Supply Chain Resilience: The Case of Chinese Pig Industry

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Abstract

The focus on lean production in a turbulent business environment and increasing unforeseen adverse events have resulted in a higher likelihood of severe supply chain disruptions. This drives the need for supply chain resilience (SCR) building as means for organizations to achieve business continuity through adapting, responding, and recovering from unexpected risks.

Responding to the call to better understand the mechanism of SCR building and framed by the contextual issues arising from the agricultural supply chain, the overarching purpose of this study is to advance the knowledge in supply chain resilience beyond the traditional risk management and static resilience approach. More specifically, this study explores how organizations make decisions on resource investment and build SCR capabilities during risk recovery and discovered how the supply chain co-evolves with its environment in terms of SCR building through analysing the organization's resources investment configuration strategies. Building on the conservation of resources theory and ambidexterity theory, a novel resilience-building framework was revealed, and a theory of Resilient Resource Based View (RRBV) was developed.

This thesis presents the empirical findings drawn from multiple case studies within four Chinese leading pig production organisations, focusing on their risk mitigation processes. The result of this study highlights that the stress of resource uncertainty or loss may trigger organizations to engage in different resource management strategies. The organization achieves SCR by investing on different bundles of resources considering three resource factors within their supply chain, the resource Valence (appropriateness), the Resource availability of existing resource caravan and the complementarity of future invested resources toward the existing resources. Subsequently, two resource management strategies, knowledge-based resource management strategy and relationship-based resource management strategy were identified to enable organizations to replenish the loss of resources. During the resource accumulation and acquisition process, organizations focus on either vertical integration and knowledge management capability building or supplier integration to construct highly resilient systems.

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Finally, I wish to thank the Economic and Social Research Council which funded this studentship.

Declaration

I, the author, confirm that the Thesis is my own work. I am aware of the University's Guidance on the Use of Unfair Means (www.sheffield.ac.uk/ssid/unfair-means). This work has not previously been presented for an award at this, or any other, university.

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List of Acronyms

SCR	Supply chain resilience
SC	Supply Chain
UN	United Nations
RRBV	Resilient Resource Based View
SCRM	Supply chain resilience management
ABS	Chartered Association of Business Schools
RBV	Resource Based View
DC	Dynamic capabilities
SEM	Structural equation modelling
COR	Conservation of Resources Theory
PRRS	Porcine reproductive and respiratory syndrome
COFCO	China Oil and Foodstuffs Corporation
RMB	Renminbi
CNY	Chinese Yuan
ERP	Enterprise resource planning
EAS	Enterprise Application Suite
KPI	Key Performance Indicator
IoT	Internet of Things

Chapter 1. Introduction

1.1 Problem Statement

According to United Nation's (UN) report on disaster risk reduction, the annual number of high-risk events worldwide almost tripled between 1980 to 2014, from around 350 to over 1,000 (UN, 2015). Business Continuity Institute's survey on supply chain resilience revealed that 75 per cent of companies had experienced at least one disruption in 2013, spanning from equipment malfunctions, unforeseen supply disruption, and information technology collapse due to natural disasters (Business Continuity Institute, 2013). The risks exposed by sudden-onset natural and man-made disasters are on the rise globally and the significant impacts are severe and widespread. This has stressed the necessity for the supply chain and community to be better prepared and be able to recover rapidly from sudden and unexpected disruptions and still perform efficiently (Cimellaro et al., 2010). Creating more resilient supply chains may provide a better approach to manage and mitigate those risks and challenges facing businesses today and in the future. In a recent editorial on organisational resilience published by the Academy of Management Journal, editors have raised the question of why some organizations are able to successfully rebound from and even thrive after adverse events while others fail to do so. Research on the role and functioning of organizations has been called to better manage the devastation of these disastrous events and ultimately benefit society as a whole (Van der Vegt et al., 2015).

Within agricultural supply chains, risks are inherent and varied. This is caused by a range of factors including current climate sensitivity, the sensitive nature of biological processes, the complex structure of the industry, the pronounced seasonality of production and adverse changes in market prices, the geographical separation of production and end uses, and the unique social and economic uncertainty of food and agriculture sectors, both domestic and international (Jaffee et al., 2010). Generally, emphasis has been put on the impact of one type of risk facing particular stakeholders (e.g., climate change facing farmers; market price fluctuation facing traders). However, within agricultural supply chains, stakeholders are frequently interdependent and interconnected and need to check and cope with multiple risks at the same time or on a simultaneous basis (Jaffee et al., 2010).

To understand the relationships between resilience and the agri-food supply chain, some of the current conceptualisations of the food systems and agri-food supply chains need to be clarified. Food systems can be seen as coupled social ecological systems with the integration of humans and the environment or nature (Ericksen, 2008). It involves activities including food production, processing and packaging, distribution and retail, and consumption (Ericksen, 2008). All encompass social, economic, political, and environmental processes and dimensions. Agri-food supply chains are composed of processes of production, distribution, processing, and marketing of agricultural products that bring agricultural products from the farms to the tables to satisfy the final consumers (Aramyan et al., 2006).

Some of the typical characteristics of food supply chains are summarized as shelf-life constraints, long production lead times, seasonality in production, variability of quality and quantity of farm-based inputs, requirements for conditioned transportation and storage, variable process yield, need for traceability and restricted storage buffer capacity (Van der Vorst, 2000). These characteristics not only add complexity to the food supply chain but also are drivers of risks. For example, some drivers of complexity in the food supply chain are identified including "low cost and lean supply chains, availability of less stock when disruption occurs, reduced control over the process due to global supply chains and the difficulty in allocating resources for risk mitigation" (Peck, 2006). Moreover, the above complexities coupled with a complex supply network among different actors make it even more difficult to manage such a dynamic supply chain and the risks associated with it (Sheffi and Rice, 2005). So, a holistic framework of Supply Chain Resilience (SCR) framework is required to better illustrate time bound process geared toward providing an assessment of system-wide of key vulnerabilities in the agricultural supply chain and a deep understanding of key resources and capabilities, which require prioritised attention and investment to deal with the uncertainties facing agricultural supply chains.

1.2 Research Objectives

Most of the influential publications on Supply Chain Resilience (SCR) are conceptual in nature or modelling based, there is a lack of empirical research (Linnenluecke, 2017). To address this gap and explore the topic, which is timely and interesting both theoretically and practically, taking a social ecological resilience perspective, the overall aim of this research is to *understand supply chain system dynamics in the agri-food sector during unforeseen risk events and develop a resilient supply chain resources theory*. This is further divided into two objectives for this study:

Explore and advance understanding of **How organizations make decisions on resource investment and build SCR capabilities during risk recovery?**

Discover **how the supply chain co-evolves with its environment in terms of SCR building by analysing the organization's resource change and resource investment configuration strategies.**

This study takes organizational resources as a unit to observe since the organization is where resources are gathered. When risks occur, disruption happens when there are insufficient resources within the organization and its supply chain. It acknowledges that an organization and its supply chain need to adapt over time to remain smooth operation and production, which requires the organization to invest in resource configuration and building resilience for adaptability and transformability. Through tracking the dynamic change of resources when risks happen, this research reveals the evolutionary processes which allow firms to not only adapt to new circumstances but also transform to a more desirable status in a turbulent and uncertain environment (Davoudi et al., 2013; Evans, 2011; Gunderson, 2002). That is why understanding the principles of resource management strategy is essential to understand how organizations build resilience and successfully mitigate sudden supply chain disruption.

