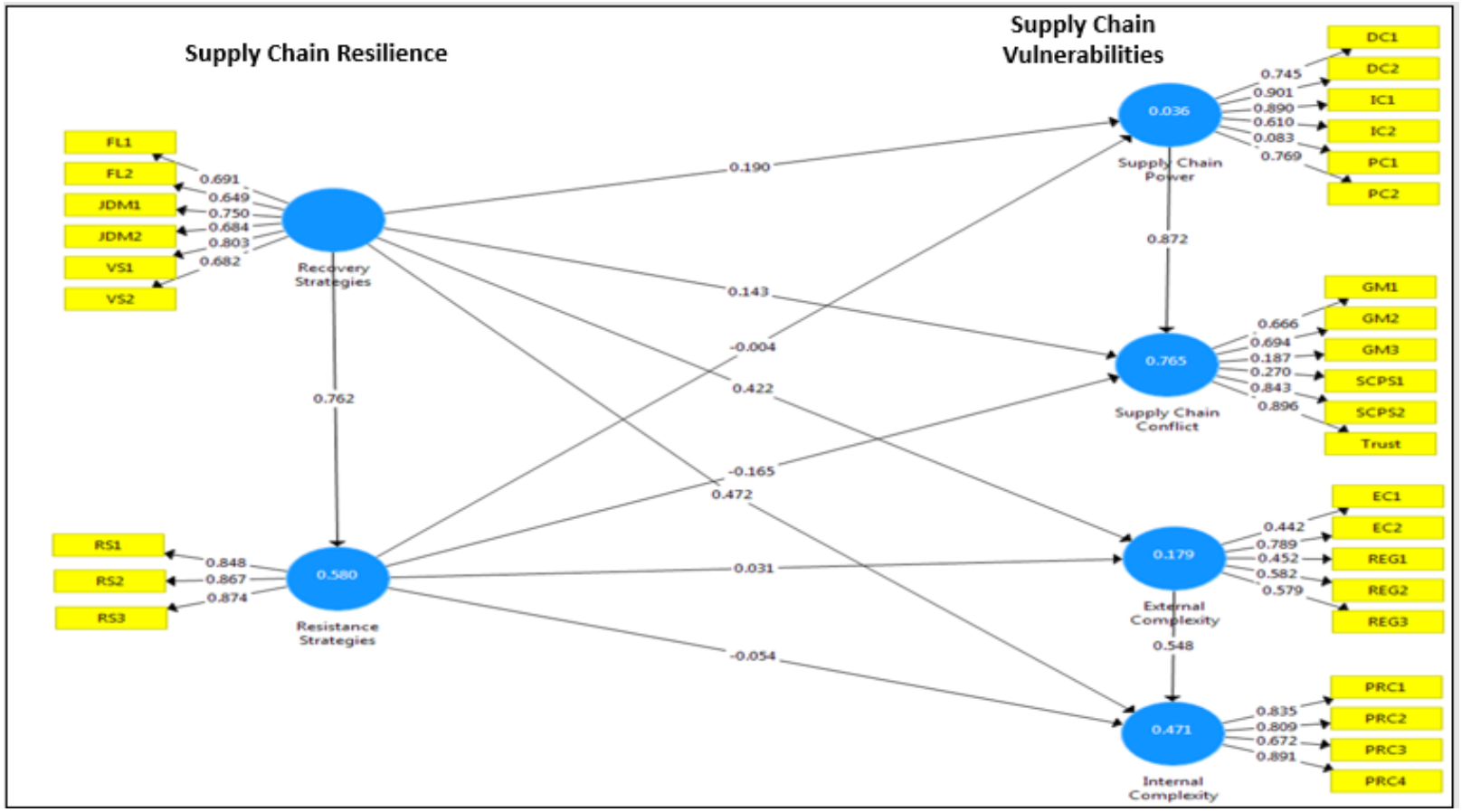

Figure 6. 3 Vulnerability Drivers and Resilience Strategies.
Positive values denote increase, and negative values denote decrease.

6.7.5. Summary of the Path Model

Table 6.23 and Figure 6.3 above present the summary for the path coefficient values for the themes that emerged in the qualitative phase of this research which has been confirmed in the quantitative phase of the study as presented in this chapter. These themes included supply chain power, supply chain conflict, internal and external complexity, as well as recovery and resistance strategies. The findings indicate a mixed relationship between elements of vulnerabilities and resilience strategies.

On the left-hand side of the diagram are the resilience strategies and the resistance strategies, the study finds a negative coefficient (β=-0.054). This implies that the resistance strategies relating to technology and resource sharing used by actors in the PSC mitigates the impact of supply chain complexity when the complexities involve production characteristics. The analysis, however, finds a positive coefficient between complexity and resistance strategies when the complexities in the supply chain emanate from regulations, policies, political and economic issues. The path coefficient here is (β=0.031). This implies that if a resistance strategy increases by 1%, supply chain complexities will also increase by .03%.

The study also examined the relationship between recovery strategies and resistance strategies and found that there was a strong positive and significant link between the two variables with a path coefficient of (β=0.768). This suggests that an increase in recovery strategies increases resistance strategies by about 76%. Table 6.23 presents the degree of relationship between the variables presented in the model. The analysis shows that resistance as a resilience strategy mitigates the impact of external complexity within the supply chain as the degree of the relation is valued at (-0.054). However, the values showed that recovery strategies adopted by supply chain actors increased the level of external complexity in the supply chain significantly where (β=0.422)

Table 6. 23 Summary of the path model

Linkage	Direction	Description	Estimates (β)
Recovery Strategies and Power	→	Increases power in the supply chain	0.190***
Recovery Strategies and Conflict	→	Increases conflict in the supply chain	0.143*
Recovery Strategies and Complexities	→	Increases complexities (internal)	0.422
Recovery Strategies and Complexities	→	Increases complexities (external)	0.472
Resistance Strategies and Power	←	Decrease the level of power in the supply chain	-0.004
Resistance Strategies and Conflict	←	Decreases the level of conflict in the supply chain	-0.165
Resistance Strategies and Complexities	←	Decreases the level of internal complexities	-0.054
Resistance Strategies and Complexities	→	Increases external s complexities	0.031**

*,**, *** are significance at 1%,5% and 10% respectively
→Denotes increase, ← denotes decrease

6.8. Summary and the Case for a Systemic Analysis of PSC Resilience

In this chapter, the findings from the quantitative phase of the study were presented. The activities, constructs and themes from the previous chapter were developed into items on the questionnaire, where the data generated from the questionnaire were analysed, and the findings presented. The chapter thus began by presenting the demographic characteristics of the respondents who completed the questionnaire, the findings from the responses collected; the Kruskal Wallis test was used to confirm the variation of responses across supply chain actors; the Cronbach's alpha was used to assess the reliability and validity of the data and the Structural Equation Modelling (SEM) used to measure the relationship between the identified

activities, constructs and themes. Based on the analysis, the output of the quantitative phase confirms the findings of the qualitative phase of the study. It also shows that the vulnerabilities and resilience strategies differ across supply chain actors.

Some of the vulnerabilities, as well as the interactions between vulnerabilities and resilience strategies discussed in the findings' chapters (Chapters Five and Six), were not previously considered in the literature. These chapters hence provide contributions to the literature. However, it was challenging to explain vulnerabilities and resilience strategies in the PSC in isolation, as the consequences for some of the vulnerabilities by certain supply chain actors were identified as threats by other supply chain actors. Figure 6.3 showed that some of the resilience strategies adopted by supply chain actors increased vulnerabilities instead of reducing them as existing literature suggests. Figure 6.3 also revealed that recovery strategies reinforced resistance strategies, for example, resource sharing and increased visibility among supply chain actors. The findings also revealed that some supply chain actors adopted decisions based on characteristics of the PSC.

Ultimately, the underlying argument here is that although the findings chapters attempted to categorise vulnerabilities and resilience strategies individually and separately, it was clear that vulnerabilities are interrelated, and the resilience strategies developed to mitigate the impact of disruptions. This inter-relatedness may sometimes lead to outcomes like recovery strategies increasing the level of power within the supply chain or the increase in power emanating because of misalignment of goals. This inter-relatedness appears fundamental to how supply chains behave as Complex Adaptive Systems when any attempt is made to change them. The next chapter, therefore, discusses the findings and then adopts CAS as a framework to further explore PSC resilience.

Chapter Seven: Discussion

7.1. Introduction

This chapter discusses the findings from the qualitative and quantitative data collected for this study. The discussion is centred around key areas: disruptions, characteristics of the pharmaceutical supply chain (PSC), issues of vulnerabilities as well as resilience strategies as presented in Chapters Five and Six. CAS theory is then used as a framework to explore how the elements of resilience in the PSC were developed.

This chapter is thus divided into five sections. The first section (7.2) discusses the supply chain disruptions and builds into how the characteristics of the PSC may influence the decisions made by supply chain actors in responding to the disruption. The outcome of these decision-making processes may leave the supply chain vulnerable (7.2.3) or develop resilience strategies (7.2.4). These interactions suggest system thinking, and as such, in section 7.3, the PSC, its vulnerabilities and resilience capabilities are presented as a system using the CAS theory. Section 7.4 presents the Pharmaceutical Supply Chain Resilience (PSCR) framework (Figure 7.9) developed from the study and implications for vulnerabilities and resilience strategies in the PSC. A summary of the chapter is presented in 7.5.

As a reminder, to support the following discussions, the research questions generated for this study are as follows:

RQ1: Why is the PSC in the UK susceptible to dynamic disruptions?

- What are the drivers of vulnerability in the PSC?
- How do these drivers expose the supply chain to the impact of dynamic disruptions?

RQ2: How are resilience strategies used to mitigate the impact of dynamic disruptions in the PSC?

- What strategies do supply chain actors adopt to build resilience against dynamic disruptions?
- What are the outcomes of implementing these strategies?

RQ3: What impact do resilience strategies have on vulnerabilities in the PSC?

7.2. Discussion of Findings

The discussions are structured around the major themes that emerged from the findings of both phases of this research. This section begins by examining the disruptions in the PSC and the underlying characteristics of the PSC. These feed into the discussions on the vulnerabilities drivers, resilience strategies, and the relationship between the identified resilience strategies and vulnerabilities in the PSC. These will be presented in the sections following this.

7.2.1. Disruptions in the Pharmaceutical Supply Chain (PSC)

According to the findings from this study, all actors in the PSC experienced various forms of disruptions. However, the disruption that had the most impact on the supply chain was medicine shortages, as 92% of the respondents from the quantitative phase of the research confirmed this. This implied that the respondents did not refer to specific high-profile events like the Tsunami or Hurricane Maria or generic categories of events as explored in the taxonomies from supply chain risk literature (Ambulkar et al. 2015; Ivanov et al. 2017).

The discontinuity of patients' treatment, which is the likely outcome of PSC disruptions caused by medicines shortages, impacts negatively on patient safety. Patient safety has not been hitherto, considered as an outcome within existing operations management literature about PSC disruptions. Therefore, the scale of impact cannot be measured by existing criteria such as those described by Ambulkar et al. (2015) and Schiebe and Blackhurst (2018).

Also, the indication of medicine shortages as a form of disruption in the PSC, denotes that supply chain actors have had to respond to this form of disruption at various point in time. These responses were influenced mainly by the process involved in manufacturing a pharmaceutical product and/or patient safety. For instance, a hospital pharmacist explained that the nature of pharmaceutical products affected the time required in manufacturing as well as the decision-making process in responding to disruption. Therefore, in the event of a disruption, it was difficult to meet sudden increases in demand

because the average lead time for a pharmaceutical product was twelve weeks. This suggests that the decisions supply chain made in responding to a disruption were influenced mainly by characteristics of the PSC.

Traditional languages of decision making may entail a deterministic connection between the decisions and the end goal (Bennet and Bennet 2008). In conventional wisdom, therefore, when a supply chain actor decides to respond to a disruption, the expected outcome is specific: which is to prevent the impact. This may not be the case for PSC's as the decisions may be influenced by the underlying characteristics of the supply chain, which increases the complexities of making decisions. As a result, the outcomes of the decision-making process of PSC actors when responding to disruptions may be unpredictable because of the characteristics of the PSC. The next section, therefore, explores how the characteristics of the pharmaceutical supply chain may influence the decisions of supply chain actors when responding to disruptions.

7.2.2. Characteristics of the Pharmaceutical Supply Chain (PSC)

Some studies have identified that the characteristics of a supply chain increase vulnerability (see Wagner and Bode, 2006; Hallikas et al. 2005; Blackhurst et al. 2018). This study, however, argues that supply chain characteristics influence vulnerability drivers and resilience strategies. Thus, PSC characteristics transcend beyond supplier and consumer dependence (see Wagner and Bode, 2006) to other features such as the criticality and nature of the products, regulation of the industry, limited manufacturers and patient safety.

The findings in this study denoted that the nature of the pharmaceutical product was critical in designing the PSC as well as developing resilience strategies. For instance, a research respondent explained that it was challenging to stockpile some pharmaceutical products because; they may have shorter shelf lives, it may be cost-intensive, and/ or the treatment regimen for patients may have changed. Schwartz and Zhao (2011), also explained that because of the varying consumption points of pharmaceutical products,

the operational capacity differs. Thus, understanding the criticality and nature of pharmaceutical companies is essential. Similarly, if decisions around PSC are treated in the same way as other commodities, it may undermine the quality of the pharmaceutical product (de Rima et al. 2018).

Frequently highlighted in the data analysed was the limited number of manufacturers of pharmaceutical products. A manufacturer explained that as a result of the investment required in manufacturing pharmaceutical products, as well as the high level of expertise, the number of manufacturers was limited. This was also pointed out by Narayana et al. (2014). The limited number of manufacturers also affected the decision-making process for supply chain actors. For instance, a regulatory body explained that they could not impose sanctions and/or punish manufacturers who had failed to meet their tendering contracts as there would be no manufacturers left to meet their demand.

Regulation is another pertinent feature of the PSC and was also identified to influence the decisions of PSC actors immensely. While pharmaceuticals are one of the most regulated products in the world with regards to marketing and sales, their regulations have been argued to be like the food industry (Ahmad et al. 2009). However, medicines are substances or combinations of substances presented as having properties for treating or preventing disease in human beings (MHRA, 2019). Medicines also involve absorption, distribution, metabolism and excretion from the body, which is only understood by the specialists and as such, must be proven to be safe and effective in fulfilling its intended purpose. The approval process has additional controls such as medical and scientific review, as well as clinical trials with patients, to empirically test effectiveness within the population (Jetly et al. 2012).

Another characteristic of the PSC is the issue of patient safety. This implies that the underlying objective of the PSC is to ensure access and availability of medicines to patients without causing harm. Patent safety is defined as the prevention of harm to patients (Erickson et al. 2003; Mitchell, 2008; Vincent, 2011). Thus, some of the decisions made by PSC actors were to ensure that no harm came to the patient. For instance, a community pharmacist indicated that the decision to stockpile products when there was a disruption was to ensure that patients continued treatment. Further, a regulatory body explained

that the decision to ration products in the PSC was to ensure patient treatment continuity. The findings from the data, thus, showed that patient safety was at the core of the PSC and largely influenced the decision-making process of supply chain actors.

The findings also revealed that some of the identified characteristics such as regulations, patient safety and production processes of the PSC contributed to making the supply chain vulnerable to the impact of disruptions. Take, for instance, the decisions to stockpile to ensure patient safety or the inability to respond timely to demand during a disruption due to complex production processes. This is called structural adaptation because the issue of vulnerability may lie within the structure and features of the PSC (Bennet and Bennet, 2008).

The PSC has unique characteristics which influence vulnerability drivers and resistance strategies. The next section discusses supply chain vulnerabilities as an outcome of the decisions made by PSC actors in responding to the incidences of disruption.

7.2.3. Supply Chain Vulnerability as an Outcome of the Decision-Making Process

According to the findings of this study, power, conflicts, and complexity are drivers of vulnerability in the PSC. These vulnerability drivers are the outcomes of the decision-making processes of supply chain actors. As presented in Figure 7.1 below, 16 factors were identified as the underlying drivers of vulnerabilities in the PSC. These factors were further categorised into sub-themes to provide a holistic discussion on supply chain vulnerabilities. The analysis further depicts that these factors were dynamic, as their mechanisms and application in the PSC constantly changed when disruptions occurred. Also, the sub-themes and outcomes, however distinct based on their identified factors, interacted with each other to a certain degree. Figure 7.1 below presents a summary of the findings that emerged from the data.

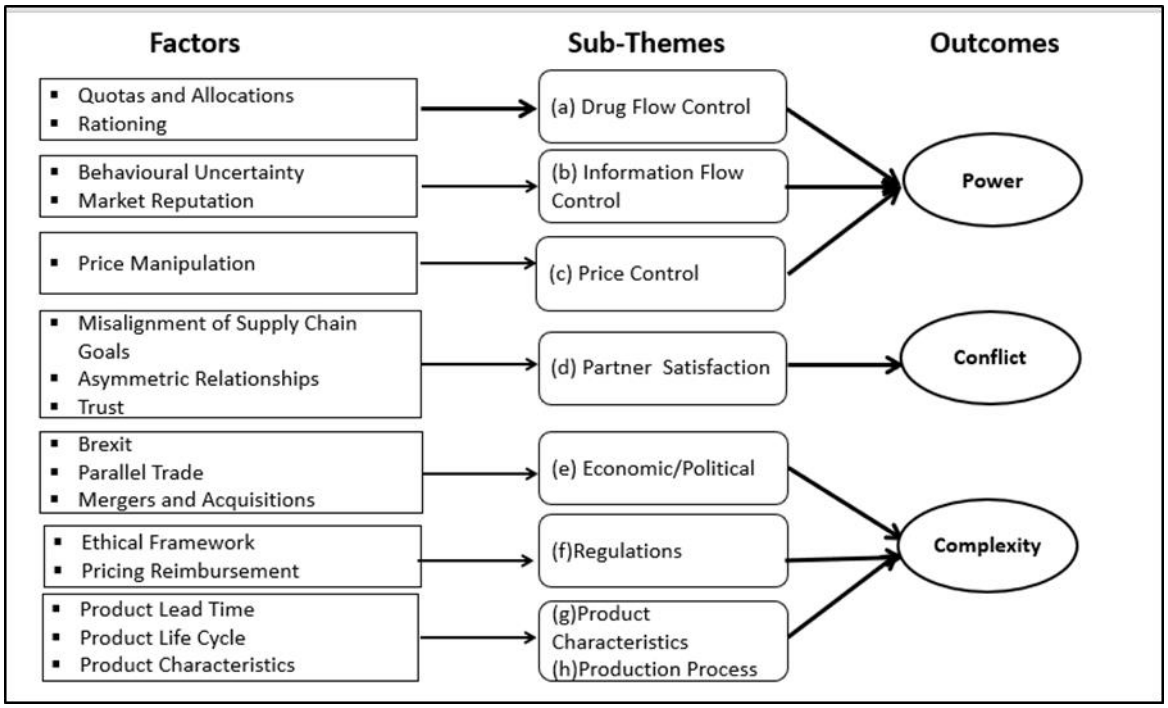

Figure 7.1 Drivers of Vulnerability in the PSC
Source: Researcher's Own (2019)

7.2.3.1. Power

The ability of some supply chain actors to control the basic tenets of the supply chain: product, information and price, depict the presence of power asymmetry (Benton and Maloni, 2005, Bandara et al. 2017). The findings revealed that some supply chain actors controlled the flow of drugs, information as well as prices and thus indicated the presence of power asymmetry. Although the exhibition of power dynamics by supply chain actors was to ensure efficiency in the operations and financial performance of their firms, it, however, increased vulnerabilities in the PSC. For instance, with regards to the control of drug flow, supply chain actors used quotas and rationing as power mechanisms. The decision to impose quotas and rationing was to guarantee that operations continued, as usual, ensure financial performance as well as patients' treatment continuity.