This study contributes to the SCR literature in the following ways: first, it is one of the first attempts that applies both conservation of resources and ambidexterity lenses to investigate SCR, which builds a theory of Resilient Resource Based View (RRBV). Second, the empirical research on SCR is still in its infancy (Kamalahmadi and Parast, 2016), this study explores SCR development in an agri-food context. Third, taking a social ecological resilience thinking, this study examines the system dynamic co-evolution and resource configuration process between the agri-food supply chain and its environment. The value of the supply chain not only depends on the capabilities, interrelation and process happening within a supply network but also is related to the dynamic reaction with the external environment or agents. Through achieving resilience, supply chains and ecosystems may share the same value, or they are going through similar co-value creation processes. The resilience capabilities or processes in the supply chain may help to achieve social ecosystem resilience. Finally, this research overcomes traditional supply chain static and reductionist assumptions and provides a dynamic view to analyse how a firm changes its supply chain structure and processes as a result of both internal dynamics and external interactions in the complex world over time (Wieland, 2021).

In practice, the research could potentially provide some exemplar cases of the agri-food supply chains in China, which could be learned by firms in other emerging economies to improve their SCR. Also, "Resilience is the ability to know where, how and when to use your energies to improve” (Daniel, 2008:61). This research provides supply chain practitioners with new insights into their own resilience improvement processes and may lead to sustainable development of the whole industry. Last but not least, this research produces significant supply chain policy implications for policymakers in agri-food sectors.

1.3 Structure of This Thesis

This thesis is structured across eleven chapters in total. Figure 1.1 presents the structure of the thesis. The thesis starts with an introduction with explains the significance and objectives of this research. Chapter 2 presents a review of existing research in the field of resilience. key concepts and theory development in resilience have been examined to identify the theoretical position of this research. The theoretical gaps are identified. Chapter 3 explains the author’s philosophical perspective and research approach and methods. In Chapter 4, a detailed overview of the background and the structure of the Chinese pig supply chain is given. Also, major risks embedded in the pig supply chain are highlighted. Chapters 5 to 8 provide the single case analysis of Muyuan, Lihua, Hanshiwei and Nanchuanhe on what resource management strategies were adopted to mitigate various risks. In Chapter 9, cross-case analysis is provided to compare the similarities and differences among the four cases. Chapter 10 presents the findings and discussion of the empirical research process, based on the evidence derived from four case studies. The empirical findings are aligned with that of extant literature, to answer the research objectives. Chapter 11 summarizes the findings and provides an overview of the insights gained from the research. The theoretical and practical implications of the research are highlighted. The limitations of the study are concluded and future directions for research are recommended.

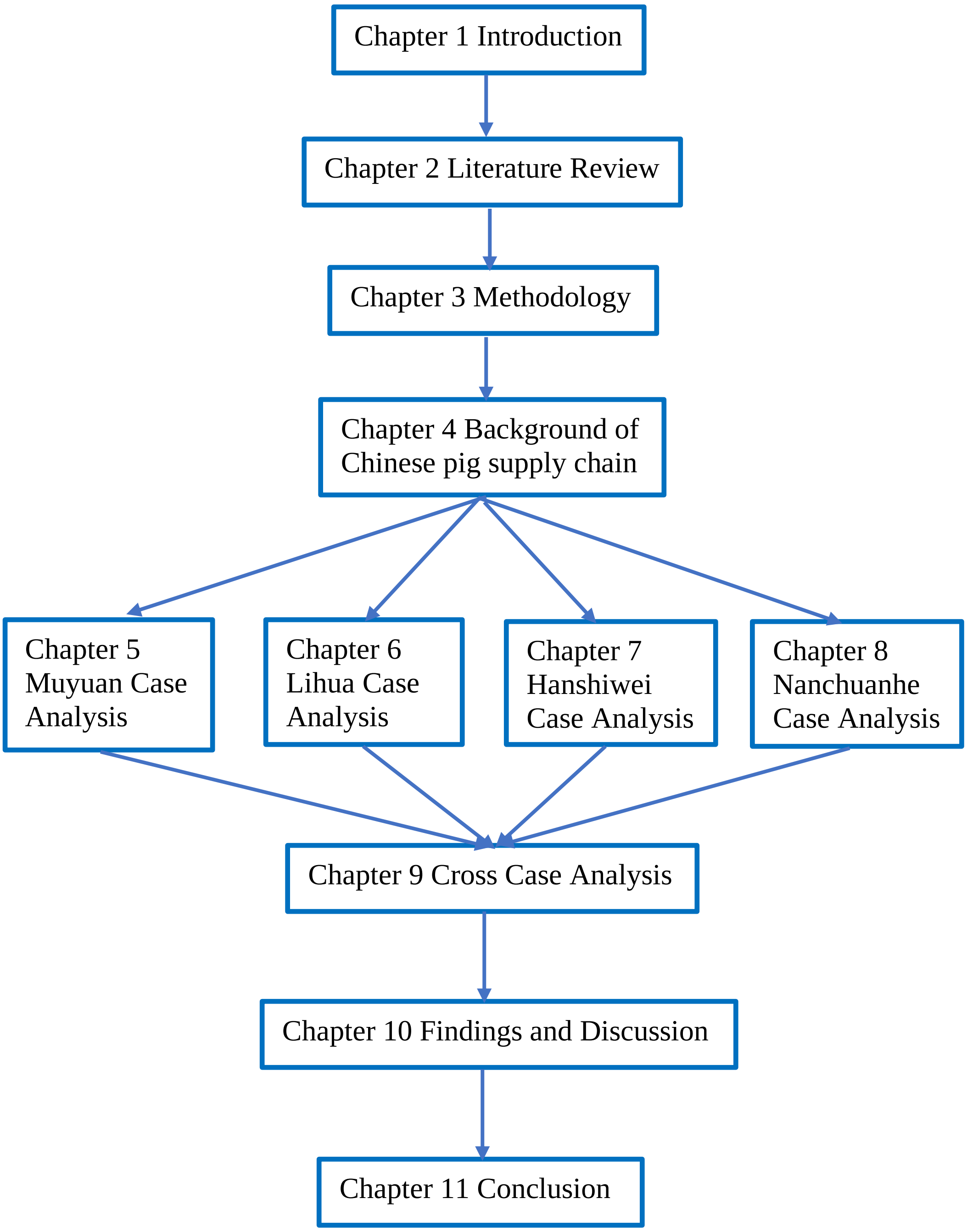

Figure 1.1 The structure of the thesis

Chapter 2. Literature Review

This chapter aims to provide a review of relevant literature pertaining to the general topic of supply chain resilience management (SCRM) where this research is positioned. An overview of SCR concepts and theory including definitions and a range of key issues in managing a supply chain is given and discussed.

2.1 Two Approaches of Supply Chain Uncertainty Management

The supply chain uncertainty issue is derived from the increasing complexity of the supply chain network. Wildavsky (1988) concluded that two strategies were important in responding to potential uncertainties: (1) anticipation (or stability) as a strategy for assessing hazards and avoiding potential risks. This risk management approach is the conventional way to handle uncertainty; (2) resilience as "the capacity to cope with unanticipated dangers after they have become manifest, learning to bounce back" (p. 77). This definition was originated from development perspective and suggested that resilience is a generalized capacity to positively rebound from unexpected adversity, and it requires activating, combining, and recombining the overall capabilities and resources.

2.1.1 Risk management approach

Unexpected incidents and events may occur in supply chains, which might affect the normal or expected flow of materials, information, operation, and finance (Svensson, 2002; Wu et al, 2007). These unexpected events have caused increasing vulnerabilities in the supply chain and have been principal concerns in supply chain management. Vulnerability is defined by Svensson (2002:17) as "unexpected deviations from the norm and their negative consequences inside or outside of the supply chain". Christopher and Peck (2004) defined supply chain vulnerability as "the susceptibility of the supply chain to the likelihood and consequences of disruptions". Sheffi and Rice (2005:42) explained that "vulnerability can be measured in terms of risk as the combination of the likelihood of an event and its potential severity" and is closely linked to supply chain sensitivity, deviation to the expected performance and estimation of risk impacts. Wagner and Bode (2006) stated that it is critical to identify areas of potential vulnerability in the supply chain, in turn, the supply chain risks could be addressed.

Traditional supply chain risk management focuses on developing approaches and systems to identify, assess, mitigate, and control risks (Hallikas et al., 2004). It always involves identifying potential failure points, predicting the frequency and impact of the risks and developing strategies to mitigate the consequences of the crises in the supply chain (Jüttner et al., 2003).