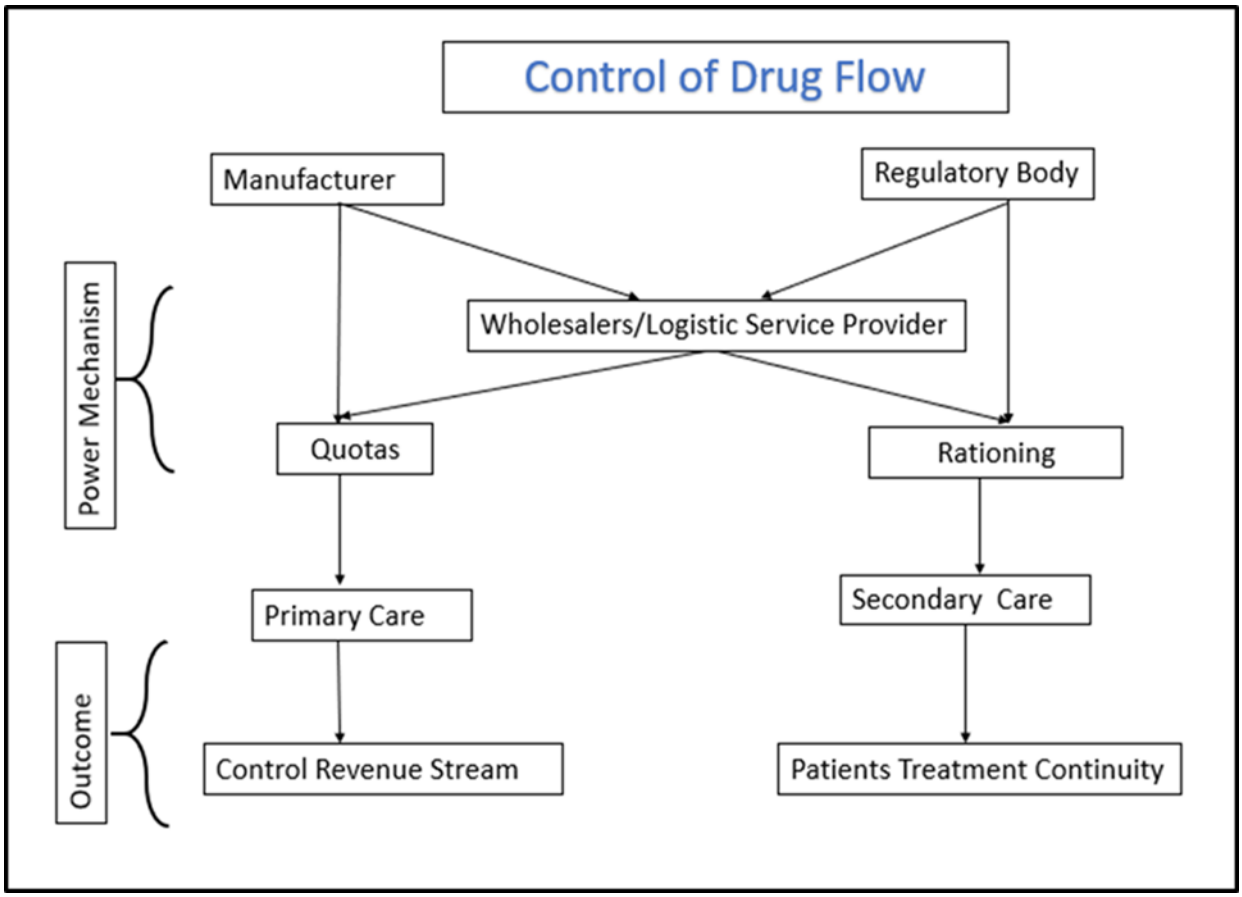

Figure 7.2 Diagram Depicting Control of Drug Flow in the PSC
Source: Researcher's Own (2019)

Figure 7.2 above provides a pictorial representation of the control of drug flow in the PSC. The diagram shows that drug flow was controlled mainly by manufacturers and or regulatory bodies. With quota systems, the manufacturers' outcome was to control the revenue stream, and with rationing, regulatory bodies' outcome was for patients' treatment continuity. This suggests that in the bid to achieve their desired outcome, these supply chain actors decided to use their position of power to control the quantity of drugs other supply chain actors had.

This exhibition of power asymmetry in this study is referred to as mediated power (see Benton and Maloni, 2005; Bandara et al. 2017). Here, power is imposed on weaker supply chain actors to achieve their desired outcome based on their perceptions and capability with regards to power (Chen et al. 2014; Golgelci et al. 2018). The control of drug flow, however, hampered other supply chain actors' ability to plan for disruption as they were unable to engage

buffer stock and/ or flexible operations thus exposing the supply chain to the impact of disruption.

In the same vein, information flow control was also identified as a driver of power in the PSC. The findings in this study depicted that supply chain actors' decisions to control the flow of information about disruptions, was to protect their reputation and/or prevent uncertain behaviours. Thus, when disruptions occurred in the PSC, supply chain actors decided to manage the disruption rather than share the information with other supply chain actors. As manufacturers pointed out, they were reluctant to inform supply chain partners about the disruption they were experiencing in case supply chain partners switched from their products to alternative products. The findings from the survey corroborated this as 61.3% of the 106 respondents strongly agreed that they would not buy from a supply chain actor who frequently encountered disruptions.

Thus, controlling information about incidences of disruptions to supply chain actors was pertinent in preserving reputation. Reputation increases market share and can be a source of competitive advantage in supply chains (Oyedijo et al. 2018). Supply chain actors' reputations were often reflected in the number of disruptions they were prone to (Franke et al. 2005; Petersen and Lemek, 2015). However, the decision to protect market share by controlling information flow increased the vulnerability of the PSC as other supply chain actors were unable to prepare for disruptions or plan adequately.

According to the findings in this study, another reason why supply chain actors decided to control the flow of information in the PSC, was to reduce the behavioural uncertainty. Manufacturers and regulatory bodies indicated that most times they decided not to share information about disruption was because they were unsure of how other supply chain actors would react. This was because, in the past, supply chain actors had engaged in extreme behaviours like panic buying or ceased stocking of the product. For instance, a hospital representative explained that when there was a disruption and no further information was provided regarding the nature of the disruption; they engaged in panic buying to meet their organisational objectives. The findings from the survey further confirmed these influences on the flow of information

through behavioural uncertainty. Panic buying may distort actual demand, thus creating further disruptions, and this increases supply chain vulnerability. Also, the decision to stop stocking products can affect the market share of other supply chain actors, and this may also increase susceptibility to the impact of disruptions.

Thus, the degree of control of information flow in the PSC is directly related to the level of behavioural uncertainty amongst supply chain actors. This implies that information sharing may reduce behavioural uncertainty, as suggested by Kwon and Suh (2004) and Zhao et al. (2019). Figure 7.3 below presents a summary of information flow control in the PSC. A possible explanation for the ability of supply chain partners to control the flow of information is the absence of a centralised database where supply chain partners can receive and exchange information. Therefore, the presence of a centralised information system may facilitate information sharing and thus limit the power to control information among supply chain partners as proposed by Luthra et al. (2018) and Dominguez et al. (2018).

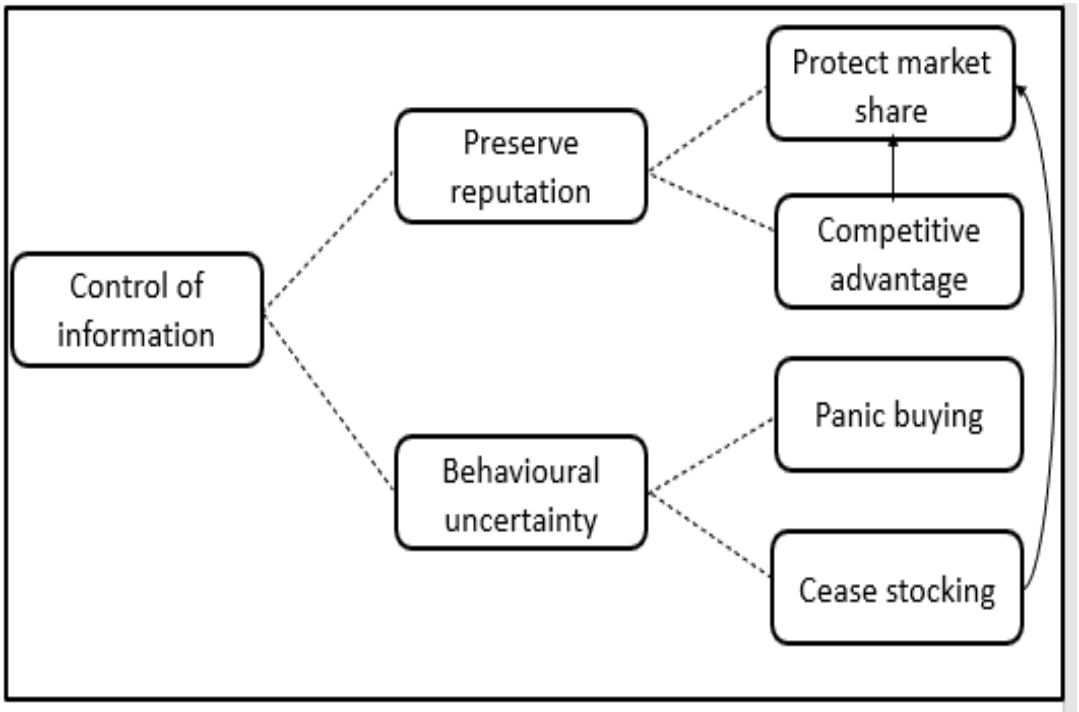

Figure 7.3 Diagram Depicting Control of Information Flow in the PSC
Source: Researcher's Own (2019)

Another situation of power asymmetry in this study was price control. The analysis showed that manufacturers and wholesalers as supply chain partners controlled the pricing mechanism in the PSC. For instance, a research respondent explained how supply chain actors created artificial demand by withholding the product from the market and then reintroduced the product at a higher price for a profit. This implied that product prices could be manipulated by some supply chain actors within the PSC. To further confirm these findings, responses from the survey indicated that, 66% of the respondents agreed that information regarding pricing of pharmaceutical products was not readily available. The ability of supply chain actors to control the prices and flow of products thus impedes planning for other supply chain actors which makes them susceptible to the impact of disruptions.

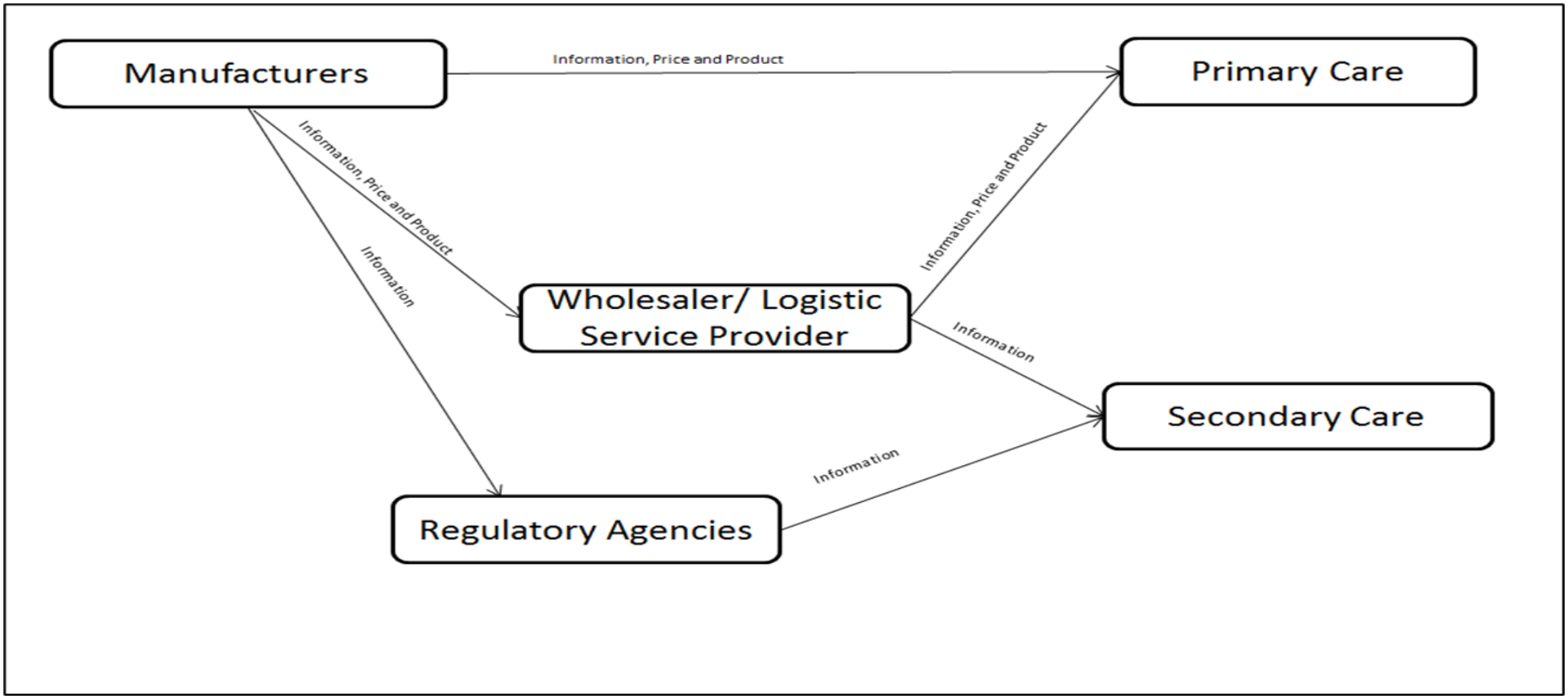

Figure 7.4 Power Flow within the PSC
Source: Researcher's Own (2019)

Figure 7.4 above provides a graphical representation of the flow of power within the PSC. The figure shows that power was concentrated with the manufacturers, regulatory bodies and sometimes wholesalers/logistic service providers.

Hence, the presence of power as a driver of vulnerability may be attributed to the PSC's characteristics which are a manufacturer led supply chain. Here, the manufacturer controls the resources; information and medicine and there are a limited number of alternatives. Therefore, overreliance on a single manufacturer and/or a limited few may have accentuated the vulnerabilities in the supply chain because of the power asymmetry among supply chain partners. Also, most pharmaceutical products are critical to survival (Narayana et al. 2014). These findings support the assertions by Madichie and Yamoah, 2016; Golgeci et al. (2018) who suggest that the strategy of the supply chain to wield power affects outcomes for supply chain partners. This research, therefore, proposes that the misuse of power is detrimental to the efficiency of the PSC.

7.2.3.2. Conflict

According to the findings, the presence of conflict made it difficult for the PSC to withstand the impact of disruptive activity. Conflict in the PSC emanated from the level of satisfaction among supply chain partners measured through the misalignment of supply chain actors' goals, dependence asymmetry and the absence of trust.

The findings from both qualitative and quantitative data revealed that the differences in organisational goals of supply chain actors increased the incidences of conflict. A careful examination of the qualitative data revealed that not all actors in the supply chain engaged in business activities to make a profit, and these differences created conflict. This was further corroborated by the quantitative data, where 68.8% of the 106 respondents, supported the presence of goal misalignment. The analysis of the quantitative data further revealed that although supply chain actors understood the market demand,

they took decisions independent of supply chain partners to meet their individual firm's business goals rather than overall supply chain goals.

Factors signalling misalignment of goals in the study included: The NHS tendering strategy, service orientation of the pharmacists and profit margin goals for manufacturers. With regards to tendering, the research respondents explained that the NHS offered contracts to a limited number of suppliers on a regional basis. This is based on its goal to supply medicines to patients at the minimal possible costs (PMSG, 2018). The action of the NHS reflects welfarism; where individual utilities are maximized subject to a budget constraint (Gyrd-Hansen, 2005). The pharmacists at the patient-facing end of the supply chain also indicated that their goals as pharmacists were more about patient care and less about making a profit. Thus, the goal of these pharmacists transcends beyond increasing sales to ensuring continuity of patient care.

The objectives of the NHS, and the pharmacists, differed from the manufacturers/ wholesalers whose goal in the PSC were to make a profit. The manufacturers in this study explained that the cost implication of providing a pharmaceutical product at a lower price was not profitable and was incompatible with the NHS tender strategy. This indicated that supply chain actors were chasing different goals, where every firm behaved in ways that maximized their interests. The differences in organisational goals, thus, created conflict and made it difficult for supply chain actors to collaborate and strengthen the PSC. Although this conflict was not inherently visible, it contributed to making the PSC susceptible to the impact of disruptions. This finding supports the assertions by Ludin and Norman, (2010), who explained that the presence of goal misalignment might not be visible, but their activities may lead to decreased efficiency and diminished services.