However, cases of potential disruption caused by unexpected natural causes or man-made disasters such as floods, droughts, earthquakes, fires, equipment breakdowns, labour strikes, pandemics, economic crises, or terrorist attacks are becoming increasingly frequent (Sheffi, 2005). The traditional risk management approaches have been challenged for their ability to identify, assess, and control all the risks, especially if some risks are unpredictable or difficult to be identified or assessed due to insufficient statistical information (Fiksel et al., 2015). Meanwhile, the rapid change in an uncertain business environment and the growing complexity of supply chain networks have elevated higher uncertainties (Christopher and Peck, 2004).

In contrast to the traditional supply chain risk management approach that relies mainly on risk source identification and statistical analysis, a resilience approach has been recognized by academics, policymakers, and the industry practitioner community as an important approach to withstand adverse setbacks and avoid or mitigate negative outcomes when facing unexpected disruptions (Ponomarov and Holcomb, 2009; Ates and Bititci, 2011).

2.1.2 Resilience approaches (Static / Dynamic)

Although 'resilience' has emerged as a notion in academic research, business practice, public policy, and media coverage to react, respond and cope with uncertain, volatile, and rapid change, the term resilience has been applied broadly in different disciplines which led to the proliferation of multiple definitions of the concept. Indeed, several authors have proposed the multidisciplinary and multidimensional characteristics of resilience (e.g., Ponomarov and Holcomb, 2009; Bhamra et al., 2011; Ponis and Koronis 2012; Spiegler et al., 2012). Folke (2006) summarized three terms of resilience representing three schools of thought: *engineering resilience*, *ecological resilience*, and *socio-ecological resilience*. The final one has been adopted widely in agri-food supply chain research. Others elaborate on resilience making a distinction between static and dynamic resilience (Folke, 2006). A static resilience perspective aims to "create 'fail-safe' systems that are stable, efficient, and predictable, whereas a dynamic resilience approach embraces change and unpredictability and "designs systems to be safe to fail" (Holling, 1996:33).

The resilience concept originated from physical and engineering science and refers to the ability of the system to bounce back to its original stable equilibrium after a disturbance (Folke, 2006). *Engineering resilience* is a transactional concept where the focal point for management is task-oriented and is one of recovery, constancy, and continuity (Morecroft et al., 2012). Engineering resilience focuses on "behaviour near stable equilibrium and the rate at which a system approaches steady state following a perturbation, i.e., the speed of return to equilibrium" (Folke, 2006:256). Engineering resilience assumes that systems are characterized by a static and predictable single equilibrium status and puts emphasis on efficiency which is the speed of the system to return to its original status. This definition has been adopted by a great number of supply chain researchers (Brandon et al., 2014; Barroso et al., 2010; Sheffi and Rice, 2005; Yao and Meurier, 2012). The faster the supply chain bounces back, the more resilient the system is. Return time is the key index. However, compounded perturbations derived from hazards can have unexpected and highly uncertain effects on ecosystems. Bouncing back to a previous equilibrium may be impossible to achieve in complex ecosystems because they can shift between multiple stable states (Gunderson, 2000). The supply chain may not be able to return to its original status following a disruption, but rather to adapt and robust into a new equilibrium. So, the application of this perspective is restricted and may not represent the true resilience development process. This approach has been largely static, and less attention has been given to the dynamics within and between the stocks and flows, spatial-temporal scales of supply chains, or socioeconomic and ecological dimensions of the metabolism (Meerow and Newell, 2015).

Realizing the limitation of the engineering resilience perspective, incorporating complexity theory and systems theory, Holling (1973) introduced his notion of ecological resilience which is understood as "the magnitude of the disturbance that can be absorbed before the system changes its structure" (Holling, 1996:33). This perspective still focuses on system's ability to resist or withstand shocks (Adger, 2003:1). Holling (1973) considers that a system can absorb a certain amount shock and recognizes that system may keep functioning and reach a new equilibrium following a disturbance, rather than bounce back to previous states. From an ecological resilience perspective, multiple equilibria status is recognized. Ecological resilience focused on the functioning of the system, rather than maintaining a single steady state (Adger, 2000). However, ecological resilience ignores the social elements. The existence of institutions involves the effective maintenance of social capital. The resilience of institutions is not only a matter of the economic relations between them but also is bonded with social capital (Adger, 2000: 351). Thus, the resilience of institutions has to consider the social elements (Adger, 2000). In addition, both engineering and ecological resilience perspectives still imply that there is the existence of one or more systems' equilibrium statutes. The equilibrium-based resilience has the assumption that the world can be seen as orderly and mechanical. The behaviour of the system can be predicted and controlled by mathematical rules (Davoudi et al., 2012). These two resilience approaches have shaped much resilience-building research which largely focuses on risk prevention and control to build a controllable and stable system. However, the nature of the world can be dynamic, complex, and unpredictable (Davoudi et al., 2012). The system may evolve with or without an external disturbance (Scheffer, 2009). So, the resilience of an institution is related to its historical evolution. Recognized that the system may change radically, and social elements should be taken into consideration, *social-ecological resilience* emerged.

The *social-ecological resilience* is defined as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker et al., 2004: 5). In this perspective, resilience is no longer simply about recovery to a new status after being disturbed (Folke, 2006: 7), but instead seen as an emergent property that includes two dimensions. One is the adaptive capacity of the system components such as the capacity to learn from previous experiences and absorb new knowledge, "response to changing external enablers and internal initiatives, and continue to perform" (Berkes et al., 2003: 13). The other one is the transformative capacity such as "the capacity to create a fundamentally novel system when ecological, economic, or social structures make the existing system disturbed" (Walker et al., 2004: 5). From social-ecological perspective, resilience has evolved to allow the system to undertake continuous development, adaptation, and transformation through self-organization, learning, changing, and renewal within a dynamic environment in response to stresses and strains (Carpenter et al., 2005; Anderies et al., 2013), which is largely dynamic in nature. The social-ecological perspective acknowledges that resilience does not happen as the outcome of external disturbance and may not present as a linear and proportional cause and effect relationship. Considering from social ecological perspective, supply chain resilience (SCR) development could be viewed as a self-organizing process which reflects the interplay among supply chain disturbance, supply chain capabilities reorganizing, and internal resources sustaining and development.

The social-ecological perspective of resilience is adopted in this research. The focus of this study is on the agricultural system which should be explored from both social and economic aspects. The agricultural supply chains are naturally embedded with various risks and uncertainties. The building of SCR can influence other stakeholders in the supply chain and the environment it operates. Changes in the environment may happen to require further adaption and different strategies to those previously adopted. The social-ecological perspective of resilience which emphasises inherent uncertainty and discontinuities provides a useful approach to explore the dynamic interplay of how the interdependencies within complex agricultural supply chain work and change. This perspective allows us to consistently capture the dynamic co-evolving change patterns of agricultural organization's supply chains system in response to stresses and strains caused by sudden risk events, which is the research question of the study.

2.2 Supply Chain Resilience (SCR)

Over the years, the concept of resilience has been applied to organizational management literature to study organizational responses to external threats (Meyer et al., 1990; Wildavsky, 1990). At the organizational level, resilience enables firms to develop capabilities to anticipate, resist and recover from traumatic events, shocks or disasters (Coutu, 2002). By studying supply chain risks and vulnerabilities embedded in an organization and its upstream and downstream network, Christopher and Peck (2004) extended the logic of organizational resilience to the supply chain level. Supply chain resilience management involves designing a supply chain (across the organization and its upstream and downstream network) and developing various capabilities to efficiently anticipate, prepare for, respond to, and recover from risks (Christopher and Peck, 2004).