The absence of trust was also identified as a driver of conflict within the PSC in the UK. According to the findings of this study, instances that portrayed the absence of trust among supply chain actors included the scanning of anonymised prescriptions; increased blame; reduced confidence in supply chain partners' ability by introducing direct to customer (DTC) models and refusing to share information. For instance, a community pharmacist stated

that they believed the wholesalers deliberately withheld products and information so that they could make a profit. Another manufacturer cited that they believed that some supply chain actors were selling their products abroad for a profit. The findings from the data, therefore, revealed that supply chain partners believed that their partners engaged in opportunistic behaviours which violated the terms of their relationship. The strength of these beliefs increased the absence of trust and provided avenues for conflict (Minerbo et al. 2018). The absence of trust, thus, weakens any form of collaborative practices, thereby exposing the PSC to the impact of disruptions (Fawcett et al. 2015).

The findings from the quantitative data, however, differed slightly from the qualitative data as the primary care respondents were the only category that indicated that they did not trust their supply chain partners with 60% agreeing to this statement. This could be as a result of lack of information from upstream partners about prices and products and could as well explain the possible blame that ensued. Low levels of trust among supply chain partners may, thus, occur as a result of power embeddedness. Yeung et al. (2009) further explained that the presence of power reduces the level of trust among supply chain partners and may provide a possible explanation for the absence of trust. Also, Ojala and Hallikas (2006) argued that the absence of trust among supply chain partners might be responsible for the control of information sharing, which leads to imbalance power.

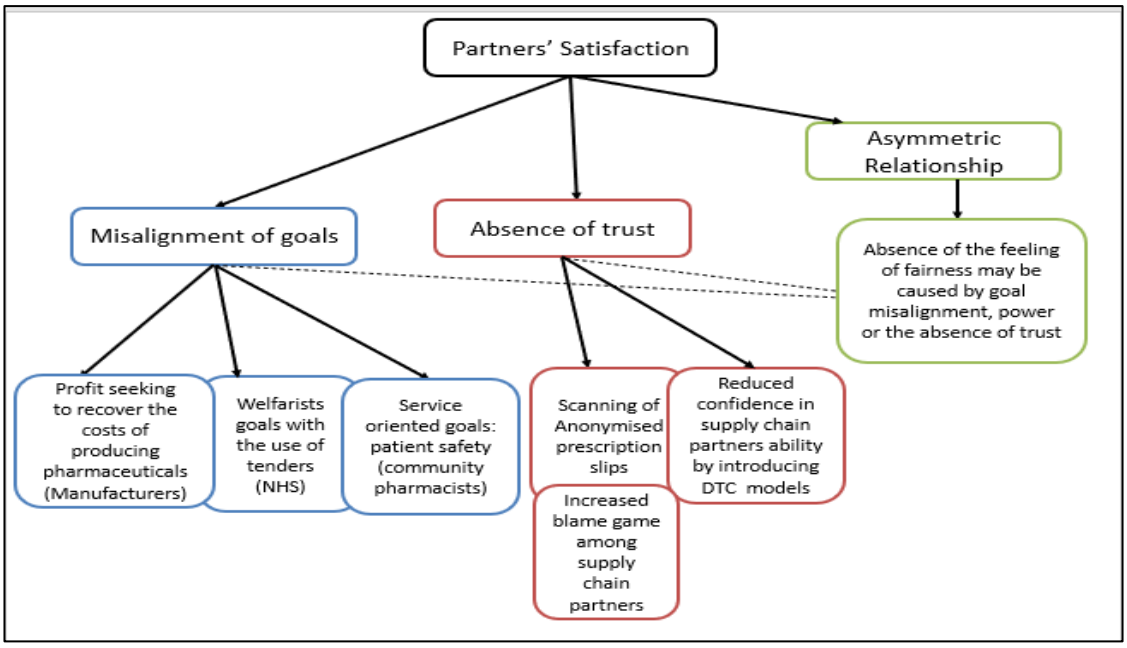

Figure 7.5 Conflict within the PSC
Source: Researcher's Own (2019)

Figure 7.5 above provides a summary of the presence of conflict in the PSC through partners' satisfaction. The summary indicates that partners' level of satisfaction emanated from the level of asymmetric relationship in the supply chain, conflicting goals and the absence of trust. Thus, when supply chain partners had different goals and/or developed business strategies to achieve their individual goals, it decreased the level of partners' satisfaction. The exertion of these business practices on supply chain actors reduced the feeling of fairness among supply chain actors which increased the level of conflict.

These findings follow the argument by Benton and Maloni (2005), who investigated how power-driven relationships affect partners' satisfaction and conclude that power must be included in understanding supply chain partnerships. The findings from the survey, however, revealed that only primary care and regulatory respondents indicated the feeling of dissatisfaction. The possible explanation for this may be ascribed to the exertion of power on primary care respondents using the quota system by manufacturers.

7.2.3.3. Complexity

As presented in the findings' chapters of this thesis, complexity was as a vulnerability driver in the PSC. Complexity aligns with other researchers that have highlighted complexity as a key impediment to the operational and

financial performance as well as precipitating disruptions in supply chains (Craighead et al. 2007; Bode and Wagner, 2015).

Four significant drivers of complexity that increased vulnerability within the PSC were identified, these included: - regulations, economic /political factors, products factors, and production process factors. These complexity drivers differed slightly from the identified drivers of complexity within extant literature (see Cheng et al. 2014; Bode and Wagner, 2015; Vogel and Lasch, 2018). However, the findings indicated that these drivers were pertinent to increasing complexity within the PSC and thus increased vulnerabilities.

The findings revealed that regulatory activities, although inevitable, were quite cumbersome and increased vulnerability in the PSC. These regulatory activities included pricing reimbursement mechanisms, constant change in the regulatory framework as well as the processes involved in handling the storage and distribution of pharmaceutical products. For instance, a primary care respondent (GP) described the process of reimbursement to involve a back-log order where the pharmacists had to dispense the drugs before being paid. Prices were not certain, and as such, supply chain actors had to juggle decisions between meeting the criticality of patients demand as well as ensuring operational continuity of the firm. This also inhibited flexibility as some pharmacists chose to stock their pharmacies with essential products or what they termed as ‘fast liners’ (items considered as fast-moving goods) and as such, may intensify the impact of disruptive activities.

Also, frequent changes in regulations were detrimental to supply chain operations and patient care. An example is the recent Falsified Medicines Directives (FMD) on regulating counterfeit medicines which took effect on the 9th February 2019 (PSNC, 2019). Here all supply chain actors were required to register all pharmaceutical products to a centralised European database using a batch code. Thus, a unique identifier on medicine packages is compulsory to ensure that these identifiers are decommissioned when the medication is handed to the patient (Ogden, 2019). While this regulation is essential in reducing the incidence of counterfeiting within the Eurozone, it is cost-intensive, increases complexity and creates duplication of efforts (Borup et al. 2019).

These complexities thus made it difficult for supply chain actors to pre-plan in the face of disruption as the implementation process added an additional layer to the decision-making process of the supply chain actors. This is in line with the study by Huq et al. (2019) who pointed out that implementation of the FMD required a greater level of planning, organisation, technical support, and training if the decommissioning of the medicines were to be successful.

According to the findings in this study, economic and/ or political factors such as globalisation, mergers and acquisition, BREXIT and inflation increased the level of complexity. Economic and/or political uncertainties were quite uncertain and random. For instance, the uncertainty around BREXIT (which was quite high during the data collection process) increased the level of complexity as it largely influenced the decision-making process of the supply chain actors. The randomness associated with this political uncertainty is that three years before this study, BREXIT was not an issue. Thus, the decisions supply chain actors had to make in the event of a disruption before BREXIT differed significantly. However, BREXIT is going to have a profound impact on trade agreements with regards to pharmaceutical products. The geopolitics behind BREXIT may alter trading agreements like parallel trade, the redesign of the PSC and raise awareness of the vulnerabilities (Breen and Yaroson, 2018).

The findings indicated that globalisation increased complexity in the supply chain. As pointed out by a manufacturer, globalisation occurred because of the increase in demand for cheaper products by other supply chain actors and the need for manufactures to reduce costs of production. Although globalisation is cost-effective (Jüttner and Maklan, 2011), it, however, reduced visibility between manufacturers and their various manufacturing plants. Reduced visibility increased uncertainties and created communication gaps between supply chain actors. Thus, when there were incidences of impending disruption, it was difficult to communicate quickly. The findings from the survey, however, indicated that secondary care and primary care respondents did not identify globalisation as an issue within the supply chain. It could be that primary care and secondary respondents do not engage in the manufacturing of pharmaceutical products.

Research respondents in this study explained that the length of time required to produce a pharmaceutical product was complicated as it required a series of production phases coupled with meeting underlying regulations. For instance, research respondents explained that because of the nature and the time required for the manufacturing of pharmaceutical products, it was challenging to meet sudden increases in demand. Therefore, when disruptions occurred, the decision-making process was cumbersome. Existing studies suggest that production complexity can be mitigated by standardising the products, shipments methods and/or by collaborating with supply chain partners (Serdarasan, 2013; Bode and Wagner, 2015). This may not be the case for the PSC as specifications for production are heavily regulated and follow stringent guidelines. This highlights the non-linearity of the decision-making process in the PSC.

7.2.3.4. Summary

From the analysis of the qualitative and quantitative data, it was established that several vulnerabilities exist within the PSC in the UK context. These vulnerabilities cause considerable operational problems, thus, preventing an effective and efficient PSC. As presented in Figure 7.1, there are several emerging issues which are closely linked to three primary themes: i) power; ii) conflict and, iii) complexity.

Also, by discussing vulnerabilities, it is apparent that there is a multi-dimensional link between some of the factors and themes. For instance, the display of power may emerge as a result of behavioural uncertainty and reputation. However, the display of power may be as a result of the absence of trust, which increased supply chain conflict. The discussion also identified that some of the underlying drivers of vulnerabilities in the PSC stemmed from the decisions of supply chain actors had taken in trying to build resilience or protect revenue stream. These decisions were also influenced mainly by the characteristics of the PSC. This further highlight that the decision-making process in responding to disruptions is complex where the outcomes are uncertain.

Table 7.1 below presents a summary of what is known about supply chain vulnerability from existing literature and how this study adds to current knowledge but also differs in certain aspects. The table shows that this study extends knowledge about supply chain vulnerability in several ways. For instance, the presence of power has not hitherto been identified as a driver of vulnerability within PSC. Also, the identified vulnerabilities of the PSC transcend its macro-economic environment (see Peck, 2005; Wagner and Bode, 2006) to include conflict and power dynamic. The study identified vulnerability as weaknesses in the PSC and not risks as some existing studies have suggested. Given the preceding, the next section discusses the antecedents of resilience strategies as outcomes of the decision-making process in the PSC.

Table 7.1 Supply chain vulnerabilities: comparison of existing literature and findings in this thesis

Supply chain vulnerability literature		Findings from this research
Prior empirical research	**Drivers of supply chain vulnerability**	
Peck (2005) Wagner and Bode (2006) Craighead et al. (2007) Konig and Spinler (2016)	The emphasis here is that macro-economic factors such as regulations and the political environment increase vulnerability in the supply chain.	This study findings show that vulnerability drivers transcend beyond macro-economic factors to include power dynamics and conflict.
Wagner and Bode (2006) Craighead et al. (2007) Wagner et al. (2014) Konig and Spinler (2016)	The studies here identify supply chain characteristics, customer and supplier dependence.	This study finds that inherent supply chain characteristics influence the decision-making process in the PSC.
Stecke and Kumar (2009) Vlajic et al. (2013) Chowdhury and Quaddas (2017) Ruel at al. (2019)	Supply chain complexity is identified as the major vulnerability driver.	Various forms of complexity have been identified as vulnerability drivers in the PSC. These complexities can either be internal or external.
Peck (2005) Wagner and Bode (2006) Wagner and Neshat (2010)	Outsourcing	Outsourcing was identified as a vulnerability driver that increased complexity in PSC.
Juttner and Maklan (2011) Ambulkar et al. (2015)	Emphasis is on resilience strategies as strategies in mitigating vulnerability.	This study shows that vulnerability and resilience strategies are as a result of the interactions between supply chain actors in response to changes in their external environment.

Source: Researcher's compilation (2019)

7.2.4. Supply Chain Resilience as an Outcome of the Decision-making Process

Recovery and resistance strategies were the major mechanisms that enhanced resilience in the PSC according to the findings in this study. This is

in consonance with some existing literature (e.g. Blackhurst et al. 2011; Scholten et al. 2019).

7.2.4.1. Recovery Strategies

Recovery strategies included engaging in activities that helped the supply chain recover from a disruption, minimizing the impact on patients' safety and ensuring continuity of operations. Flexibility, visibility and joint decision were the elements of recovery strategies employed in building resilience in the PSC. Hence, to achieve flexibility in the PSC, supplier flexibility as well as the use of closely related products in the right dosage, volume or form was employed to ensure operations and patient care continued.

According to the findings, supplier flexibility was usually used by manufacturers and/ or wholesaler. Closely related products in the right dosage, volume or form were employed by patient-facing supply chain actors to enable them to respond quickly to patients' demands. For instance, primary care and secondary care respondents indicated that they preferred this form of flexibility strategy rather than sourcing alternative suppliers by engaging the services of short liners. Short liners are specialist wholesalers with limited stock often scattered across the country. Their products tend to be more costly, and the process of reimbursement cumbersome. This supports the assertion by (Tukamuhabwa et al. 2015) who suggested that for a strategy to be classified as resilient, it had to be cost-effective.

Manufacturers and wholesalers, on the other hand, supported access to alternative partners as their form of flexibility strategy as they had built this into their supply chain design. However, flexibility as a strategy was used after the disruption had occurred. This type of flexibility, however, differed at various levels of the PSC. It may imply that flexibility may be a temporary departure from practice as a short-term solution and may not be sustainable, as argued by Fayezi et al. (2017).

Supply chain visibility also referred to as the ability to get access to viable (timely, accurate and purposeful) information, which provides a reliable

description of the ability of supply to meet demand (Wei and Wang, 2010). For supply chain actors in this study, the timing of the information shared, and the quality of information was pertinent in planning against a disruption. The quality of information was measured the disruption causes, length of time the disruption was expected to last and the information regarding the use of alternatives and or substitutes. This follows the findings by Brandon-Jones et al. (2014) and Scholten and Schilder, (2015).

However, the reaction of stakeholders to information shared on impending supply chain disruptions also restricted the type of information shared. This could result in a potential barrier to making information visible, as vulnerable firms may regard the release of information as a threat to their survival (Jüttner and Maklan, 2011). The findings also suggested that sharing of information triggered panic buying, leading to further disruptions. This argument thus provides possible explanations for the reluctance of supply chain partners to share information regarding disruptive activities.

Based on the findings from the qualitative and quantitative phases of this study, joint decision making also contributed to building resilience in the PSC by restricting the negative impact on patients' treatment continuity as well as maintaining operations. On the matter of maintaining operations, a research respondent from the interviews explained that joint planning involved various meetings to inform supply chain actors about the disruption and its duration. Supply chain actors jointly decided the best possible course of action and ensured these were carried out to prevent operational and financial losses as well as the potential death of patients.

The courses of action, for instance, involved the regulatory bodies acting as intermediaries with competitors to see if they could ramp up production and/or move products to areas of scarcity. The Commercial Medicines Unit (CMU) and the Department of Health and Social Care (DHSC) had conversations with secondary care pharmacists to determine how to recover from the disruption. This was to be achieved either through sourcing for product alternatives, rationing, importing from abroad or manufacturing within the NHS production

plant. This finding was confirmed by the data analysis from the survey, which indicated that 60% of the respondents thought that jointly deciding on strategies to mitigate the impact of disruption enhanced supply chain resilience.

Joint decision making, however, occurred after the distribution, thus helped in responding to the disruption. In the PSC, the findings indicated that the success of the joint decision-making process stemmed from relationships that had been built among supply chain actors over the years as asserted by Li et al. (2015). This implies that external relationships have to be established if supply chain partners are to agree on mutually defined goals, reduce operating costs and encourage better use of resources. The joint decision-making strategy adopted by actors in the PSC was, however, a recovery mechanism which differed from existing literature where coordination of decisions is a proactive, collaborative process (Scholten et al. 2019).

7.2.4.2. Resistance Strategies

Resistance strategies were identified as mechanisms which provided supply chain actors with the capacity to prepare for disruption. The findings showed that the resistance strategies which increased the ability of supply chain actors to plan for disruption were achieved through resource sharing particularly by forming strategic alliances, sharing of infrastructure as well as stockpiling and or holding buffer stock with supply chain partners.

The data analysis of interviews and questionnaires showed that through the sharing of resources with supply chain partners, the PSC actors were able to plan and prepare for disruptions. This sharing of resources was only feasible when strategic alliances had been formed. Thus, a strategic alliance was a “purposive relationship” between supply chain actors to facilitate the exchange and sharing of resources or capabilities for mutual benefits (Kale and Singh, 2009; Sambasivan and Yen, 2010). By forming strategic alliances with supply chain partners, actors were able to share timely information, infrastructure and technology. As such, supply chain actors were able to pre-plan for disruption and curtail its impact. A community pharmacist that engaged in strategic

alliance practices explained that their suppliers usually provided up to date information about pending disruptions as well as provision of the infrastructure to stockpile. This strategy is in contrast with the 'just in time' practices that are in existence with independent supply chain actors. This was further confirmed at the quantitative phase of the study where the analysis indicated that all the respondents (100% of the 106) agreed that sharing of resources was critical to building supply resilience.

Strategic alliance in the PSC was successful among supply chain partners who had closely linked goals, and it involved independent tasks from each supply chain actor. In this arrangement, manufacturers formed strategic alliances with wholesalers as well as community pharmacists in the supply chain, where the wholesalers engaged in the warehousing and transportation of the manufacturer's products and the pharmacists aided in the distribution of manufacturers' products at the community level. Strategic alliance here increased visibility, information sharing and facilitated decision making. Therefore, in the event of a disruption, supply chain actors were able to mitigate the impact of disruption as they had developed resilience by forming a strategic alliance as explained by (Minerbo et al. 2018).

Strategic alliances, thus, reduced the incidences of power, as issues like reputation, behavioural uncertainty, price manipulation, and quota system were less likely to occur. For instance, by forming a strategic alliance, supply chain partners may have also agreed to jointly plan as to how to handle risks when they occurred and as such manufacturers may not be wary of their reputation or unsure of how their supply chain partners will act when information is shared. Also sharing of information technology such as platforms for product stock and pricing increases transparency and reduces the ability to manipulate prices (Wang et al. 2014; Cao et al. 2015). As Ambrose et al. (2010) also asserted, when the duration and intensity of interactions between supply chain partners increases, their bonds of attraction develop into established relationships that breed trust, causing positive behavioural expectations about the relationship.

Based on the findings in this thesis; therefore, recovery and resistance strategies were the two types of resilience strategies that supply chain actors had adopted in mitigating the impact of medicine shortages. Flexibility, visibility and joint decision were the elements of recovery strategies employed in building resilience in the PSC. However, due to some of the underlying characteristics of the PSC, these strategies may be temporary activities to ensure continuity of operations.

The discussions also showed that to build resistance mechanisms as resilience strategies in the PSC, supply chain actors had engaged in some form of strategic alliance. These strategic alliances also helped in reducing the PSC's susceptibility to the impact of disruption. Strategic alliance was identified to reduce incidences related to trust, facilitate information sharing, which ultimately enhanced visibility. However, due to the characteristics of the PSC, the role of strategic alliance in building resilience may be limited. These findings thus imply interrelationship between some of the elements of PSC resilience which highlights the ripple effects of supply chain actors' decisions. The next section, therefore, discusses the links between elements of PSC resilience, based on the findings and built on the discussion in this Chapter.

7.2.5. Relationships between Vulnerability Drivers and Resilience Strategies

Based on the discussions above and the quantitative phase findings, there is clear evidence of relationships between various elements of resilience in the PSC. Some of these relationships will be discussed in the following sections. Figure 7.6 provides a graphical representation of the relationships between the identified resilience strategies and vulnerabilities drivers in this study. The figure shows that the antecedents of resilience strategies had an impact on vulnerabilities in the PSC. The black arrows and red lines running from resilience strategies to vulnerabilities drivers were used to identify the relationships between the elements. The red and dashed lines denote a positive relationship between resilience strategies and vulnerability drivers signifying an increase. This indicates that recovery strategies increased the level of power, conflict and complexity as vulnerability drivers in the PSC. Also,

resistance strategies increased the level of complexity in the PSC. The black arrows show that resistance strategies reduced the level of power and conflict in the PSC.

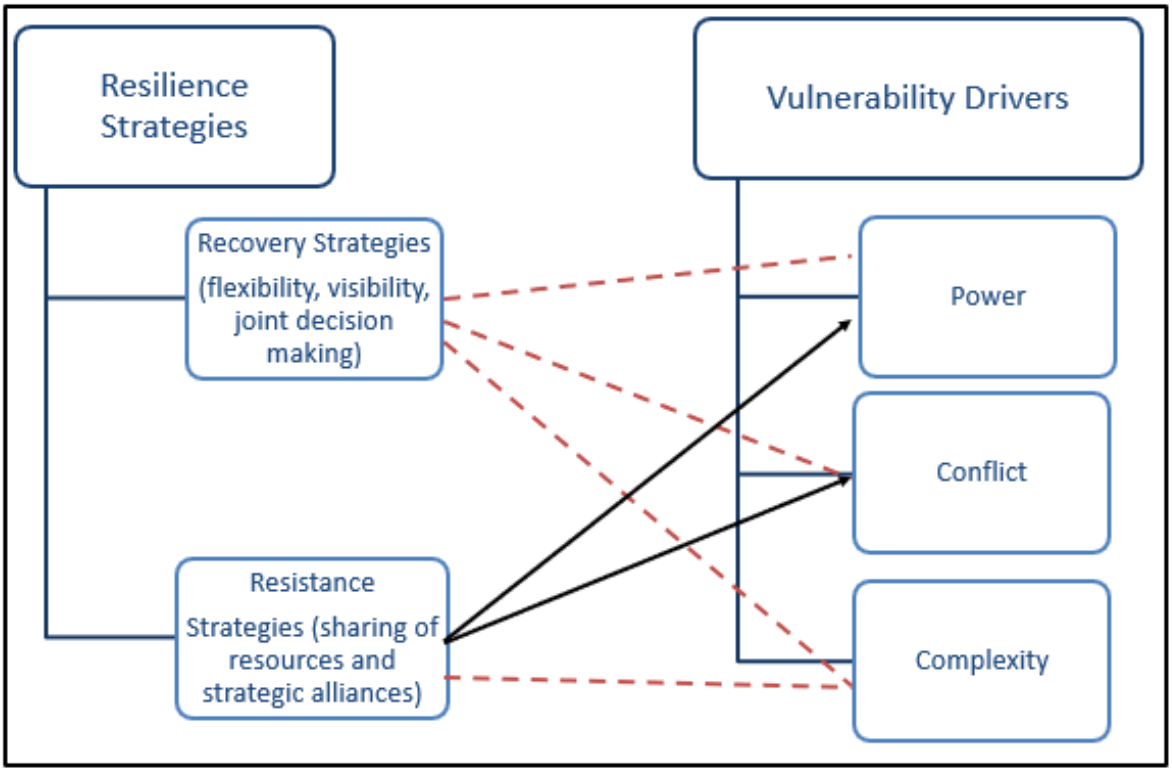

Figure 7.6 Resilience strategies and vulnerability drivers in the PSC
Source: Researcher's Own (2019).

The findings from the SEM, show that power as a vulnerability driver had a positive relationship with recovery strategies with a beta of (β1= 0.190). This infers that the identified recovery strategies in the PSC increased power as a supply chain vulnerability by 19%. Also, the identified recovery strategies increased the level of conflicts and complexity among actors in the PSC at 14% and 47% respectively (refer to Figure 6.2 for the summary). This implies that recovery strategies increased vulnerabilities in the PSC by varying degrees. These findings are in contrast with existing supply chain resilience literature which suggests that by building resilience strategies into the supply chain, the vulnerability will be reduced (Jüttner and Maklan, 2011).

Several plausible explanations for these findings include the forms of flexibility used, the time required in sharing information and the characteristics of the supply chain. For instance, according to the data analysed, the most common type of flexibility was the form or volume of the medicine. This involved the use of an alternative formulation or alternative strength or a generic equivalent or a therapeutic equivalent. There are however several implications for this, which include:- increased costs, which may emanate from time spent in sourcing for the new medicine (Fox et al. 2014); the cost of the new medication (Bodie et al. 2018), medication errors, additional workload for supply chain actors as well as lack of focus on core supply chain activities. This implies that although flexibility can mitigate the impact of disruption, it may not be sufficient to reduce the underlying vulnerabilities in the PSC.

Another probable explanation could be the length of time required in passing information to the relevant stakeholders, as well as dissemination of actions to curb the disruption. Take, for instance, the case of the Serious Shortages Protocol (SSP) (PSNC, 2019). The SSP facilitates joint decision making and aids in curbing the impact of medicine shortages. The process of SSP is, however, cumbersome as the inputs required from several supply chain partners (doctors, pharmacists, relevant patient groups, the devolved administrations, NHS England manufacturers relevant pharmacy organisations including PSNC) may be time-consuming. Thus, before a decision is reached as to how to handle a shortage jointly, there may have been whispers of the impending shortage. These whispers may lead to panic buying by some supply chain actors, which may result in supply chain actors imposing quotas if they notice a spike in demand. To build resilience into the PSC, therefore, decision making must be carried out on time (Ponomarov and Holcomb, 2009; Tukamuhabwa et al. 2017; Hendry et al. 2019).

The characteristics of the PSC may provide another possible explanation as to why recovery strategies could mitigate the impact of disruption but not reduce supply chain vulnerabilities**.** For instance, in the event of a disruption, it is plausible that the alternative manufacturer will react in the same way as the original manufacturer by employing quotas when they notice a spike in

demand for their product. This is because manufacturers do not communicate with each other about issues they may be experiencing in the PSC. These activities thus increased the level control and could result in a conflict which may increase the level of vulnerability within the supply chain. Also, supply chains are designed with efficiency in mind rather than flexibility; their ability to adapt to changes in the environment is limited to dynamic flexibility (Christopher and Holweg, 2011).

The findings in this thesis also showed that resistance mechanisms reduced the level of vulnerability within the PSC. For instance, the SEM showed that when resistance strategies increased by 1%, the level of power in the supply chain decreased by 0.4% (β=0.004). This suggests that sharing of resources (information, infrastructure, and technology) amongst partners through forming strategic alliances in the supply chain increased the capacity of the PSC to mitigate the impact of disruption as well as reduce underlying vulnerabilities. Thus, strategic alliances, formed from long-standing relationships among supply chain partners, increased trust, alignment of goals and satisfaction with partners. These findings, thus, confirm the assertions in the literature that resilience strategies, mitigate the impact of disruption by reducing the vulnerabilities in the supply chain (Blackhurst et al. 2011; Tukamuhabwa et al. 2015; Li et al. 2017).

The analysis from the qualitative data suggested that sharing of resources among supply chain partners occurred, especially when these partners had some form of strategic alliances. This denotes that supply chain actors increase information and product flow in the event of a disruption with actors they have some form of alliance and/or partnership agreement with and where they have agreed to share risk and resources. This

aligns with Min (2015), who explained that strategic alliance is based on joint decisions to achieve agreed goals of aligned companies that share resources, information, profits, knowledge, and risks. The theory of opportunism posits that as a result of dysfunctional activities within a supply chain, supply chain partners may engage in forms of integration to mitigate the impact of

opportunistic behaviours. As such, firms may integrate their operations with carefully selected supply chain partners for effective monitoring (Anan et al. 2016).

There was also a positive relationship between resistance strategies and complexities based on the findings from the quantitative data analysis. As such, increased resistance strategies increased external complexity (with issues like economic, political factors and regulations as external complexities). As discussed in section 7.2.3.3 of this Chapter, the root causes of external complexities vary, which further complicates the decision-making process in the PSC. For instance, in the case of BREXIT, supply chain actors had jointly agreed to increase the level of stock (stockpiling) against the uncertainties of the political situation. The above example implied that manufacturers had to increase the production of pharmaceuticals which had its complexities.

However, as a result of the nature of pharmaceutical products, stockpiling may not be the right strategy to deal with political uncertainty. As Teimoury et al. (2010) pointed out, lack of understanding of risks by supply chain partners results in alliances failing. Thus, for resistance strategies to have the capacity to reduce external complexities in the PSC, they must be more dynamic, forward-thinking and proactive.

The discussions so far on vulnerabilities and resilience strategies in the PSC have identified interrelatedness among elements of PSC resilience. Hence, PSC resilience can be understood by examining systemically, the decisions, actions and interactions of supply chain actors. For instance, although the display of power emerged as a result of revenue flow, behavioural uncertainty and reputation may have also propelled it. Another underlying issue was as a result of the absence of trust, which inadvertently increased supply chain conflict.

Although the issue of tenders has been addressed earlier as a source of conflict through misalignment of supply chain partners goals, its impact on the supply chain is no less corrosive (Gloor et al. 2013). The tender system adds another level of complexity to the supply chain due to the rapid change in

suppliers. This rapid succession makes business continuity difficult, unattractive to some supply chain partners and weakens the supply chain. For instance, one of the regulators explained that there are four regional procurement offices in the UK, and the tendering process for drugs is carried out almost annually.

Figure 7.7 below provides a pictorial representation of the interconnections and interactions of PSC actors in responding to disruptions in the PSC. By following the arrows in the figure, shows that almost every decision made by a supply chain actor when interacting with other actors in the PSC had a ripple effect or the outcome was mostly unknown. This further argues the need for systemic thinking about PSC resilience as understanding the actions and interactions of supply chain actors can only be achieved on a systemic level. The next section, therefore, uses CAS as a framework to explore PSC resilience on a systemic level based on the underlying interrelatedness discussed in the sections above.

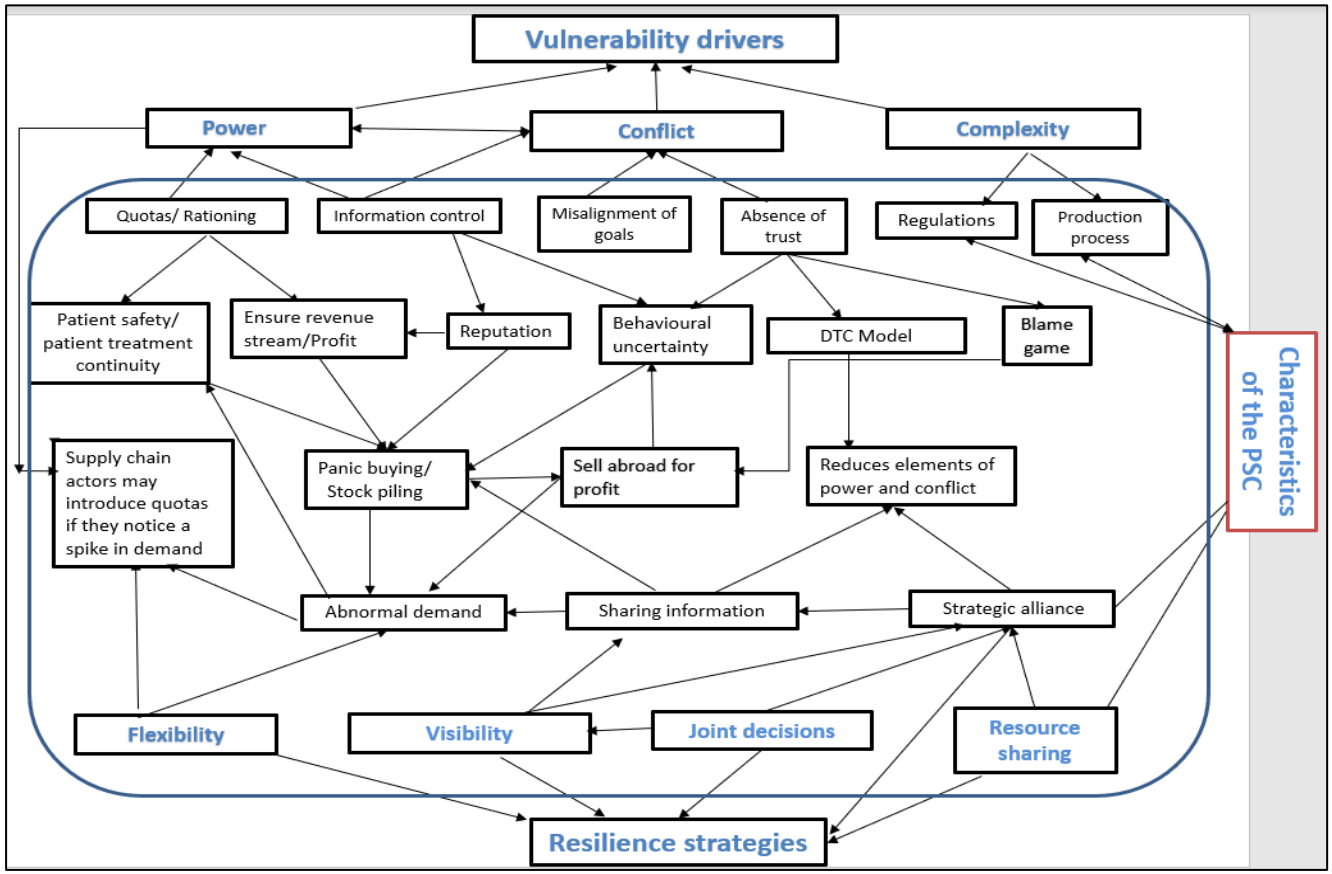

Figure 7. 7 Interrelatedness of resilience strategies and vulnerability drivers in the PSC
Source; Researcher's Own (2019

7.3. PSC Resilience as a CAS

The CAS theory advocates for a systemic view to understanding PSC resilience, and this involves the interrelationships among disruptions, characteristics of the PSC, vulnerabilities and resilience strategies. These interrelationships have been identified from the data and discussions presented in the sections preceding this. The findings have shown clear evidence to suggest that the development of PSC resilience can be explained more effectively through the adoption of CAS theory and its key components: internal, external and co-evolution. PSC characteristics, vulnerabilities and resilience strategies are all interconnected in the building of resilience in the PSC. In this section, the CAS theory is used as a framework to show the interactions between supply chain actors and how supply chain resilience is built on a systemic level.

First, the findings depict that the PSC is an open system that interacts with its environment and these interactions influence the ability of the PSC to develop resilience strategies as argued by Nair and Reed-Tsochas (2019). For instance, when a disruption occurs (such as medicine shortages), the manufacturer responds to this disruption by sharing the information with other supply chain actors on time. The sharing of information provides supply chain actors, the ability to plan and prepare for the disruption and as such, makes the PSC more resilient to the impact of disruption (Tukamuhabwa et al. 2015). However, controlling of information to supply chain actors about a disruption, inhibits the building of resilience strategies and hence make the PSC vulnerable to the impact of disruptions.

Further, the findings showed that the internal system of PSC resilience consists of agents (manufacturers, distributors, secondary and primary care pharmacists), regulations as schemas and adaptability. Agents (supply chain actors) are at the core of PSC resilience. They are responsible for the decision-making process regarding responses to disruptions as well as actions to achieve organisational goals. The decision-making process of the CAS is

primarily influenced by its environment and determines the interactions that occur between the agents based on the nature of the supply chain (Nair and Reed Tsochas, 2019).

Also, in responding to other economic factors in the external environment, like parallel trade, some wholesalers and pharmacists decided to sell abroad for profit, especially when the exchange rates were favourable. The decision to sell abroad for profit was a response by supply chain actors to the external environment of the CAS. The issue with trading abroad for profit is that it makes the PSC susceptible to the impact of disruption as there may be no buffer stock available in the event of a disruption.

Similarly, manufacturers indirectly responded to parallel trading activities induced by favourable economic activities by imposing quotas. Although the decision to impose quotas or ration products was to build resilience as well as to ensure revenue flow, these indirect responses increased the vulnerability of the PSC to the impact of disruption. This may suggest that the interrelatedness of the decision-making process by supply chain actors in responding to the environment either builds resilience strategies or increases supply chain vulnerability. This interrelatedness also depicts systemic behaviour. Thus, a given single decision made by supply chain actors produced a new behaviour.

The results also reflected that supply chain actors acted independently and were guided by internalised primary goals as explained by Nair and Reed-Tsochas, (2019). Participants in our study indicated that they had diverse goals. The purpose of the NHS as a supply chain actor was to provide quality medicines at the lowest possible cost. The community pharmacists indicated that their goal was service-oriented; seeking patient safety, and the manufacturers identified making a profit as their internalised goals—these internalised goals provided supply chain actors with reference points for their behaviour. For instance, the findings showed that since the goal of the manufacturer was to make a profit, their inability to compete favourably for tenders by the NHS forced them to seek profits in other markets and increased vulnerabilities in the PSC. When their goals were strategically aligned, as seen

in the case of a strategic alliance among supply chain actors, they developed resilience to disruptions.