A firm may improve its market position as a result of proper responses to disruptions. SCR "encompasses the ability to prepare for unforeseen disruptions and to respond and recover from them better than competitors do" (Rice and Caniato, 2003; Christopher and Peck, 2004; Jüttner and Maklan, 2011; Chopra and Sodhi, 2014). SCR building can go through preparation for an unexpected event, response to disruption and recovery from the event. Later, Benjamin et al. (2015) identified a further stage – growth, which implied that the supply chain may adapt and further transform by learning and changing. However, Hendricks and Singhal (2005) found that firms often do not react and recover quickly enough from the negative consequences of the disruption, which have a significant negative impact on the company's both short and long-term operational and financial performance. Therefore, designing a resilient supply chain can be crucial both to short-term and long-term competitive advantage (Hamel and Valikangas, 2003; Yao and Meurier, 2012).

2.2.1 Definitions

Based on different resilience perspectives, various researchers have different definitions of SCR. There is still a lack of consensus on the definition of SCR (Mensah and Merkuryev, 2014). Taking an engineering resilience perspective, Christopher and Peck (2004) first proposed the definition of SCR, which is "the ability of a system to return to its original state or transfer to a new or more desirable state after being disturbed". Similar to Christopher and Peck (2004), Rice and Caniato (2003) defined SCR as "the ability of the supply chain to react to a disruption or disturbance and restore normal operations". In the same vein, Cardoso et al. (2015) and Sheffi (2005) emphasized SCR as the ability of a supply chain to return to its original state. These definitions are largely according to the notion of static engineering resilience perspective, emphasizing recovery speed and costs.

Many researchers have taken the evolutionary view of resilience to reframe and explore the SCR phenomena (Ponomarov and Holcomb, 2009; Ambulkar et al., 2015; Tukamuhabwa, 2015). These studies highlighted the importance of building a capacity or capability to seize the opportunities that always arise during a crisis to develop a stronger supply chain than what it was before (Seville, 2008). For example, Ponomarov and Holcomb (2009) defined SCR as "the 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 structure and function." Adaptation means a supply chain has the potential ability to develop different responses to accommodate the nature of the uncertainties it faces. This implies that the supply chain's elements may improvise to provide a proper response to a disruptive event instead of selecting from a pre-defined set of responses. This definition is also aligned with Benjamin et al.'s review (2015) that resilience building may encompass a growth stage. The adaptive capability matches the nature of disruptive events, which might be unpredictable, inherent to the supply chain, and coevolving with the supply chain's responses. It allows the supply chain to absorb and utilize the change, explore, and develop proper strategies and behaviours in response to disturbance. The supply chain may learn from disruptive events and corresponding responses and develop new capabilities rendering it more resilient to future similar uncertainties. It is claimed that SCR can create a sustainable competitive advantage by continuously adapting, developing capabilities, and learning to make a supply chain more resilient (Hamel and Välikangas, 2003). In today's highly volatile business environment, organizations in the supply chain focus more on keeping a dynamic equilibrium than returning to its initial state after a perturbation (Dauphiné and

Provitolo, 2007). Resilience equips the system to develop autonomously. A resilient supply chain can absorb the effect of disturbances and regain normal functions following a disturbance (Yao, and Meurier, 2012). Natural selection is responsible for its adaptation to a variable environment.

For this paper, adopting a social ecological perspective, emphasizing a dynamic co-evolution view, and building on Walker et al. (2004), we, therefore, define SCR *as the capacity of a supply chain to absorb disturbance and reorganize in a timely and resource effective and efficient manner while undergoing change so as to still retain essential continuity of operations at the desired level of connectedness and control over structure and function*. An important aspect of this conceptualisation is the recognition that the SCR is capacity rather than capability, and it could be enhanced by improving the performance of overall capabilities. This definition suggested that the supply chain may not bounce back to its previous status after turbulence, Instead, through using internal and external resources to adjust and adapt, the supply chain may not only keep operational continuity but also evolve and grow from the event.

In the context of agriculture, a resilient supply chain implies the capacity to continue to provide a function over time despite disturbances. It is not to achieve a single optimal, steady state. Rather, it entails a continuous absorption, adaptation, and transformation to enhance the performance of the food system, thus forming an essential part of what enables sustainability. "Assurance of resilience requires the integrated engagement of supply chain actors at all stages of food production, distribution, financial control and information exchange to limit vulnerability, external and internal risks" (Manning and Soon, 2016).

2.3 Bibliometric Analysis of Supply Chain Resilience Literature

The emergent SCR has been growing for almost 20 years. The concept of SCR management has received more attention in the past decade and has risen to prominence in recent years because of the increasingly turbulent, uncertainty in the business environment and market dynamics, especially after the financial crisis in 2008 and Covid 19 pandemic. A wide range of SCR studies focusing on different aspects have been carried out such as a literature review to show the evolution of SCR (Kamalahmadi and Parast, 2016), the capabilities required to achieve SCR (Scholten et al., 2014), proactive and reactive resilience strategies for the ex-ante/ex-post disruption stage (Hohenstein, et al., 2015), resilience strategies such as developing suppliers' relationships, redesigning supply chain structure and enhancing the cooperation between competitors (Juttner and Maklan, 2011; Johnson et al., 2013; Scholten and Schilder, 2015), organizational resilience in certain types of organization (such as small medium enterprises) (Bhamra et al, 2011) and the role of procurement to achieve SCR (Roberta Pereira et al, 2014). Due to the multi-disciplinary nature of SCR, the research of SCR draws on a broad swathe of disciplines such as business management, engineering, decision science, social science, environmental and agricultural science. Each study has provided valuable insight into SCR literature.

To map out the current characteristics and knowledge structure of SCR, identify potential research gaps and highlight future research directions, a systematic literature review combined with mathematical and statistical analysis, bibliometric and network analysis is used to evaluate the relevant SCR literature and understand distinct research fields through identifying themes of various clusters.

2.3.1 Research methodology

The systematic literature review is a well-established evidence-based review approach in management research (Tranfield et al., 2003; Denyer and Tranfield, 2006). Through identifying, selecting, analysing, and integrating the relevant articles, the systematic review could enable researchers not only to map and assess existing intellectual territory (Tranfield, et al., 2003) but also give a critical overview of the existing knowledge in a field of enquiry to specify the research gaps and develop the knowledge further (Cooper, 2003; Denyer and Tranfield, 2009). For this research, the SCR literature is reviewed.

The literature review started with identifying and selecting the most relevant papers from the Scopus database. Then a bibliometric analysis was conducted which includes citation analysis and co-citation analysis (Pilkington and Meredith, 2009; Sánchez-Riofrío et al., 2015) considering author influence, journal quality, and keyword statistics to identify the papers that most contributed to theory-building in the field. Citation analysis is used to identify heavily cited articles and major changes in research directions based on citation rates of cited references (Pilkington and Meredith, 2009). The co-citation analysis illustrates the major themes of the knowledge field based on linkages among the cited references (Leydesdorff and Vaughan, 2006). Finally, a content analysis was conducted to provide insights into current research interests and directions for future research in the field. The flowchart for the literature review and analysis process is shown in Figure 2.1.