However, because internal goals guide supply chain actors, their interactions produce non-linear dynamics as in a CAS system (Choi et al. 2001; Holland, 2006). In this thesis, conflict was identified as an example of non-linear interaction. Manufacturers indicated that they were uncertain about what other supply chain actors did with their products and as such decided to introduce the quota system to guarantee the continuity of revenue stream. The pharmacists explained that they wanted to ensure patients continued their treatment and as such stockpiled products. The outcome of these interactions produced elements of conflicts such as the absence of trust and asymmetric relationships which made the PSC vulnerable to the impact of disruptions.

Furthermore, the findings demonstrated increased anticipations by supply chain actors. Holland (2006), described anticipation as rules that have been developed when a system is seeking to adapt to the changing circumstances in the environment. For instance, the introduction of the Serious Shortage Protocol (SSP) (PSNC, 2019) as a strategy developed to manage medicine shortage as a disruption in the PSNC. The SSP depicts learning as well as anticipation by supply chain actors' regulatory bodies in the UK have learnt from past disruptive events and are anticipating future and have developed strategies.

The interactions of actors in the supply chain also increased complexities. These interactions were essential in achieving the goal of the supply chain. Take, for instance, a logistic service provider explained that decisions made by pharmacists who may be more patient-centric than other supply chain actors had an impact on the way the wholesaler chose to distribute their products as well as how manufacturers choose to manufacturer their products. The findings revealed that as a result of the regulations that existed within the PSC as well as the criticality of patients care, when supply chain disruptions occurred as an environmental factor, supply chain actors would take decisions independently that were in the best interest of the patients. These interactions

thus created complexities which may have increased vulnerabilities in the PSC.

Interactions between supply chain actors also produced new behaviours. These new behaviours emanated from past interactions between supply chain actors. The findings show that as a result of manufacturers sharing information about a disruption, which led to stockpiling, thus creating false demand, manufacturers decided to display power. Supply chain actors learnt from these actions and made new decisions when disruptions occur, which cause the supply chain to evolve. For instance, supply chain actors' decision to jointly share resources, which increased visibility and flexibility depicts strategic alliances are formed as a new behaviour.

The findings also depicted that learned behaviours in the PSC led to the elimination of supply chain actors. For instance, the NHS procurement practices in awarding tenders sought the lowest price irrespective of who could supply products. As a result, manufacturers who were unable to compete favourably either exited the market or ceased production. A manufacturer thus explained that rather than bidding for tenders, they decided to seek better market opportunities abroad. The decision of some supply chain actors to find alternative markets as a result of the NHS procurement practices identified the interrelatedness of supply chain actors' decision-making process. It also eliminated some supply chain actors, led to the emergence of new actors as well as making the PSC vulnerable to the impact of disruption.

The outcome of the decisions by supply chain actors as well as their interactions in responding to the external environment either builds resilience strategies or increases vulnerabilities. In a CAS system, these outcomes are referred to as coevolution (Choi et al. 2001; Holland 2006). Thus, the feedback to the external environment may be either resilience or vulnerability to the impact of disruptions. The changes made by supply chain actors in responding to the environment caused further changes to the environment, thereby causing the supply chain actors as well as the environment to coevolve.

Thus, using CAS theory as a framework depicts that building resilience in the PSC is determined by how supply chain actors interact with each other in response to the external environment. These interactions are often depicted by the decisions supply chain actors make and, how they respond to the decisions by other actors in the PSC. Thus, the decisions, actions and interactions of supply chain actors cause the PSC to change its form, to become either resilient or vulnerable to the impact of a disruption. This suggests that decisions by a supply chain actor to build resilience in the PSC may result in the whole supply chain being vulnerable to the impact of disruption.

Figure 7.8 below shows PSC resilience as a CAS. The internal environment is where the decision-making processes and interactions among supply chain actors occur. The figure also shows the response of supply chain actors to medicine shortages as a disruption, and this is from the external environment. The underlying processes involved in developing resilience in the PSC stem from supply chain actors' interactions with each other given underlying PSC characteristics in responding to their environment. The outcomes of these interactions either build resilience into the PSC or increase supply chain vulnerability.

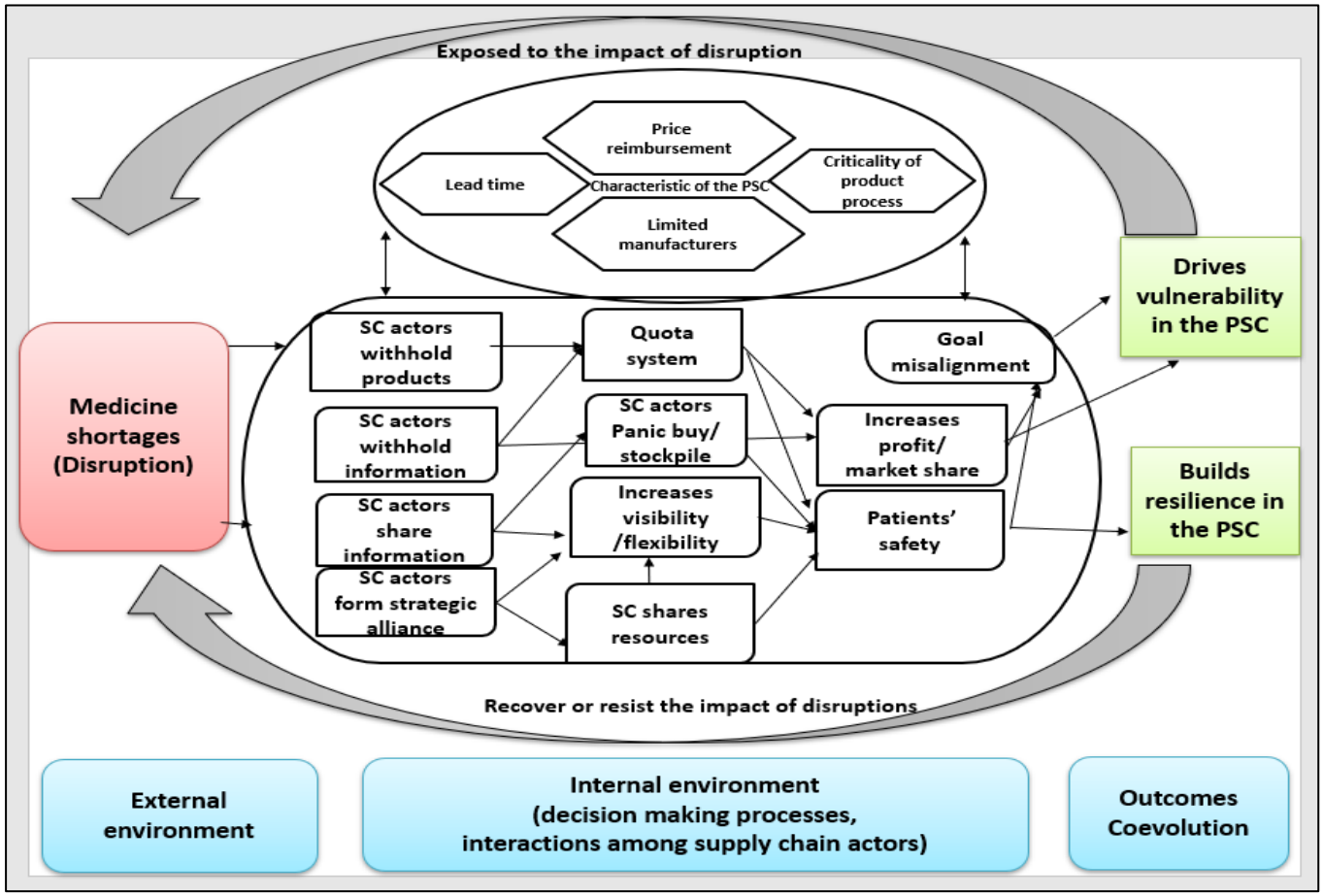

Figure 7. 8 PSC Resilience as a CAS through its decision-making process
Source: Researcher 's Own (2019)

7.4. PSC Resilience Framework (PSCRF)

The PSC Resilience Framework (PSCRF) presented here, has been generated from the findings of the mixed-method approach employed in this study and the discussion in this chapter. This framework identified the characteristics of the PSC as well as factors that either increase vulnerabilities or resilience. Figure 7.9 below, thus, represents the changes, adaptability and evolving dynamics of vulnerabilities and resilience strategies within the PSC which is closely linked to this study's contribution to knowledge. The centre of the diagram depicts that the PSC consists of several supply chain actors which include manufacturers, wholesalers, secondary care and primary care agents as well as regulatory bodies. The PSC is characterised by product criticality, which impacts on patients' safety, lead times and the number of manufacturers.

On the right-hand side of the diagram, are the vulnerability drivers of the PSC and the factors that propel these vulnerabilities. The resilience strategies and the factors that drive resilience within the PSC are on the left. The factors that lead to vulnerabilities and resilience strategies, as indicated in the diagram, are dynamic and change depending on the circumstances. This implies that the outcomes vary, but their severity and how they manifest themselves will always change based on the level/nature of disruption and how impactful it is on the organisation/SC (based on their level of resilience/vulnerability). The feedback loop from the centre towards antecedents of resilience strategies and vulnerabilities drivers indicates that these outcomes exist as a result of the characteristics of the PSC. The intersection of the consequences implies that although the drivers are independent, there is a degree of interaction between them.

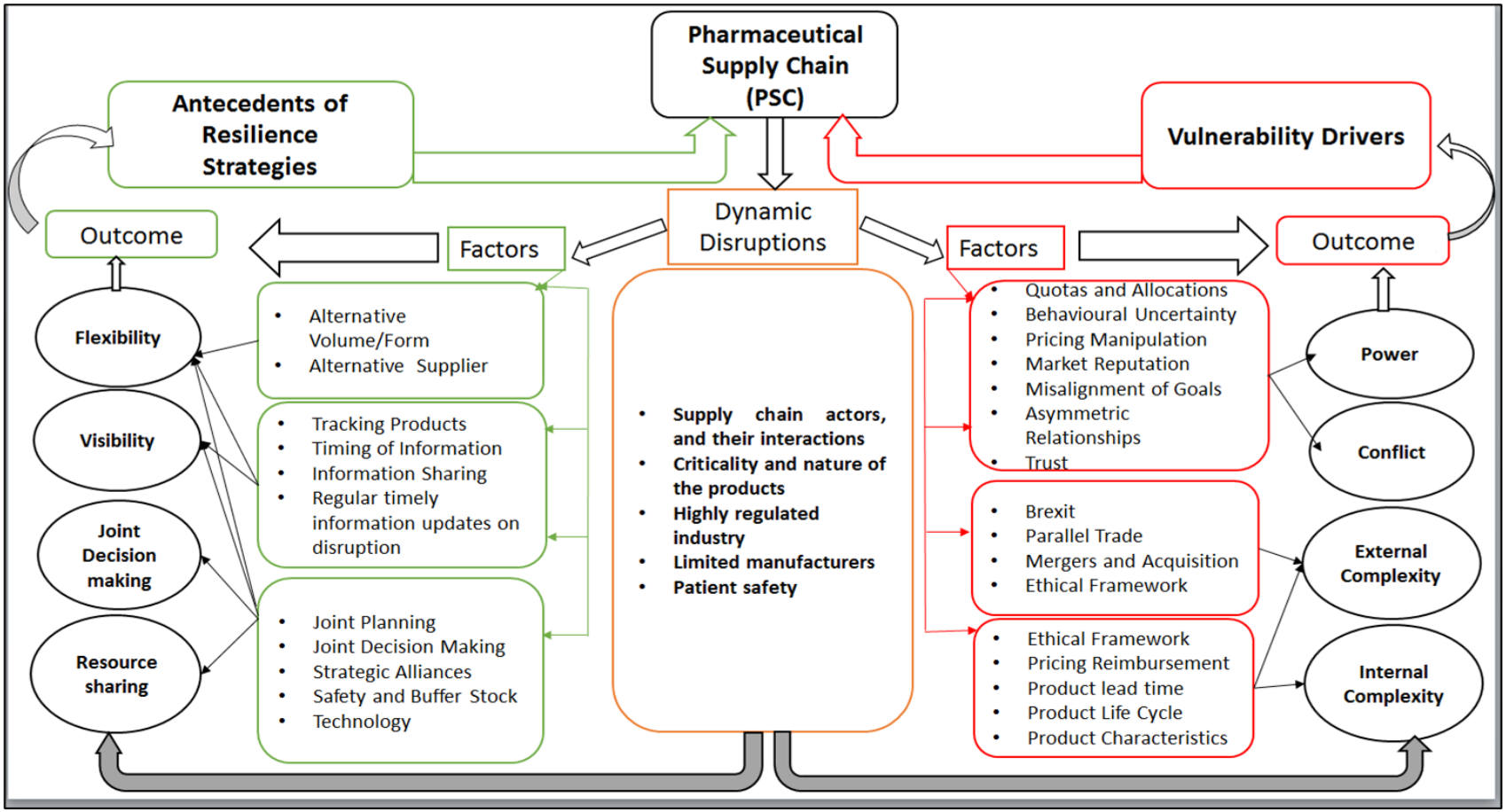

Figure 7. 9 A Framework of PSC Resilience
Source: Researcher ‘s Own (2019)

7.5. Summary

In this chapter, the research findings were discussed in line with reviewed literature for the phenomenon under investigation. More specifically, the analysis was based on the findings from the qualitative and quantitative data. The aim was to ascertain and examine the concepts of resilience strategy in the PSC in the UK. The discussion focused on key areas: disruptions, characteristics of the pharmaceutical supply chain (PSC), issues of vulnerabilities as well as resilience strategies. CAS theory was then employed as a framework to explore how the elements of resilience in the PSC were developed.

The analysis revealed that vulnerability and resilience strategies were outcomes of the interactions and decision-making processes by supply chain actors in response to disruptions. These interactions thus, suggest system thinking as resilience strategies cannot be developed in parts. CAS as a framework was also used to enhance system thinking and further revealed systemic behaviour where a decision made by a supply chain actor at any level of the supply chain caused emergent behaviour. CAS theory also showed that the relationship between resilience strategies and vulnerabilities in the PSC was non-linear and had a dynamic effect. As such, it was not easy to draw direct conclusions on the relationship between resilience strategies and vulnerabilities in the pharmaceutical supply chain. Thus, the decision of a supply chain actor to build resilience strategies in response to disruption may result in the supply chain being vulnerable to the impact of disruption. These non-linear responses to decisions by PSC actors were influenced mainly by the characteristics of the PSC. These findings differed from existing literature which emphasises an inverse relationship between vulnerability and resilience strategy.

Chapter Eight: Conclusions and Recommendations

8.1. Introduction

This study aimed to explore the vulnerabilities of the PSC as well as its resilience strategies in the face of dynamic disruptions. The motivation for the thesis stemmed from the shortage of empirical studies examining vulnerabilities and resilience strategies, specifically those focusing on the PSC. Studies of PSC resilience have been highlighted as critical as this supply chain can encounter significant disruptions, some of which are not only exclusive but can result in tragic consequences, including fatalities (Merucheck et al. 2011, Stevenson and Busby, 2015).

To achieve the research objectives, therefore, data were gathered through an extensive review of the literature and the use of a mixed-method approach where semi-structured interviews of 23 PSC actors and an online survey of 106 supply chain actors, were employed. The outputs of which are presented as findings in Chapters Five and Six and the discussion of these findings in Chapter Seven. In this chapter of the thesis, therefore, conclusions are drawn on the reality of PSC resilience from a UK perspective. More specifically, the chapter will summarise the thesis findings in light of the research objectives (8.2); answer the research questions (8.3); outline and defend the thesis's original contribution to knowledge (8.4); develop propositions about PSC resilience (8.5); explain the implications and recommendations of the findings to practice (8.6); address in detail the limitations of the study as well as propose areas for further research (8.7); before concluding with the final thesis summary (8.8).

8.2. Summary of Findings

The findings of this thesis emanated from two significant sources: the qualitative and quantitative phase of the data collection.

The goal of the qualitative phase of this study was to explore why the PSC in the UK is susceptible to the impact of dynamic disruptions and the strategies

employed in mitigating the effects of these disruptions. The study identified supply chain power, conflict and complexities as the three major drivers of vulnerabilities in the PSC. The drivers of these vulnerabilities included information, drug and price control, partners' satisfaction, goal misalignment, absence of trust, regulatory, economic, political, product and production issues. These vulnerability drivers were also classified as either internal or external, depending on the nature of their vulnerability. For supply chain resilience, two forms of resilience strategies were identified, namely, recovery and resistance capabilities. The antecedents of resilience strategies included: flexibility, visibility, joint decision making, collaborative practices, such as strategic alliance and resource sharing. These identified themes were used to develop the survey instrument for the quantitative phase of this research.

The goal of the quantitative phase of the study was to confirm the findings of the qualitative phase and to examine the relationship between the identified vulnerabilities and resilience strategies in the PSC. The data were gathered using questionnaires from 106 respondents across the various levels of the PSC. The findings confirmed the existence of supply chain power through information, drug and price control. However, power flows from the upper level of the supply chain- i.e. the manufacturer, to the lower end of the supply chain, i.e. primary and secondary care respondents.

With regards to supply chain conflicts, the quantitative data confirmed the presence of conflicts. The perception of these conflicts, however, differed according to supply chain actors. For instance, while primary care respondents indicated the absence of partner satisfaction among supply chain actors', manufacturers and regulatory bodies indicated they were satisfied. With regards to goal misalignment, the source of conflicts emanated from supply chain actors' decisions on issues about the supply chain and not from the lack of understanding the market demand. The study's data also confirmed the presence of complexity with regards to regulations, political and economic factors as well as production processes. These complexities however affected the supply chain actors differently. Although manufacturers agreed to the presence of all forms of complexity, secondary care respondents failed to

acknowledge that production processes increased their susceptibility to disruptions.

Based on the identified findings, the next section, answers the research questions as originally posed in section 1.4 of this study.

8.3. Addressing the Main Research Questions

The three research questions posed in this study will be addressed subsequently in this section.

RQ1: *Why is the PSC in the UK susceptible to dynamic disruptions*?

This research sought out to understand why the PSC in the UK was susceptible to the impact of dynamic disruptions. This research question was developed following the identified research gap in the existing literature on studies focusing on supply chain vulnerabilities with a PSC context (see Peck 2005; Craighead et al. 2007; Jüttner and Maklan, 2011). The findings from the data analysis as presented in Chapters Five and Six suggest that the PSC is susceptible to the impact of dynamic disruptions as a result of underlying vulnerabilities drivers which include: - i) power; ii) conflict and: - iii) complexity. The existence of these vulnerability drivers, thus, increases operational inefficiencies and as such, makes the PSC susceptible to the impact of dynamic disruptions.

Further, the findings also show that these vulnerability drivers are the outcomes of the interactions between actors in the PSC, which are, in turn, influenced by the characteristics of PSC. With regards to the display of power, for instance, which was identified through drug, information and price control, manufacturers' decisions to impose quotas was to ensure revenue flowed back to their coffers. Also, the control of information was to protect firms' reputation and market share as well as avoid issues such as panic buying from other supply chain actors. However, these actions, limited the ability of other supply chain partners to plan and/or prepare for disruptions, thus exposing the supply chain to the impact of disruptions. The exhibition of power was an outcome of the interactions with supply chain actors which exposed the supply chain to the impact of disruption.

Also, the existence of a conflict in the PSC decreased the PSC's ability to plan for a disruption. Conflict arises because of misalignment of goals and the absence of trust. Misalignment of goals means that there are no collaborative practices (Barrett and Oke, 2007), and the absence of trust implies that PSC actors have lost confidence in their supply chain partners. Thus, when there was a medicine shortage -as a dynamic disruption- supply chain actors found it difficult to reach mutually agreed goals in an attempt at combating these disruptions. Also, the scanning of anonymised prescriptions as an indicator of the absence of trust depicts that supply chain actors did not trust their supply chain partners with their goods. As some believed they were selling abroad for profit—this decision affected patient safety, thus exposing the PSC to the impact of disruption. For example, some patients, who were not initially accounted for with the quota system, may be prevented from accessing their medicines. This can have an impact on the continuity of patients' care, thus exposing the supply chain to unacceptable consequences of the impacts of disruption.

The interactions between supply chain actors were also largely influenced by the characteristics of the PSC. For instance, because of the limited number of manufacturers in the PSC, exhibition of power during interactions with supply chain actors was possible as there were fewer alternatives available.

RQ2: *How are resilience strategies used to mitigate the impact of dynamic disruptions in the PSC*?

The current empirical literature on supply chain resilience reported that supply chain resilience strategies included flexibility improvement, creation of redundancy, building collaboration as well as improving agility (Brandon-Jones et al. 2014; Holstein et al. 2015; Tukamuhabwa et al. 2017). There was, however, lack of evidence of how resilience strategies could be employed to mitigate the impact of disruptions, especially in the PSC. This research question, therefore, looked to understand how resilience strategies were used to alleviate the effects of dynamic disruptions in the PSC.

According to findings from the qualitative data and confirmed by the quantitative data, supply chain actors employed flexibility, visibility, joint decision making, as well as resource sharing in mitigating the impact of dynamic disruptions. Some of these resilience strategies (flexibility, recovery and joint decision making) were used to recover from the disruption and as such, provided the PSC with the ability to continue operations. Other strategies were developed before disruptions which implied, supply chain actors could prepare for and plan for a disruption. However, the ability to build resilience strategies within the PSC was influenced mainly by the underlying characteristics of the PSC and the interactions of supply chain actors with one another.

With regards to flexibility, for instance, in response to a disruption, the commonly used flexibility strategy by PSC actors was volume/form flexibility. Volume/form flexibility entailed using closely related products in the right dosage, volume or form to ensure patient treatment continuity. Volume flexibility was considered appropriate since it was cost-effective, and the time required to manufacture new pharmaceutical products was slightly too long to meet demands caused by the disruptions. This decision, however, had a ripple effect on the PSC, as volume/form flexibility meant that the alternative products would also be affected. Further, since manufacturers were not allowed to talk to each other as an underlying regulation of the PSC when the alternative product manufacturer notices a spike in demand for their products, they may employ quotas to control its flow.

Sharing of resources such as infrastructure and technology was identified as a form of resilience strategy that increased the resilience capacity of PSC actors. With resource sharing, PSC actors were able to prepare and plan for disruptions adequately. Resource sharing, however, was facilitated through strategic alliances which were built over time through relationships formed with supply chain partners. The findings showed that alliances succeeded because supply chain actors had common goals, and this facilitated the decision-making process, as the issues of quotas, pricing manipulation, absence of trust and other vulnerabilities were adequately addressed.

Similarly, shared infrastructure offered systemic thinking as supply chain actors were able to see through their supply chain as well as understand the intention behind supply chain actors' decisions. It is in consonance with Min (2015), who explained that strategic alliance is based on joint decisions to achieve agreed goals of aligned companies that share resources, information, profits, knowledge, and risks. The shortfall to these is that it may create monopolistic behaviour.

RQ3: *What impact do resilience strategies have on vulnerabilities in the PSC*? Underlying literature suggests that the application of resilience strategies can mitigate the impact of disruptions by reducing the vulnerabilities within the supply chain (Ponomarov and Holcomb, 2009; Jüttner and Maklan, 2011; Scholten et al. 2014; Namadar et al. 2018). However, empirical evidence examining the link between resilience strategies and vulnerabilities within the supply chain is limited. The existing studies that have investigated the relationship between resilience and vulnerabilities have been carried out based on assumptions.

Jüttner and Maklan (2011) in their study examining supply chain resilience in the face of the global financial crises, identified flexibility, visibility, velocity and collaboration as antecedents of supply chain resilience and assumed that these strategies were able to reduce the negative impact of disruption because they reduced vulnerabilities. It may not be the case, however, as they failed to measure the weaknesses of the supply chains before understanding the underlying resilience strategies. This study, therefore, takes their research further by conceptualising vulnerabilities and resilience in the supply chain as well as directly examining the link between them. The third objective of this study, therefore, sought to examine if the resilience strategies employed had any impact in decreasing the underlying vulnerabilities within the PSC.

The findings from the data analysis provided mixed results as to the impact of resilience strategies on vulnerabilities in the PSC. The analysis showed that recovery strategies increased vulnerability in the supply chain, while

resistance strategies reduced vulnerabilities. For instance, with regards to power as a supply chain vulnerability, the analysis showed a positive relationship between recovery strategies and identified vulnerabilities with a beta of (β1= 0.190). It infers that the identified recovery strategies in the PSC, which included; flexibility, joint decision making, and visibility increased power as a supply chain vulnerability by 19%. Thus, when flexibility, joint decision making, and/or visibility were employed by individual supply chain actors to recover from a disruption, the susceptibility of the PSC increased. The limited number of manufacturers, the peculiarity of the product provides possible explanations as to why recovery strategies increased supply chain vulnerabilities in the PSC. These findings are in contrast with existing studies of resilience strategies predict (Pettit et al. 2010; Lücker and Seifert, 2017; Ward and Hargaden, 2019).

Further, analysis of the findings, as well as using CAS theory to enhance systemic thinking, showed that the relationship between resilience strategies and vulnerabilities in the PSC was non-linear and had a dynamic effect. As such, it was not easy to draw direct conclusions on the relationship between resilience strategies and vulnerabilities in the pharmaceutical supply chain. Thus, the decision of a supply chain actor to build resilience strategies in response to disruption may increase the weakness of the supply chain to the impact of disruption. The characteristics of the PSC primarily influenced these non-linear responses to decisions by PSC actors.

8.4. Research Contributions

The contributions of this study relate to the three main research questions formulated based on the gaps found in the extant literature. The main areas, therefore, where this thesis makes contributions are: i) operations management literature/methodology and ii) practice. More specifically, this study provides more precision to the operational management of the PSC as well as the elements that characterise it as a complex system.

In view of this, the focus of this study was to contribute to the existing literature by proposing strategies that will facilitate the ability of the PSC to withstand disruptions when they occur. This was done by exploring disruptions, vulnerabilities and resilience strategies in the UK. This study also provides preliminary evidence of elements that might expose the PSC to the impact of various forms of disruptions. Based on the findings, this investigation allowed the researcher to recommend actions that could overcome the identified issues and thus, enhance the operations of the PSC.

8.4.1. Contribution to Academic Literature and Methodology

This study contributes to operations management literature on issues relating to disruptions, vulnerabilities and resilience strategies within the PSC. These include extending the literature on supply chain vulnerability and resilience strategies, the development of conceptual models and the use of mixed methods in the study of supply chain resilience.

Existing studies that have examined drivers of vulnerability in supply chains are limited, and they have argued that vulnerabilities can be counterbalanced by entrenching resilience strategies (Peck, 2005; Wagner and Bode, 2006; Pettit et al. 2010). More so, there are limited studies that have examined vulnerability in the PSC, and most of the studies have focused on building resilience strategies without considering underlying vulnerabilities (Aigbogun et al. 2015; Lücker and Seifert, 2017; Ward and Hargaden, 2019). This study, therefore, contributes to the literature on supply chain resilience by first exploring vulnerabilities in PSC to understand how resilience strategies can be developed.

Thus, this research extends earlier studies by Peck (2005); Craighead et al. (2007) as well as Jüttner and Maklan (2011) who provided empirical evidence on the concepts of vulnerabilities and resilience strategies in supply chains. Besides, the drivers of vulnerability that have been identified in this study like power have not been considered in PSC resilience literature or broader supply chain resilience literature. Power, as a vulnerability driver reflected the

characteristics of the PSC. Although some of the identified vulnerability drivers in this study have been previously mentioned in existing literature, this study offers different explanations backed by new empirical evidence within the PSC context.

While existing studies suggest that higher levels of resilience strategies reduce vulnerability drivers, they have been based mainly on assumptions with scanty empirical evidence. This study provides empirical evidence on the relationship between vulnerabilities and resilience strategies. It asserts that for the PSC building resilience strategies is an outcome of the decision-making process of supply chain actors influenced mainly by the peculiarities of the PSC. The study, therefore, contributes to academic knowledge by examining the outcomes of resilience strategies in reducing vulnerabilities in the PSC. By providing empirical evidence of the impact of supply chain resilience in curbing vulnerabilities within the PSC, the study offers vulnerability benchmarks against which resilience strategies can be employed.

In this study, five conceptual models have been developed (see Figure 7.1-7.9). The first four conceptual models were related to the identified drivers of vulnerability in the PSC. The antecedents of resilience strategies model, interactions between supply chain resilience and vulnerability drivers as well as the PSCRF are the other four models developed in this study which can be empirically studied in different supply chains.

This study also used CAS theory as a framework to explore the interactions of the various elements of resilience in the PSC. This is in response to the call for the use of theory in the study of supply chain resilience strategies as well as the need for more system thinking with supply chain resilience (Day, 2014; Kim et al. 2015). This study, therefore, attains practical benefits using CAS theory as a framework in understanding PSC resilience. However, the study found that the characteristics of the PSC contribute to the non-linear, sequential traits exhibited in building resilience. Thus, vulnerability and resilience strategies were the outcome of the decision-making process by

supply chain actors and the reactions by other supply chain actors. These decisions were interrelated, non-linear and primarily influenced by the characteristics of the PSC.

This study also contributes to the enhancement of methodology. The study used the mixed-method approach under a pragmatic paradigm to achieve the objectives set out. This approach has contributed to existing supply chain management literature by showing that qualitative and quantitative techniques can be mixed within a single research framework to offer a more parsimonious analysis. Although there has been a call for the use of the mixed-methods approach in supply chain management research, it has however not been fully established (Davis et al. 2010; Golicic and Davis, 2012). This study, therefore, followed a developmental mixed-method approach to achieve the research objectives. The findings from the qualitative phase of the study contributed to the development of the questionnaire. The questionnaire, thus, contributes to researches in pharmaceutical supply chain resilience.

Although extant literature has identified vulnerabilities and resilience strategies in supply chains (see Kalamahadi et al. 2016), these studies are based on the review of the literature with no empirical evidence. Also, studies that have provided empirical evidence have employed a single method approach in their (Peck, 2005; Craighead et al. 2007; Macdonald et al. 2018; Ribeiro and Barbosa-Povoa, 2018). This increases the level of biasedness which single method has been criticised for. This study goes a step further by providing credibility and reliability when conclusions are drawn from both interviews and surveys as well as mitigates the bias accompanied when using a single method in the study.

This research provides evidence of following through the developmental mixed-method approach in supply chain management research. In this case, the findings from the qualitative phase of the study, as well as existing literature, were used to develop the quantitative phase of the study in addressing different research questions. The qualitative data were the

foundation for developing the current research, the quantitative data was, however, collected and analysed as a confirmatory source of data. Similarly, the quantitative data conducted, was to measure the vulnerabilities and resilience strategy variables in the PSC as identified from the qualitative method. The questionnaire had items relating to forms of disruptions, trust, conflict, complexities and other underlying resilience strategies. It also provided insight into measuring the relationship between the conceptualised variables in this study by providing breadth and depth of understanding as well as corroborating findings.

8.4.2. Contribution to Practice

The findings from this study contribute to operations management practice on issues concerning resilience strategies in the PSC by providing tools and information that can assist practitioners at various levels of the PSC. These include the PSC Resilience Framework (PSCRF), analysis on building resilience strategies and information about resilience strategies investment decision.

First, the PSC Resilience Framework (PSCRF) shows that PSC resilience is influenced mainly by the characteristics of the PSC. This includes stringent regulations, patient safety, the criticality of the product, the limited number of manufacturers as well as the interactions of supply chain actors. Thus, the PSCRF provides a tool to assist supply chain actors in PSC resilience strategies. PSCRF can also be used as a guide to increase goal alignment and enhance trust if strategic alliances are adopted and implemented in the PSC. Strategic alliances can be useful when supported by integrated Information Technology (IT) and specialised data hubs for effective decision making and proper visibility.

Although the PSCRF is tailored to the UK PSC, the framework hinges on the idea that other countries with similar PSC practices can adapt it. Thus, the framework asserts that by adopting best practices that have been successfully applied at various levels of the PSC, resilience can be enhanced using

visibility, flexibility as well as information technology tools which can also be fostered through strategic integration and alliance.

The conceptual models developed in the study can help supply chain actors in analysing drivers of vulnerability in the PSC. This will offer the necessary steps to building resilience strategies and their possible impact in mitigating disruptions. These models especially Figure 7.7, can be employed as a decision-making tool that will foster the decision-making processes when preparing and responding to disruptions in the PSC. For instance, the decision model will provide manufacturers with outcomes on their decision to impose a quota and the pharmacists with outcomes on their decision to engage in panic buying.

The conceptual models can be used as tools in training pharmacists to improve their non-clinical skills, as this will help in developing effective PSC resilience strategies. This can be achieved by introducing requisite managerial skills development into undergraduate, postgraduate and Continuing Development Programmes (CPD) curriculum.

Also, by highlighting the factors that facilitate resilience in the PSC, supply chain actors are offered insights into investment decisions regarding what resilience tools are right for investment. For instance, manufacturers can invest in visibility tools to help the sharing of information as well as increase traceability of products which will significantly reduce the impact of disruptions.

8.5. Developing Propositions about PSC Resilience

Based on the identified research contributions in this chapter, the following propositions have been developed about resilience in PSC.

First, the findings showed that in responding to disruptions such as medicine shortages, supply chain actors engaged in decision-making processes that determined their actions and interactions. Thus, the identified underlying

vulnerabilities and resilience strategies in the PSC were outcomes of decision-making processes influenced mainly by the characteristics of the PSC. This shows that building resilience in the PSC involves a complex decision-making process that involves schemas or sets of features which control the decision-making process.

As shown in Figure 7.7, although most of the decisions were to enhance the supply chain, these decisions affected the entire operations of the PSC. This was due to the interconnectedness of the complex decision-making process where the decisions of a supply chain actor could lead to the vulnerability of other supply chain actors, and so on. Therefore, understanding of the interconnections and outcomes when making decisions may alert supply chain actors to the unintended consequences of their actions (Stacey et al. 2000). Thus, system thinking may contribute to developing PSC resilience as changes in a single decision can affect the entire system. The findings on strategic alliance shed light on interconnected decisions. Resistance capabilities are developed by forming strategic alliances with partners in the PSC, which increases visibility, reduces incidences of trust and aids manufacturers in focusing on core manufacturing components. The decision-making process shows that PSC resilience is a continuous process that evolves based on the interactions of supply chain actors.
This leads to the following propositions:

Proposition 1: Pharmaceutical supply chain resilience is a systemic and dynamic process that emanates from the decisions, actions as well as interactions of supply chain actors in response to disruptions from the environment and is mostly influenced by the underlying characteristics of the PSC.

Proposition 2: Strategic alliance between supply chain actors is a critical resistance strategy for building resilience against dynamic disruptions in the PSC. This is necessary to (i) reduce existing vulnerabilities in the PSC, such as the absence of trust, (ii) sense the impact of potential disruptions and accurately anticipate the disruptions by sharing information, (iii) increase goal congruence.

The findings and discussions suggest that an effective resistance strategy in building resilience in the PSC is to align vertically with supply chain partners. This involved the sharing of resources (information, products, and infrastructure). This strategy reduced the incidences of power and conflicts as well as increased trust among supply chain actors. To achieve strategic alliance, therefore, firms within the PSC must agree on common goals. These shared goals should include patients' safety as well as working jointly to understand the likely effect of disruptions at various levels of the PSC. This enables the development of visibility, joint decision making and the ability to prepare adequately for disruptions. Although antecedents of resilience strategies have been discussed in prior literature (Jüttner and Maklan, 2011; Pettit et al. 2013), they have been discussed independently of their interactions with supply chain actors.

This implies that by increasing strategic alliance, supply chain actors can share information on time; supply chain partners with less power can have a louder voice by collectively allaying their fears; trust is built and anticipation for disruptions adequately planned for. These findings align with the underlying resilience notion which asserts the need to plan for disruption accurately and set up resistance strategies as a form of building resilience in the supply chain (Tukamuhabwa et al. 2017; Stone and Rahimifard, 2018; Hendry et al. 2019).

8.6. Limitations of the Study

Like every research work, limitations exist, and this study is no exception. However, these limitations may be avenues for further research. This section will, therefore, discuss the limitations of the study.

One major challenge when conducting this study was related to accessing the required data. Due to the relatively heavy workload that professionals working within the PSC had, several potential participants were reluctant to be involved in this research. Also, the data collected was during the agitation created by BREXIT, which affected the willingness of potential participants because of the uncertainties.