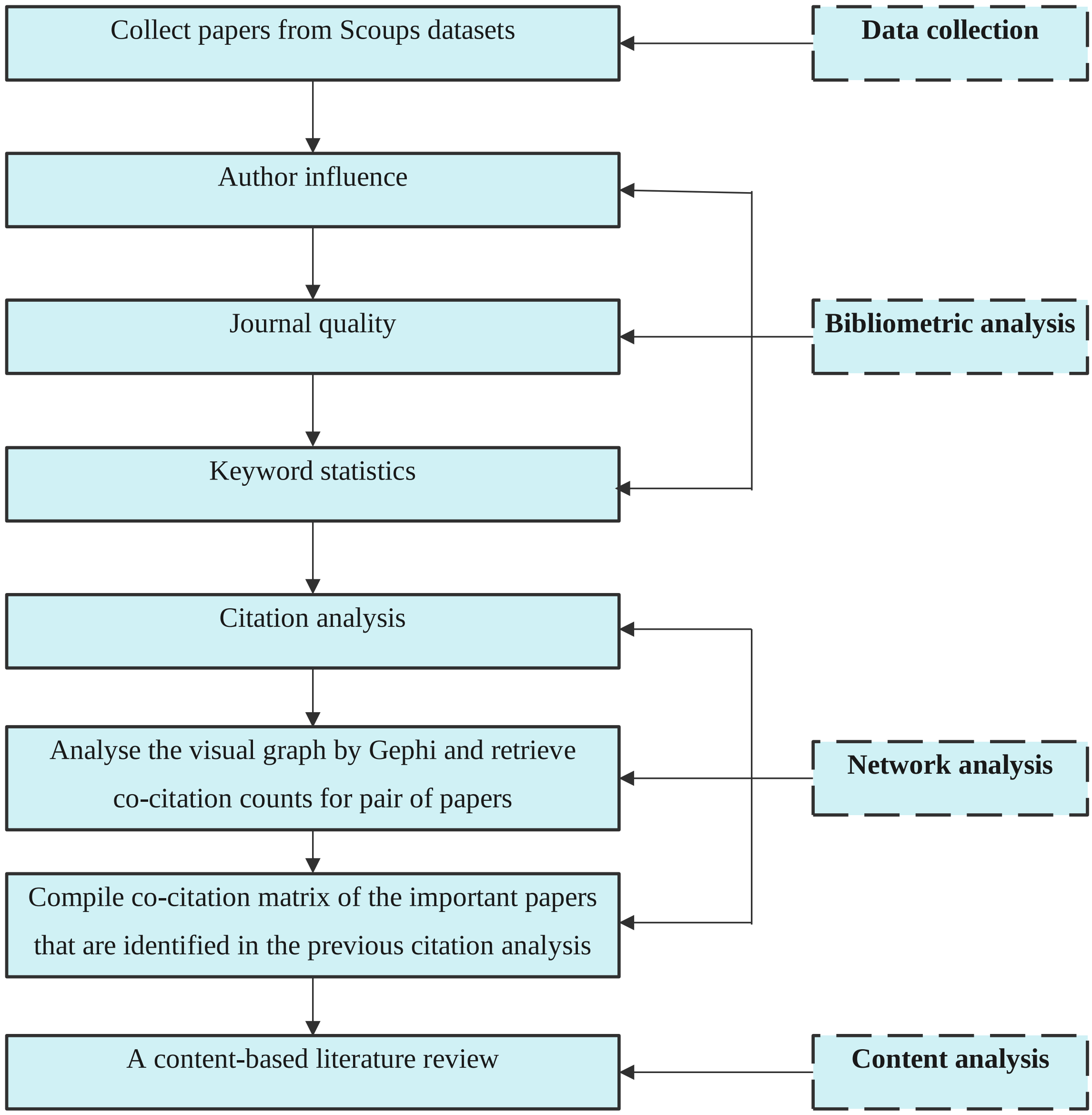

Figure 2.1 Steps for literature review

2.3.2 Defining the appropriate search terms

This review adopts the Scopus database, which is regarded as the largest database for peer-reviewed literature (Hassini et al., 2012). This allows the researcher to collect comprehensive literature related to SCR. To collect the relevant literature, this systematic literature review has been conducted systematically, following steps of identifying keywords, selecting inclusion and exclusion criteria, assessing the quality of data and extracting the data (Tranfield et al., 2003).

First, the identification of the keywords was built by means of reading relevant literature, brainstorming and empirical experience of the author and supervisor teams. Two search strings were identified for SCR. One is resilience related. Resilien* (resilience and resilient) were used as the focal keyword in the research of articles related to resilience. The other string is supply chain related terminologies such as “supply chain*”, “supply network”, “value chain”, “logistics”, “inventory”, “procurement”, “purchasing” or “sourcing”. These two search strings then were combined using Boolean logic ‘AND’. Table 2.1 shows the search strategy for this literature review.

Boolean Logic	**Searching strings for literature review**	
AND	**Supply chain Related**	**Resilience Related**
	“supply chain*” OR “supply network” OR “value chain” OR “logistics” OR “inventory” OR “procurement” OR “purchasing” OR “sourcing”.	Resilien*

Table 2.1 Searching strategy for literature review

2.3.3 Search results

10,325 document results were collected through an initial “article title, abstract, keywords” search using the defined search terms in the Scopus database, with an open starting time to trace back to the origin of SCR research up to 14th May 2022. Subsequently, by limiting parameters such as subject area (Business management, multi-discipline, and decision science), source type (article and review) and language (English), 1,483 relevant articles remained. We intentionally only kept articles published in 2 stars and above journals listed in The Chartered Association of Business Schools (ABS) list. Because articles published in 2 stars above journals can be seen as internationally recognized peer-review papers with good quality. After reviewing the titles and abstracts and reading the full paper by applying inclusion and exclusion criteria (see Table 2.2), ultimately, 206 articles were selected for final review.

Inclusion criteria	**Exclusion criteria**
Focus on both supply chain management and resilience	Supply chain management not related to the resilience concept
Peer-reviewed journal paper in English	Resilience development not related to supply chain management
	Non-English language journals

Table 2.2 Inclusion and exclusion criteria

2.3.4 Descriptive analysis

As shown in figure 2.2, the number of articles published has changed over time with an upward trend since 2004. Especially, the number of articles has sharp increase since 2019 showing a growing number of interests from the academic community of SCR. This may be due to the impact of a sudden outbreak of the Covid 19. The Covid 19 pandemic has challenged the effectiveness of the traditional crisis planning approach and reshaped the thinking towards SCR.

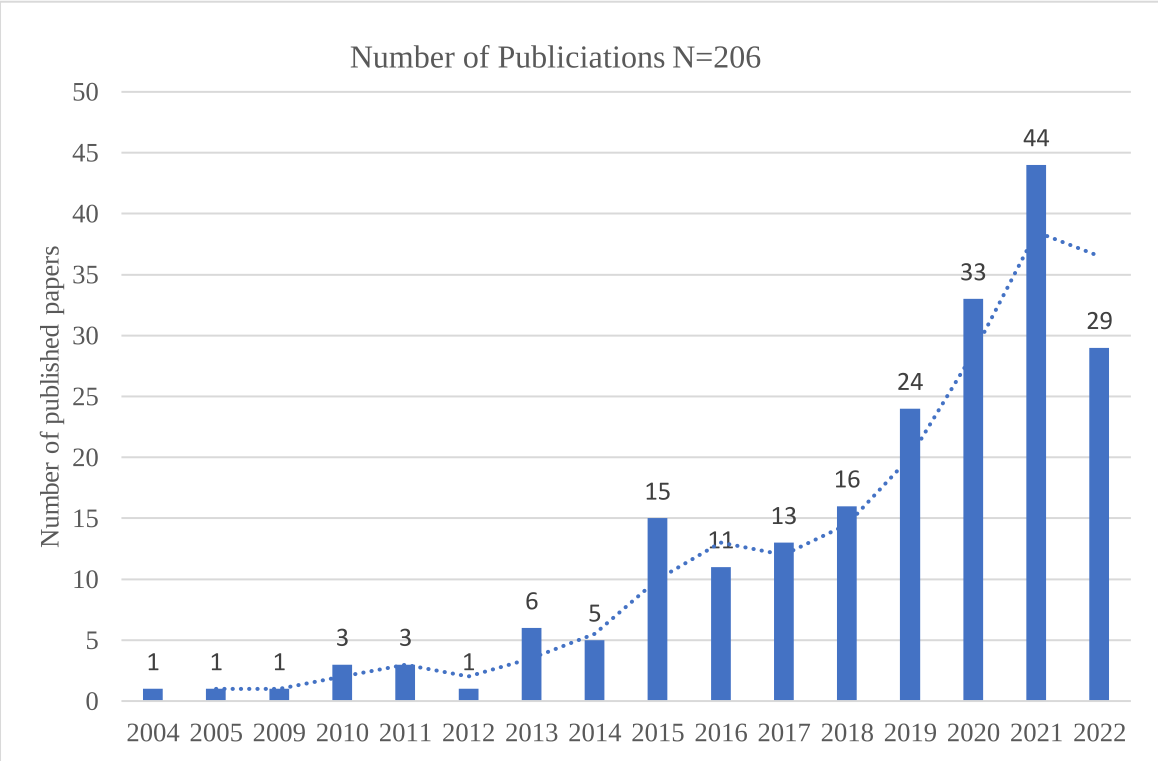

Figure 2.2 Publishing trend in supply chain resilience management

Figure 2.3 shows the research methodology used in the 206 sample articles. The modelling method appears to be the prevalent research method adopted by SCR researchers, which accounts for 36.4% of overall articles. Survey is also widely used. It is interesting to see there are 21 literature review papers which tried to explore the research trend in SCR and generate future research areas and directions.