As explained throughout this thesis, the study was exploratory, and as such, it did not examine underlying vulnerabilities and resilience strategies from various vantage points. For instance, it would have been desirable to investigate vulnerabilities and resilience strategies for specific medicines within the PSC like orphan drugs to see if their supply chain differs. This was, however, not possible due to time and resource limitations.

The study assumed that the PSC was linear and as such, focused on key actors: manufacturers, wholesalers, primary care, secondary care, and regulatory bodies to gather valuable insights. This may limit the perspective of the interrelatedness within the PSC.

As reported in the Methodology Chapter, a snowballing sampling technique contributed to identifying and recruiting potential respondents. The final sample for the quantitative phase, therefore, was small (n=106) in comparison with studies reflecting the views of the general PSC population. However, through the systematic nature of this research which involved comparing similar positioned studies from relevant literature and robust qualitative analysis, these findings can provide a precise signal of what the right answers might be. The collection of more quantitative data would have further strengthened the results.

The questionnaire used at the quantitative phase of the study was developed from the findings of the qualitative phase of the study and existing literature. Thus, the process involved in scale development, as suggested by Churchill and Peter (1984), was omitted as this was not the focus of the study. This limitation was addressed by conducting reliability tests using Cronbach's Alpha.

In analysing the qualitative data, the thematic analysis undertaken was driven by the underlying theoretical and analytical goal of the research, which might have influenced interpretation. Although objectivity was challenging to achieve in this regard as in most social science research studies, this limitation was addressed through transcribing of interviews verbatim as well as using the direct quotes of research participants to support research findings.

8.7. Recommendation

This thesis makes the following recommendations for PSC in the UK, based on the contributions found in this study. This section discusses recommendations for practice as well as showing areas for further research.

8.7.1 Recommendations for Practice

First, by adopting strategic alliances where information technology and infrastructure can be shared mutually, the PSC can build resilience into the supply chain. As detailed by the PSCRF, implementing resource sharing strategies in the PSC could help supply chain actors to overcome identified vulnerabilities towards continuous improvement. Specifically, a systematic and more formal way of developing strategic alliances which will help factors like trust, commitment and other collaborative practices should be designed. Business analytics tools such as big data and artificial intelligence can be used to predict disruptions and the outcomes of decision-making processes. These tools can also be used to prescribe effective operations management techniques necessary for increasing resilience strategies.

To minimise the level of vulnerability, as well as build resilience into the PSC, supply chain actors should develop structural flexibility in the supply chain, which is adaptable to changes in the business environment. Building structural flexibility includes having alternative sources at cost-effective prices, being prepared to share assets such as factories, distribution centres and transportation with other companies to create economies of scale. Also, by developing flexible labour arrangements with little or no costs penalty will increase structural flexibility and will help the ability to meet demand swings at every given point in time.

Developing and using new technology in manufacturing pharmaceutical products will increase rapid manufacture, which may be more cost-effective and reduce lead times often associated with the production process of pharmaceutical products. A further recommendation is to build an integrated

information technology system that can increase the alertness of impending threats, increase the visibility of demand as well as transparency of stock levels. However, the willingness of supply chain actors in developing and implementing this information technology is critical to its success.

The decision-making process by supply chain actors is critical to the development of resilience in the PSC. Therefore, supply chains should evaluate the decisions against the impact on their supply chain partners as this may either increase vulnerability or develop resilience strategies. Decision models should be used to foster decision-making processes when developing resilience strategies. These decision models should have the ability to examine the outcome of actions as well as provide an adequate understanding of how these strategies will impact on the supply chain as a result of the underlying PSC features.

A centralized information broker should be set up to help information sharing among PSC actors. This role of this broker is to analyse the actions and decisions of supply chain actors as well as share information promptly. For instance, when manufacturers make decisions to control drug flow in the supply chain, the centralised broker should be able to analyse the impact of this decision on patient safety and make recommendations. Also, when regulatory bodies develop regulations, the centralised broker will analyse these regulations and forecast impending impact on medicine flow as well as offer necessary steps to be taken to ensure that it does not disrupt medicine flow. This can be achieved through the circulation of informative materials about the consequences of their actions. It will also serve as a form of check and balance of the excesses of actors in the PSC

8.7.2. Agenda for Future Research

Based on the limitations of the study, avenues for further research include:

- Potential research should examine vulnerabilities, resilience strategies and their interactions for specific medicines within the PSC like orphan drugs to see if their supply chain differs. Also, the studies should map

the PSC to include other supply chain actors such as packaging, labelling firms, and parallel traders. This would provide a broader and more in-depth perspective of the flow of resources in the PSC.

- Further studies could also employ tools such as Multiple Criteria Decision Making which will allow prioritisation of the vulnerabilities identified in this study as well as develop a vulnerability tool in assessing suppliers' tendering capacity. Also, using a multi-criteria method, a framework can be developed to select partners for strategic alliances among supply chain actors where the strengths and weaknesses are accessed as well as the benefits and challenges of these strategic alliances.

- This research used CAS as an exploratory framework in describing how resilience is built in the PSC. The findings show that the interactions and decision-making process of supply chain actors contribute to building resilience strategies. Further studies can explore the decision-making models identified in this study and in what capacity these models can be used to foster relationships in resilience building as well as examine the role of financial capacities in building resilience in the PSC.

- Power was identified as pertinent to the development of resilience in the PSC. Future research should explore the dynamics of power as a vulnerability in the PSC and examine if information technology tools can be used in developing resilience strategies in the PSC. It will also be interesting to examine at what point supply chain actors develop resistance and/or recover strategies to combat disruptions

- This study focused on medicine shortages as a dynamic disruption. Potential research could examine supply chain resilience strategies in the face of dynamic disruptions like counterfeits within the PSC using systemic thinking. Also, the research can be strengthened by using the

questionnaires developed in this study with the identified underlying themes and gathering more quantitative data as a possible evolution to the study.

- Finally, the study explored the UK PSC; similar studies in other parts of the world would provide a useful comparison and further the research on supply chain resilience.

8.8. Summary

This chapter presents an overview of the major findings and contributions to this study. The PSC is vital in supporting patients care and enabling the delivery of healthcare services within the UK and globally. This study has shown that to develop a resilient supply chain, understanding vulnerability, antecedents of resilience strategies and the characteristics of the PSC is essential. Thus, it is in this vein that the outputs of this study will strengthen and improve the SC to make it less vulnerable to disruptions and become more sustainable.

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Appendix A: Interview Protocol

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Date: 26th March, 2018.

Letter of Invitation to Participate

I am a doctoral student at the University of Bradford School of Management and Law and I am undertaking this research as part of my PhD thesis. The aim of this study is to explore the type of disruptions that are experienced in the pharmaceutical supply chain, the causes of these disruptions (if identifiable) and the strategies that have been adopted to reduce the impact of these disruptions. Supply chain disruptions can be defined as any activity that prevents the flow of goods and services from reaching the final consumer.

This research intends to advance our understanding of why disruptions like drug shortages as well as counterfeiting can occur within the pharmaceutical supply chain, as well as proffer strategic mechanisms that will aid in reducing their occurrence.

In view of this, I will like to conduct interviews with experts and stakeholders in the pharmaceutical supply chain as part of my data generation process. I would like you to be part of this study as an expert in this area. The interviews will last approximately one hour. The interview questions will ask participants to comment on disruption types/examples, the reasons why these disruptions occur, factors that facilitate the impact of these disruptions as well the strategies used to prevent the disruptions from adversely affecting the supply of goods to consumers.

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Faculty of
Management and Law

Participation in this study is a voluntary task. You have the full right whether to participate or not, it is entirely up to you to do so. You also can withdraw from the interview at any time even after the interview has completed and without giving reason. The data collected will be held by me as the researcher and only accessible by me and my supervisory team. It will not be shared with any other individual or organisation

The results (including anonymised short direct quotes) will be included in a research report as part of my PhD thesis at the University of Bradford, and may subsequently be published as research papers in academic journals and presented at conferences. The collected data and the research are governed by the ethical policies of the University of Bradford which guarantee the confidentiality and anonymity of all participants within this project. No individual person will be identifiable in any direct quotes, reports, papers, presentations or summaries. These policies require that names of the firms and people that participated in this research will not be revealed to any third party.

The research study is subject to approval by the University of Bradford Research Ethics and Governance Committee.

My Research Supervisory Team consists of the following:
Dr Liz Breen, Bradford School of Pharmacy and Clinical Sciences
Dr Jiachen Hou, Bradford School of Management
Dr Julie Sowter, Bradford School of Pharmacy and Clinical Sciences

If you any questions about this invitation to participate in this study please do not hesitate to ask me. Moreover, if you have any further queries about this research, please contact me at any time or contact my Principal Supervisor: Dr Liz Breen, l.breen@bradford.ac.uk.

Yours faithfully,

Emilia Vann Yaroson

Section One

Date and time of interview
Name of Interviewee and Company
Type of Company
Area of responsibility
Years of experience on Job profile
Kindly provide a brief description of your supply chain position in terms of information and material flow.

Section Two

Supply Chain Disruptions

•Could you describe a time when your firm faced a delay in the supply of its goods to consumers. How long did the delay last? Why do you think it lasted as long as it did?
•How quickly did your firm discover this disruption or the event that may have triggered the disruption? Are there metrics available to detect early warning signals of a disruptive event?
•How quickly does your firm assess the impact of the disruption when a disruption is discovered? How does your firm efficiently assess what areas of the supply chain may be affected?
•What kind of barriers to an effective disruption recovery does your firm face?

Section Three

Supply Chain Vulnerabilities

• Could you explain the major features of the products you supply to your consumers and do you think any of these features amplify the effect of a disruptive activity?
•How would you describe your supply chain? Do you think any of these features amplify the impact of disruptive activities?
•Could you describe the role of your suppliers in the event of a disruptive activity? Do they have a role and if so what do they do at this point in time?
•How would you describe the effect of your managerial decisions on the supply chain in the face of a disruption?
•How would you describe the role of regulatory bodies in the supply of your goods to consumers?

Section Four

Supply Chain Resilience

•Could you explain the type of strategies your firm employs when preparing and responding to a disruption?
•What type of resources and process enablers are available to the firm to withstand the impact of a disruptive event?
•How would you describe the effect these strategies have in reducing the impact of a disruption? How would you describe your firm's competitive position with respect to the adoption of these strategies?
•How would you describe the process involved in getting information from the various stakeholders in the supply chain?
•What type of activities are in place that foster sharing of information between other firms of the supply chain?
•How would you describe your ability to source for goods on demand when faced with a disruptive activity? Are there readily available suppliers? What kind of hindrances do you encounter?
•How can the pharmaceutical supply chain be better prepared for a disruptive activity?

Appendix B: The Questionnaire: Item and Sources

Scale	Variables	Items	Authors
Supply Chain Power	Information Control (Behavioural Uncertainty)	We do not have confidence in our supply chain partners actions	Maloni and Benton (2000); Kwon and Suh (2004); Qualitative findings (2019)
	Reputation	Our supply chain partners encounter significant disruptions frequently	Kwon and Suh (2004); Pettit et al. (2013)
	Drug Control	We do not agree with supply chain partners on critical issues like the distribution of our products	Benton and Maloni(2005); Qualitative findings (2019)
		Our supply chain partners prevent us from doing what we want to do	Qualitative findings (2019)
	Pricing Control (PC)	Information regarding product prices is not readily available within our supply chain	Qualitative findings (2019
	Information Timing (IT)	Our business supply chain partners do not exchange relevant and/or timely information	Wieland and Wallenburg (2012); William et al.,(2013)
		In your opinion, when should information about disruptive activity in the supply chain be shared with you?	Qualitative findings (2019)
		Following an initial alert, when should updates about disruptive activity be provided to you?	Qualitative findings (2019)
Supply Chain Conflict	Trust	We do not trust our supply chain partners	Kwon and Suh (2004); Benton and Maloni (2005)
	Goal Misalignment	Our supply chain partners do not understand the market demand	Pettit et al.,(2013)
		Our firm does not understand the market demand	Pettit et al., (2013)
	Supply Chain Partners Satisfaction		
		Generally we are not satisfied with our overall relationship with our supply chain partners	Kwon and Suh (2004); Benton and Maloni (2005); Griffith et al, (2006); Qualitative findings (2019)
		There is no feeling of fairness with our supply chain partners	Griffith et al.,(2006);

Supply Chain Complexity	Regulations (PR)	Our operations and products are subject to stringent government regulations	Petitt et al.,(2013); Qualitative findings (2019)
		Regulation on pricing and reimbursement complicates transactions	Petitt et al.,(2013)
	Economic/ Political/ (EC)	We are uncertain about economic and /or political issues	Qualitative findings (2019)
		We are part of a global distribution network	Pettit et al., (2013)
	Process /Product Complexity (PRC)	Our products require strict storage or handling controls to maintain their purity and/or integrity that may cause delay	Pettit et al.,(2013)
		Production of our products is very complex	Pettit et al., (2013)
		The lead times for manufacturing of our products are shorter	Qualitative findings(2019)
Recovery Strategies	Flexibility	There is access to alternative supply chain partners	Kumar et al., (2006); Fantazy et al., (2009)
		There is access to alternative products	Kumar et al., (2006); Fantazy et al.,(2009)
	Visibility	We have access to tracking information throughout the supply chain	William et al., (2013)
		We have access to tracking materials throughout the supply chain	Qualitative findings(2019)
		There is no transparency in the pricing of goods within the supply chain	Qualitative findings(2019)
	Joint Decision Making	We have joint decisions with our supply chain partners when working out solutions	Qualitative findings(2019)
		Joint employee training with other supply chain partners	Pettit et al.,(2013)
Resistance Strategies	Resource Sharing	Our supply chain partners share their resources with us	Qualitative findings (2019
		We share resources with our supply chain partners	Qualitative findings (2019
		We share resources internally	Qualitative findings (2019

Appendix C: Questionnaire

Disruptions, Vulnerabilities and Resilience Strategies in the Pharmaceutical Supply Chain

This study seeks to examine why the pharmaceutical supply chain in the UK is susceptible to the impact of disruptions and how resilience strategies can be used to mitigate the impact of these disruptions

* Required

1. **Your Field of Practice: Please tick the response most suitable to you** *
   Mark only one oval.
   - ◯ Medicines Manufacturer
   - ◯ Equipment/Device Manufacturer
   - ◯ Pre-Wholesaler/Wholesaler
   - ◯ Secondary Care/Hospital Pharmacists
   - ◯ Primary Care/Community Pharmacists
   - ◯ Regulatory Body
   - ◯ Trade Associations

2. **Years of Experience in the Pharmaceutical Supply chain** *
   Mark only one oval.
   - ◯ 1-10
   - ◯ 11-20
   - ◯ 21-30
   - ◯ 31 and above

3. **In your experience what is the most common form of disruptive activity to your supply chain?** *
   Mark only one oval.
   - ◯ Natural Disaster
   - ◯ Counterfeiting
   - ◯ Medicine Shortages
   - ◯ Theft
   - ◯ Union Strike
   - ◯ Others

6. **We feel the impact of disruptive activities because: ***

Mark only one oval per row.

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	I don't know	Not applicable
Our business supply chain partners do not exchange relevant and/or timely information	◯	◯	◯	◯	◯	◯	◯
Our supply chain partners do not consider how their actions will affect us	◯	◯	◯	◯	◯	◯	◯
We do not trust our supply chain partners	◯	◯	◯	◯	◯	◯	◯
We do not have confidence in our supply chain partners actions	◯	◯	◯	◯	◯	◯	◯
Our supply chain partners prevent us from doing what we want to do	◯	◯	◯	◯	◯	◯	◯
We do not agree with supply chain partners on critical issues like the distribution of our products	◯	◯	◯	◯	◯	◯	◯
Generally, we are not satisfied with our overall relationship with our supply chain partner	◯	◯	◯	◯	◯	◯	◯
There is no transparency in the pricing of goods within the supply chain	◯	◯	◯	◯	◯	◯	◯
Information regarding product prices is readily available within our supply chain.	◯	◯	◯	◯	◯	◯	◯
Our operations and products are subject to stringent	◯	◯	◯	◯	◯	◯	◯

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	I don't know	Not applicable
Our firm does not understand the market demand	◯	◯	◯	◯	◯	◯	◯
Our supply chain partners do not understand the market demand	◯	◯	◯	◯	◯	◯	◯
Production of our products is very complex	◯	◯	◯	◯	◯	◯	◯
Our products require strict storage or handling controls to maintain their purity and/or integrity that may cause delay	◯	◯	◯	◯	◯	◯	◯
We are part of a global distribution network	◯	◯	◯	◯	◯	◯	◯
Our supply chain partners encounter significant disruptions frequently	◯	◯	◯	◯	◯	◯	◯
We depend on the use of regulated or restricted materials	◯	◯	◯	◯	◯	◯	◯
Regulation on pricing and reimbursement complicates transactions	◯	◯	◯	◯	◯	◯	◯
There is no feeling of fairness with our supply chain partners	◯	◯	◯	◯	◯	◯	◯

Our supply chain partners do not consider how their actions will affect us	◯	◯	◯	◯	◯	◯	◯
We do not trust our supply chain partners	◯	◯	◯	◯	◯	◯	◯
We do not have confidence in our supply chain partners actions	◯	◯	◯	◯	◯	◯	◯
Our supply chain partners prevent us from doing what we want to do	◯	◯	◯	◯	◯	◯	◯
We do not agree with supply chain partners on critical issues like the distribution of our products	◯	◯	◯	◯	◯	◯	◯
Generally, we are not satisfied with our overall relationship with our supply chain partner	◯	◯	◯	◯	◯	◯	◯
There is no transparency in the pricing of goods within the supply chain	◯	◯	◯	◯	◯	◯	◯
Information regarding product prices is readily available within our supply chain.	◯	◯	◯	◯	◯	◯	◯
Our operations and products are subject to stringent government regulations.	◯	◯	◯	◯	◯	◯	◯
We are uncertain about economic and /or political issues	◯	◯	◯	◯	◯	◯	◯

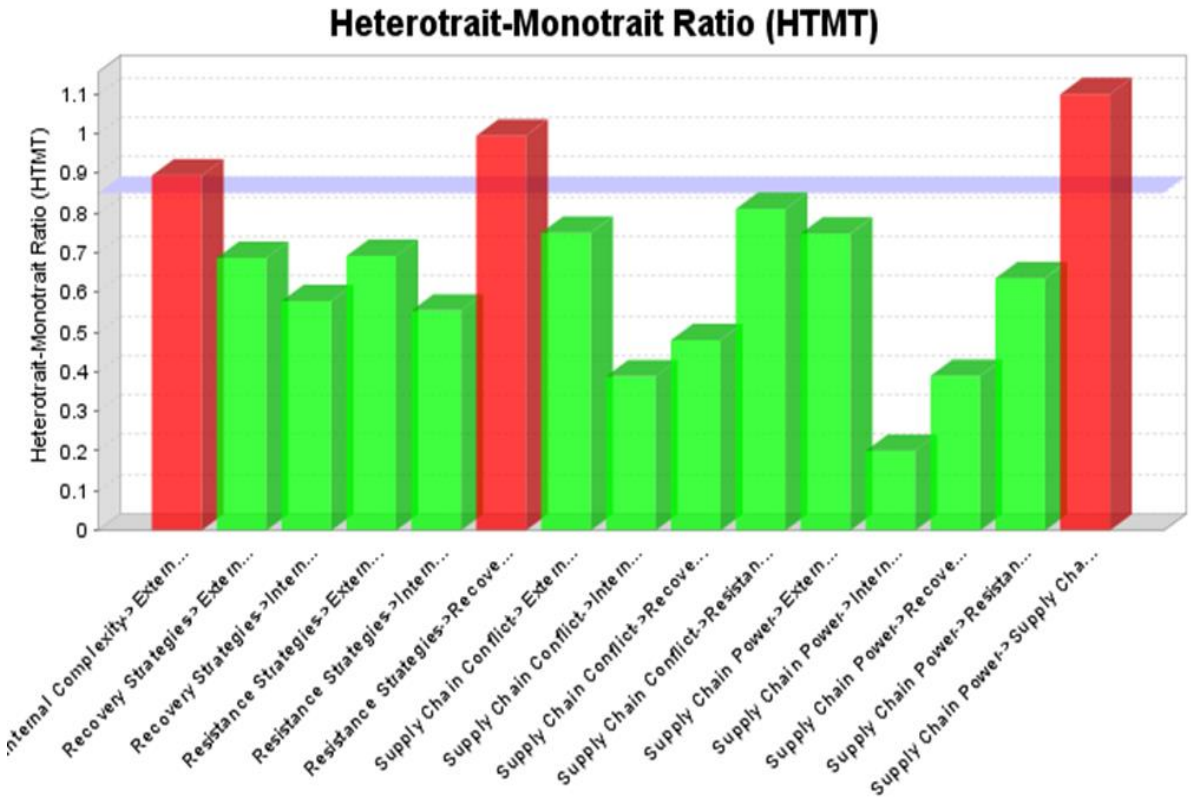
7. **The impact of disruption on the supply chain is is reduced when:** *
Mark only one oval per row.

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	I don't know	Not apllicable
The demand for our product is unstable	◯	◯	◯	◯	◯	◯	◯
There is access to alternative supply chain partners	◯	◯	◯	◯	◯	◯	◯
There is access to alternative products	◯	◯	◯	◯	◯	◯	◯
The lead times for manufacturing of our products are shorter	◯	◯	◯	◯	◯	◯	◯
We have access to tracking information throughout the supply chain	◯	◯	◯	◯	◯	◯	◯
We have access to tracking materials throughout the supply chain	◯	◯	◯	◯	◯	◯	◯
We have joint decisions with our supply chain partners when working out solutions	◯	◯	◯	◯	◯	◯	◯
We share resources internally	◯	◯	◯	◯	◯	◯	◯
We share resources with our supply chain partners	◯	◯	◯	◯	◯	◯	◯
Our supply chain partners share their resources with us	◯	◯	◯	◯	◯	◯	◯
Joint employee training with other supply chain partners	◯	◯	◯	◯	◯	◯	◯

8. **In your opinion what other issues are necessary to consider when dealing with disruptions in the pharmaceutical supply chain?**

Appendix D: Coding of Survey Data

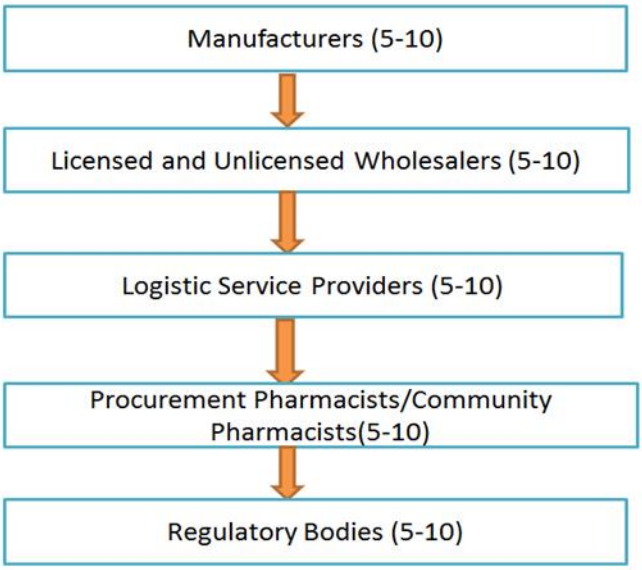
Variables	Assigned Codes
Equipment/Device Manufacturer	6
Trade Associations	5
Pre-Wholesaler/Wholesaler	4
Secondary Care/Hospital Pharmacists	3
Primary Care/Community Pharmacists	2
Regulatory Body	1
Years of Experience in the Pharmaceutical Supply chain	
1- 10 years	1
11-20 years	2
21-30years	3
31 and above	4
In your experience what is the most common form of disruptive activity to your supply chain?	
Medicine Shortages	1
Natural Disaster	2
Counterfeiting	3
Theft	4
Union Strike	5
Others	6
In your opinion, when should information about disruptive activity in the supply chain be shared with you?	
Immediately it comes to light	1
Within 24 hrs	2
Within 48hrs	3
Within 3days	4
Within 7 days	5
Other	6
Strongly agree	7
Somewhat agree	6
Neither agree nor disagree	5
Somewhat disagree	4
Strongly disagree	3
I don't know	2
Not applicable	1



Appendix D: Data Collection Strategy for Interviews

The study entails collection of data from various members of the PSC and as such the data collection strategy will be as follows: Manufacturers (5-10), Wholesalers (5-10), Logistic service providers (5-10) Procurement Pharmacists/ Community Pharmacists (5-10) and Regulatory bodies (5-10).

Pharmaceutical Supply Chain



Appendix E Correlation Statistics

	DC1	DC2	EC1	EC2	FL1	FL2	GM1	GM2	GM3	IC1	IC2	IQ1	IQ2	JDM1	JDM2	PC1	PC2	PRC1	PRC2	PRC3	PRC4	REG1	REG2	REG3	RS1	RS2	RS3	SCPS1	SCPS2	Trust	VS1	VS2
DC1	1.000	0.192	0.128	0.133	-0.247	-0.190	0.116	0.278	0.058	0.019	-0.461	0.244	-0.040	-0.022	0.133	0.128	-0.348	0.140	-0.141	0.008	0.075	0.268	-0.264	-0.281	-0.071	-0.024	-0.058	-0.295	0.223	0.019	-0.133	0.238
DC2	0.192	1.000	0.308	0.008	-0.185	-0.202	0.325	0.042	-0.022	0.195	-0.499	0.247	-0.141	0.209	0.024	-0.298	-0.176	-0.100	0.013	-0.164	0.256	0.086	-0.254	-0.063	-0.173	0.144	-0.176	-0.306	0.232	0.299	0.021	-0.027
EC1	0.128	0.308	1.000	-0.277	-0.261	-0.189	0.131	0.146	-0.087	0.133	-0.233	0.276	-0.002	0.222	0.284	-0.080	0.009	-0.097	-0.114	0.092	0.086	-0.004	-0.286	-0.219	0.008	0.009	-0.052	-0.014	0.033	0.103	-0.102	-0.149
EC2	0.133	0.008	-0.277	1.000	-0.275	-0.324	-0.227	-0.279	0.367	-0.034	0.043	-0.133	-0.015	0.012	0.179	-0.213	-0.220	0.156	0.351	-0.300	0.135	-0.130	-0.410	-0.082	0.021	0.059	-0.080	0.107	-0.042	-0.235	0.127	0.118
FL1	-0.247	-0.185	-0.261	-0.275	1.000	0.951	0.045	0.217	-0.056	-0.166	0.146	-0.094	-0.005	-0.282	-0.656	0.230	0.351	0.247	-0.208	0.086	-0.144	0.007	0.470	0.086	-0.131	-0.157	0.330	-0.104	0.099	-0.033	-0.018	-0.343
FL2	-0.190	-0.202	-0.189	-0.324	0.951	1.000	0.045	0.191	-0.074	-0.149	0.117	-0.068	0.078	-0.287	-0.662	0.277	0.324	0.250	-0.244	0.117	-0.153	0.009	0.423	0.122	-0.037	-0.168	0.288	-0.101	0.120	-0.020	0.020	-0.385
GM1	0.116	0.325	0.131	-0.227	0.045	0.045	1.000	0.145	-0.332	0.301	-0.335	0.532	0.069	0.030	-0.043	-0.261	0.105	-0.014	-0.377	0.229	-0.047	-0.243	0.215	0.030	-0.065	-0.156	0.070	-0.439	0.303	0.466	0.031	-0.159
GM2	0.278	0.042	0.146	-0.279	0.217	0.191	0.145	1.000	0.044	-0.137	-0.097	0.175	-0.118	-0.022	-0.105	0.068	0.098	-0.042	-0.190	0.077	0.105	0.300	0.082	-0.110	-0.211	-0.122	0.102	-0.533	-0.006	0.061	-0.283	0.020
GM3	0.058	-0.022	-0.087	0.367	-0.056	-0.074	-0.332	0.044	1.000	-0.229	0.212	-0.256	0.003	-0.043	0.062	-0.158	-0.202	0.016	0.460	-0.219	-0.043	-0.037	-0.257	0.156	0.321	0.195	-0.358	-0.007	-0.461	-0.393	-0.212	0.365
IC1	0.019	0.195	0.133	-0.034	-0.166	-0.149	0.301	-0.137	-0.229	1.000	-0.548	0.225	0.100	0.273	0.064	-0.102	-0.014	-0.121	-0.151	0.024	0.135	-0.144	-0.098	0.029	-0.287	0.127	0.075	-0.271	0.271	0.689	0.004	-0.231
IC2	-0.461	-0.499	-0.233	0.043	0.146	0.117	-0.335	-0.097	0.212	-0.548	1.000	-0.248	0.060	-0.135	-0.049	-0.133	-0.299	-0.013	0.060	0.132	-0.120	-0.200	0.193	0.331	0.456	-0.204	0.032	0.435	-0.328	-0.517	0.178	0.048
IQ1	0.244	0.247	0.276	-0.133	-0.094	-0.068	0.532	0.175	-0.256	0.225	-0.248	1.000	-0.048	0.197	0.107	-0.024	-0.025	-0.130	-0.209	0.065	0.138	0.044	0.020	-0.021	-0.192	0.084	-0.085	-0.187	0.291	0.233	-0.048	-0.247
IQ2	-0.040	-0.141	-0.002	-0.015	-0.005	0.078	0.069	-0.118	0.003	0.100	0.060	-0.048	1.000	0.142	0.022	-0.151	-0.058	0.196	0.021	-0.108	-0.076	-0.104	-0.032	0.106	0.203	0.264	0.014	0.049	-0.051	0.014	-0.012	-0.224
JDM1	-0.022	0.209	0.222	0.012	-0.282	-0.287	0.030	-0.022	-0.043	0.273	-0.135	0.197	0.142	1.000	-0.024	-0.276	-0.063	-0.098	-0.113	-0.020	0.204	0.029	-0.247	0.178	-0.331	0.442	-0.030	0.143	-0.008	-0.029	-0.174	-0.356
JDM2	0.133	0.024	0.284	0.179	-0.656	-0.662	-0.043	-0.105	0.062	0.064	-0.049	0.107	0.022	-0.024	1.000	-0.042	-0.192	-0.248	0.160	0.011	0.114	-0.027	-0.206	-0.217	0.179	0.261	-0.418	0.089	-0.065	0.015	-0.403	0.155
PC1	0.128	-0.298	-0.080	-0.213	0.230	0.277	-0.261	0.068	-0.158	-0.102	-0.133	-0.024	-0.151	-0.276	-0.042	1.000	0.131	0.066	-0.080	0.112	-0.104	0.251	0.224	-0.217	-0.124	-0.045	0.169	0.193	-0.100	-0.084	-0.035	0.051
PC2	-0.348	-0.176	0.009	-0.220	0.351	0.324	0.105	0.098	-0.202	-0.014	-0.299	-0.025	-0.058	-0.063	-0.192	0.131	1.000	0.005	0.108	-0.071	-0.111	0.077	0.338	-0.136	-0.329	0.138	0.121	-0.101	0.113	0.206	-0.109	-0.191
PRC1	0.140	-0.100	-0.097	0.156	0.247	0.250	-0.014	-0.042	0.016	-0.121	-0.013	-0.130	0.196	-0.098	-0.248	0.066	0.005	1.000	-0.167	-0.213	-0.299	0.206	0.005	-0.249	0.035	-0.271	0.263	-0.074	0.133	-0.066	0.098	-0.095
PRC2	-0.141	0.013	-0.114	0.351	-0.208	-0.244	-0.377	-0.190	0.460	-0.151	0.060	-0.209	0.021	-0.113	0.160	-0.080	0.108	-0.167	1.000	-0.696	0.154	-0.010	-0.125	0.050	0.173	0.353	-0.413	0.077	-0.198	-0.155	-0.108	0.351
PRC3	0.008	-0.164	0.092	-0.300	0.086	0.117	0.229	0.077	-0.219	0.024	0.132	0.065	-0.108	-0.020	0.011	0.112	-0.071	-0.213	-0.696	1.000	-0.519	-0.222	0.249	0.046	0.002	-0.213	0.250	0.159	-0.126	0.031	0.109	-0.053
PRC4	0.075	0.256	0.086	0.135	-0.144	-0.153	-0.047	0.105	-0.043	0.135	-0.120	0.138	-0.076	0.204	0.114	-0.104	-0.111	-0.299	0.154	-0.519	1.000	0.185	-0.234	0.170	-0.090	0.124	-0.138	-0.157	0.251	0.087	-0.108	-0.100
REG1	0.268	0.086	-0.004	-0.130	0.007	0.009	-0.243	0.300	-0.037	-0.144	-0.200	0.044	-0.104	0.029	-0.027	0.251	0.077	0.206	-0.010	-0.222	0.185	1.000	-0.315	-0.370	-0.217	0.094	0.012	0.018	-0.078	-0.035	-0.182	0.129
REG2	-0.264	-0.254	-0.286	-0.410	0.470	0.423	0.215	0.082	-0.257	-0.098	0.193	0.020	-0.032	-0.247	-0.206	0.224	0.338	0.005	-0.125	0.249	-0.234	-0.315	1.000	0.114	-0.090	-0.128	0.298	-0.089	0.194	0.216	0.059	-0.097
REG3	-0.281	-0.063	-0.219	-0.082	0.086	0.122	0.030	-0.110	0.156	0.029	0.331	-0.021	0.106	0.178	-0.217	-0.217	-0.136	-0.249	0.050	0.046	0.170	-0.370	0.114	1.000	0.135	0.070	-0.038	0.031	-0.046	-0.069	0.210	-0.141
RS1	-0.071	-0.173	0.008	0.021	-0.131	-0.037	-0.065	-0.211	0.321	-0.287	0.456	-0.192	0.203	-0.331	0.179	-0.124	-0.329	0.035	0.173	0.002	-0.090	-0.217	-0.090	0.135	1.000	-0.239	-0.465	0.169	-0.188	-0.296	-0.004	0.354
RS2	-0.024	0.144	0.009	0.059	-0.157	-0.168	-0.156	-0.122	0.195	0.127	-0.204	0.084	0.264	0.442	0.261	-0.045	0.138	-0.271	0.353	-0.213	0.124	0.094	-0.128	0.070	-0.239	1.000	-0.553	0.187	-0.139	-0.037	-0.391	-0.107
RS3	-0.058	-0.176	-0.052	-0.080	0.330	0.288	0.070	0.102	-0.358	0.075	0.032	-0.085	0.014	-0.030	-0.418	0.169	0.121	0.263	-0.413	0.250	-0.138	0.012	0.298	-0.038	-0.465	-0.553	1.000	-0.009	0.141	0.139	0.431	-0.281
SCPS1	-0.295	-0.306	-0.014	0.107	-0.104	-0.101	-0.439	-0.533	-0.007	-0.271	0.435	-0.187	0.049	0.143	0.089	0.193	-0.101	-0.074	0.077	0.159	-0.157	0.018	-0.089	0.031	0.169	0.187	-0.009	1.000	-0.516	-0.543	0.134	0.068
SCPS2	0.223	0.232	0.033	-0.042	0.099	0.120	0.303	-0.006	-0.461	0.271	-0.328	0.291	-0.051	-0.008	-0.065	-0.100	0.113	0.133	-0.198	-0.126	0.251	-0.078	0.194	-0.046	-0.188	-0.139	0.141	-0.516	1.000	0.375	0.116	-0.387
Trust	0.019	0.299	0.103	-0.235	-0.033	-0.020	0.466	0.061	-0.393	0.689	-0.517	0.233	0.014	-0.029	0.015	-0.084	0.206	-0.066	-0.155	0.031	0.087	-0.035	0.216	-0.069	-0.296	-0.037	0.139	-0.543	0.375	1.000	0.064	-0.090
VS1	-0.133	0.021	-0.102	0.127	-0.018	0.020	0.031	-0.283	-0.212	0.004	0.178	-0.048	-0.012	-0.174	-0.403	-0.035	-0.109	0.098	-0.108	0.109	-0.108	-0.182	0.059	0.210	-0.004	-0.391	0.431	0.134	0.116	0.064	1.000	-0.134
VS2	0.238	-0.027	-0.149	0.118	-0.343	-0.385	-0.159	0.020	0.365	-0.231	0.048	-0.247	-0.224	-0.356	0.155	0.051	-0.191	-0.095	0.351	-0.053	-0.100	0.129	-0.097	-0.141	0.354	-0.107	-0.281	0.068	-0.387	-0.090	-0.134	1.000