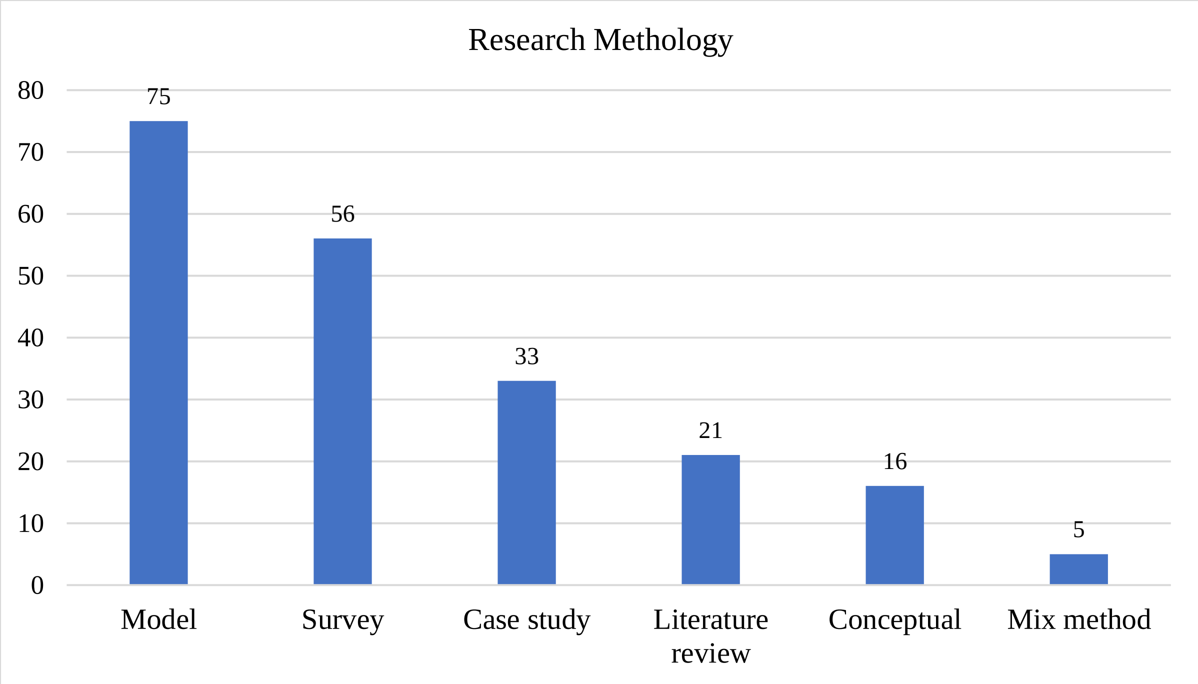

Figure 2.3 Research methodology adopted

Table 2.3 summarized the theoretical lenses adopted in SCR research. Various theories have been used to explain the SCR phenomenon. Among them, Resource based view (RBV) and Dynamic capabilities view (DC), and Systems theories are the most used theories.

Theoretical lens	Exemplar studies
Resource based view	Brandon-Jones et al.,2014; Cheng & Lu, 2017; Chowdhury et al., 2019; Drozdibob et al., 2022; Liu et al., 2018; Tan et al., 2022;
Dynamic capability view	Abeysekara et al.,2019;Ali et al.,2022; Altay et al., 2018; Azadegan & Dooley,2021; Bag et al., 2019; Brusset & Teller, 2017; Chowdhury & Quaddus, 2017; Dabhilkar et al., 2016; Golgeci & Ponomarov, 2013; Hendry et al., 2019; Iftikhar et al., 2022; Kähkönen et al., 2021; Lee & Rha, 2016; Nikookar & Yanadori, 2022; Pereire et al., 2022; Rajesh, 2017; Ruel & El Baz, 2021; Silva & Ruel, 2022; Um & Han, 2021; Umar et al., 2020; Vanany et al.,2021; Yu et al., 2019;
System theory	Blackhurst et al.,2011; Hosseini et al., 2020; Pournader et al., 2016; Tsolakis et al., 2021;
Complex adaptive system theory	Massari & Giannoccaro, 2021; Tukamuhabwa et al., 2015; Yaroson et al., 2021;
Contingency theory	Birkie et al., 2017
Relational view	Münch & Hartmann, 2022; Wieland & Wallenburg, 2013;
Social capital	Gölgeci & Kuivalainen, 2020; Johnson et al., 2013; Polyviou et al., 2020; Verghese et al., 2019;

Information processing theory	Bag et al., 2021; Belhadi et al.,2021; Gu et al., 2021; Jain et al., 2017; Modgil et al.,2022; Wong et al., 2020;
Ambidexterity theory	Bin Makhashen et al., 2020;
Network theory	Choudhary et al., 2021; Ekanayake et al., 2021 Massari & Giannoccaro, 2021; Reyes & Nof, 2015a; Reyes & Nof, 2015b;
Resource orchestration theory	Chunsheng, et al., 2020; Queiroz et al., 2022;
Resources dependency theory	Spieske et al., 2022;

Table 2.3 Summary of theoretical lenses applied in supply chain resilience research

Adopting systems theory, Ruel et al. (2021) asserted that supply chain resilience should not be seen only from the traditional perspective, as a closed system (back to normal), but rather as an open system that can adapt and survive severe disruptions and changes. In this sense, authors like Erol et al. (2010) and Blackhurst et al. (2011) studied the supply chain as an open system. Components of a supply chain (such as humans, capital, information, materials, financial resources etc.) form various subsystems which are part of a larger system of supply chain or network. Each subsystem may be vulnerable to disruption caused by environmental events which result in a larger supply chain failure (Blackhurst et al., 2011). Tukamuhabwa et al. (2015) provided a comprehensive, structured review of the available literature on SCR and proposed Complex Adaptive Systems (CAS) theory as an appropriate lens for studying SCR. Hosseini et al. (2020) offered the exploration of the methodological similarities between basic cybernetic principles and SCR, which leads to an explicit quantification of SCR in an open-system context. Pournader et al. (2016) built and tested an analytical model for resilience assessment surrounding supply chain risks at the level of the supply chain system and its tiers. Tsolakis et al. (2021) identified the structural interconnections among the SC governance and resilience constructs in networks. It can be seen that much of the literature adopting system theory is either conceptually based or structural functionalism focussed. A key assumption of systems theory is that an individual's problems are symptomatic of structural and interactional difficulties in a larger system (Minuchin, 1974).

Most of the studies adopting system theory described how SC structure and ties can influence SCR or developed SCR measures considering the interconnection of systems. However, an individual's issues such as organizational functions have not been adequately and empirically explored within present studies. In this study, I also recognized that a resilient supply chain has developed as an open complex social ecological system consisting of sub systems with multiple interactions among their parts or agents and with their environment in an adaptive way. The essential components of the supply chain as an open system including flows (Buckley, 1967), flow units (Bertalanffy, 1950), and sources of flow units (Scott and Davis, 2003) both individually and collectively influence the SCR. In this sense, the system thinking for supply chain resilience can demand different approaches for the management of the scarce resources of firms during radical changes imposed by a severe crisis. I take resource management as the angle to study the supply chain system change and recognized that SCR is created by combining both tangible (i.e., physical capital resources) (Williamson, 1975) and intangible resources (i.e., human capital) (Becker, 1964) and organizational and interorganizational capital resources (Tomer, 1987), which is consistent with the RBV of the firm (Barney, 1991). This study explored the SCR phenomenon specifically from a resource management perspective taking both organization's behaviour and supply chain structure into consideration. The motivation of organizations to invest in resilience and what ambidexterity capabilities organizations build in the process of achieving SCR are considered to address the limitation of the structural functionalism focus of current system theory studies.

In SCR research, RBV advanced the notion that SCR could be achieved through integrating unique resources (Blackhurst et al., 2011). Adopting the RBV, existing resilience studies focused on understanding the relationships between specific resources and performance in terms of supply chain resilience. Factors such as information sharing and connectivity (Brandon-Jones et al., 2014), risk management culture, agility, integration, and supply chain reengineering (Liu et al., 2018), operating frontier, trajectory, and absorptive capacity (Cheng & Lu, 2017), organizational ethical climate and information security culture (Tan et al., 2022) have been explored. Specifically, Cheng and Lu (2017) suggested that the proactive and reactive dimensions of SCR, as part of the coping strategy of the supply chain, could be effectively improved by enhancing trajectory, absorptive capacity, and operating frontier capabilities. Liu et al. (2018) empirically examined the relationship between firm performance and constructs of SCR consisting of a risk management culture, agility, integration, and supply chain reengineering using data from the Taiwanese liner shipping industry. Tan et al. (2022) demonstrated pathways to supply chain resilience (SCR) during information sharing by deploying organizational ethical climate and information security culture as non-punitive mitigation approaches.

Despite the prevalence of RBV within the extant literature, some scholars argued that RBV suffers from "context insensitivity" (Ling-yee, 2007). This suggests that it is unable to identify the conditions in which resources may be most valuable (Ling-yee, 2007). Contingency theory addresses this notion of contingent conditions and argues that internal and external conditions will influence how to manage an organization or supply chain (Grotsch, et al., 2013) and subsequently may affect the resources or capabilities needed to drive performance under diverse conditions. The RBV argues that organizations may achieve competitive advantage through the bundling of resources to create capabilities (Barney, 1991), while the contingent RBV suggests that this is dependent on certain conditions. Contingent based resource-based theory addresses the contextual insensitivity of the traditional RBV (Ling-Yee, 2007) and suggests that firms develop adaptive capability during the phase of the changing environmental scenario in which they exist (Donaldson, 2001). Underpinning this perspective, some studies leverage a contingent RBV to show how contingency factors such as supply base complexity (Brandon-Jones et al., 2014), supply chain relational practises and network complexity (Chowdhury et al., 2019), natural disasters (Drozdibob et al., 2022) influences resilience outcomes. Chowdhury et al. (2019) considered two exogenous context variables (supply chain relational practices and network complexities) and studied their moderating roles in the relationship between SCR and supply chain performance. Brandon-Jones (2014) investigated the relationship between specific resources (information sharing and connectivity, visibility) and performance in terms of supply chain resilience and robustness.

However, both the resource-based view and contingent resources-based view have been criticized for their firm focuses and does not go beyond the organizational boundary. Also, Resource based view assumes reasonably stable environments where the future value of resources can be determined (Kraaijenbrink et al., 2010). Being static and sustaining competitive advantage is unlikely in dynamic markets. Stemmed from a rapidly changing business environment, resilience has become one of the supply chains' critical properties. However, the resource-based view fails to address the influence of environmental dynamism and firm evolution over time. The Dynamic capabilities (DC) perspective addresses the limitations of the resource-based view while addressing issues concerning varying environmental dynamism. It argues that capabilities for enhancing SCR should be adapted, integrated, or modified constantly to match environmental changes (Teece, 2007). It is thus an extension of the traditional resource-based view (RBV) of the firm (Wernerfelt, 1984; Barney, 1991). This explains why DC was the most adopted theoretical lens applied in SCR research in the previous analysis (Table 2.3). The essential components of the DC relate to identifying strategic organizational processes, reconfiguring resources (integrating, gaining, and releasing), and identifying the path to follow to attain competitive advantage (Teece et al., 1997; Eisenhardt and Martin, 2000).

Aligning the Dynamic capability perspective, various SCR researchers made effort to identify key SCR capabilities and characteristics, such as agility (Christopher and Peck, 2004), visibility (Chopra and Sodhi, 2004), efficiency (Sheffi and Rice, 2005; Rice and Caniato, 2003), flexibility (Tang and Tomlin, 2008; Colicchia et al., 2010), redundancy (Craighead et al., 2007, Zsidisin and Wagner, 2010), velocity (Wieland and Wallenburg, 2013), supply chain structure (Hong and Choi, 2002), and collaboration (Sinha et al, 2004, Jutter and Maklan, 2011). Among the studies on SCR capabilities, Christopher and Peck's four resilience principles (supply chain reengineering; collaboration; agility and SCR management culture) have served as the most frequently cited foundation to understand SCR. Recently, Kamalahmadi and Parast (2016) further summarized eight key elements (flexibility, redundancy, trust, information sharing, visibility, velocity, leadership, and innovation) based on findings from a systematic review, which is crucial to create a resilient supply chain. The strategies available for building resilience have been commonly classified into proactive and reactive strategies, depending on whether they are employed to avoid or recover from a threat (e.g., Hohenstein et al., 2015; Dabhilkar et al., 2016; Tukamuhabwa et al., 2017).

Despite the increasing popularity of SCR studies adopting the DC perspective, within the extant literature, it has not yet been fully explored whether certain resources, capabilities or organizational structures should be configured together to achieve resilience, and if so, to what extent they promote resilience and how they need to be configured to achieve optimal outcomes (Linnenluecke, 2015). Many studies have reviewed the SCR literature (Hohenstein et al., 2015; Tukamuhabwa et al., 2017) and have found that generalizability has not been achieved and that a lack of clarity persists regarding SCR. One of the most likely and logical reasons is the diversity of potential disruptions and the capabilities of the specific cases studied. There is still a lack of theoretical understanding of the connotations of both SC capabilities and resilience (Kamalahmadi and Parast, 2016). Hence, this study proposed a new model for SCR capability in the context of the agricultural supply chain, aiming to fill some gaps that exist in the mainstream SCR literature.

I argue that supply chain management is a significant strategic organizational process (Tan et al., 2002) for which resilience (or the lack thereof) must be appraised following a structured path; thereafter, corrective actions can be taken by identifying and integrating appropriate resources. Exploitation and exploration serve as forces which signal and direct tangible and intangible resources and enable firms to have access to and control over those resources flowing through their network. Thus, ambidexterity as a dynamic capability (Jansen et al., 2009; O'Reilly and Tushman, 2008) can make an SC more resilient in effectively dealing with the negative impact of SC disruption. Unfortunately, the association between SC ambidexterity as a dynamic capability and resilient SC, which reduces the negative impact of SC instability, has yet to be comprehensively explicated. Following this argument, this study explored in-depth the SCR capabilities that have been deployed in responding to disruption uncertainties in the agricultural supply chain.

Furthermore, the role of managers in effectively structuring, bundling, and leveraging firms' resources to add value and thus gain performance is missing. Thus, the role of resources and motivation of resources investment for supply chain resilience needs further investigation.

Considering the singular characteristics of the unexpected risks (protraction and unpredictability), it is necessary to review the way the scarce resources of firms and organizations should henceforth be managed (Giunipero et al., 2022). Accordingly, taking both resources conversation of resources and ambidexterity approaches can successfully contribute to resource management in a highly uncertain environment. However, operations and supply chain management and related fields offer little input regarding the role of resources and organizational motivation of supply chain resilience building considering the tremendous impacts of unexpected risks in the context of the agricultural supply chain. Accordingly, the motivation and behaviour of resource orchestration (tangible, intangible, and human) by managers during severe disruptions need to be deeply examined and better understood. This is why this study aims to address these insufficiencies in the literature on the issue. As such, I take conservation of resources and ambidexterity theory as the theoretical lens to investigate what drives managers to convert a set of resources into capabilities to support resilience and how resource reconfiguration and resilience can play a key role in achieving supply chain resilience.

2.3.5 Bibliometric analysis

The Bibliometric analysis provides additional data statistics such as author, journal, keyword etc. In this study, knowledge domain software BibExcel and Pejek (Persson et al., 2009) combining the visualization software of VOSviewer (Van Eck & Waltman, 2013) were used to analyse raw bibliometric data imported from Scopus. BibExcel was used to perform bibliometric and statistical analysis. The result of statistical analysis was processed for further network analysis using Pejek, then graphically presented using VOSviewer.

The original data of 206 articles containing bibliographic information exported from Scopus were input into BibExcel to carry out a bibliometric and statistical analysis. By means of analysis of BibExcel, citation information such as author, publication year, journal, keyword and references and other metrics were extracted from the raw data file. The results drawn from the BibExcel analysis are shown in the following sections.

2.3.5.1 Author influence

Table 2.4 outlines the top 10 contributing authors and the number of papers they published. The most productive authors are Ivanov (10 articles) and Gunasekaran (6 articles). The top 10 authors altogether contributed 24.8 % of all the 206 papers.

Rank	Authors	Number of papers
1	Ivanov, D.	10
2	Gunasekaran, A.	6
3	Hosseini, S.	5
4	Giannoccaro, I.	5
5	Blackhurst, J.	5
6	Ali, I.	4
7	Li, Y.	4
8	Zobel, C.W.	4
9	Rajesh, R.	4
10	Chowdhury, M.M.H.	4

Table 2.4 The top 10 contributing authors and number of published articles

2.3.5.2 Journal quality

The 206 articles were published in 50 journals. 52% of the journals published only one article, and 22% of the journals published 2 to 3 articles. There are 11 journals with 5 or more papers published (Table 2.5). The articles published in the top 11 journals account for 66% of all the 206 papers. In terms of the journal quality for the top 11 journals, the impact factors range from 4.820 to 11.251. All these 11 journals are at least 3 stars in the ABS list and have a high influence on business management and operations management.

Ranks	Journal	Articles	Impact factor 2021
1	International Journal of Production Research	32	9.018
2	Supply Chain Management	26	8.025
3	International Journal of Production Economics	23	11.251

4	International Journal of Physical Distribution and Logistics Management	11	7.290
5	International Journal of Operations and Production Management	11	9.360
6	IEEE Transactions on Engineering Management	11	8.702
7	Production Planning and Control	9	6.846
8	Transportation Research Part E: Logistics and Transportation Review	8	10.047
9	Annals of Operations Research	6	4.820
10	Journal of Business Logistics	5	7.041
10	Omega (United Kingdom)	5	8.673

Table 2.5 Top 10 journals with most supply chain resilience publications

2.3.5.3 Keywords statistics

Table 2.6 shows the most popular words/phrases used in the article title. It is interesting to see “agri-food” and “food” appear in the title list. It implies that the agricultural and food supply chain has been one of the focus areas in SCR research. This is because agricultural supply chains are inherent unpredictable risks which may cause significant losses to the production organizations. Thus, these risks need to be managed carefully.

Words	Frequency
supply chain(s)	74
Risk(s)	64
Food	50
Food supply chain(s)	28
Case	25
Agri-food	19
Resilience	18
Management	18
Model	17
Study	17

Table 2.6 Top 10 words/phrases in the title

The top 15 keywords used in the paper are summarized in Table 2.7. The keywords of “Risk management (15)”, “Risk assessment (14)” and “decision making (19)” are listed at the top. There is an implication that the traditional risk management approach is still dominated SCR research. Through the comparison of popular words in the title and the keywords in the text, it can be noticed that there is some consistency in both lists. For example, both lists include supply chain and resilience. It may occur because these words were the search keywords chosen in this study.

Keywords	Frequency
Supply chains	73
Supply chain resilience	53
Supply chain management	30
Resilience	24
Decision making	19
Risk management	15
Risk assessment	14
Structural equation modeling (SEM)	10
Supply-chain disruptions	10
Disasters	10
Supply chain risk management (SCRM)	9
Dynamic capabilities	9
Supplier selection	8
COVID-19	8
Supply chain network	8
Stochastic systems	8

Table 2.7 Top 15 words/phrases in the keywords

2.3.6 Network analysis

Network analysis was carried out to further explore the relationship among the 206 sample articles and their references using the software Pajek (Batagelj and Mrvar, 2007). Bibliometric network data such as citation relations between publications or journals, collaboration relations between researchers, and co-occurrence relations between scientific terms can be analysed. Network analysis includes citation analysis, co-citation analysis, and content-based classification (De Nooy et al., 2005). Related graphical presentations based on the network data then were created and visualized by taking advantage of VOSviewer (Van Eck and Waltman, 2009).

2.3.6.1 Citation analysis

The significance or attractiveness of a publication may vary from one to another based on its citations and quality of contributions. Papers with high citations are likely to have a greater influence within the research domain than those less frequently cited. Citation analysis allows us to evaluate the popularity of certain papers and finally identify the roles of highly cited scientific publications by counting the number of times a publication cited by others (Cronin and Ding, 2011; Pilkington and Meredith, 2009).

The network data generated by Bibexcel were imported into Pejek to compute a ranking of articles. The ranking can be estimated in terms of the frequency of articles being cited. Table 2.8 shows the top ten publications based on the number of citations.

Ranks	Author(year)	Title	Citations
1	Christopher, M. and Peck, H., 2004	Building the Resilient Supply Chain	1441
2	Sheffi, Y. and Rice Jr., J.B.,2005	A supply chain view of the resilient enterprise	963
3	Pettit, T.J.et al, 2010	Ensuring supply chain resilience: development of a conceptual framework	536
4	Jüttner, U.and Maklan, S., 2011	Supply chain resilience in the global financial crisis: An empirical study	492
5	Brandon-Jones, E.et al, 2014	A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness	411
6	Pettit, T.J.et al, 2013	Ensuring supply chain resilience: Development and implementation of an assessment tool	388
7	Mattsson, L.-G.and Jenelius, E., 2015	Vulnerability and resilience of transport systems - A discussion of recent research	387
8	Ambulkar, S.et al, 2015	Firm's resilience to supply chain disruptions: Scale development and empirical examination	370
9	Wieland, A.and Wallenburg, C.M., 2013	The influence of relational competencies on supply chain resilience: A relational view	369
10	Kamalahmadi, M.and Parast, M.M., 2016	A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research	356

Table 2.8 Top 10 frequently cited publications

It can be seen that Christopher and Peck (2004) has been the most cited publication which is also the earliest SCR research in the supply chain discipline. Christopher and Peck (2004) first asserted that resiliency needs to be considered and integrated into traditional supply chain design. A structured definition of SCR was offered which became the foundation for further research in this area. Moreover, some of the other influential articles specifically discussed the resilience capabilities, scale development and the future research direction of SCR. The majority of highly cited papers were published at least 10 years ago and in the earlier development stage of SCR. This may be because publications need sufficient time to build up citations.

2.3.6.2 Co-citation analysis

Publications are considered to be co-cited when they appear in the reference lists of other publications at the same time. To explore the structure of bibliometric data, the co-citation map visualization based on graph theory is utilized (Pampel, 2004). A co-citation network is composed of a set of nodes representing journal articles and a set of edges or links representing the co-occurrence of the nodes (articles) in the reference list of papers (Leydesdorff, 2011; Leydesdorff and Vaughan, 2006). Papers which are more often cited together are more likely to be gathered and in turn present similar research themes (Hjørland, 2013).

In this research, Pejek was used to carry out co-citation analysis and VOSviewer was used to visualize the co-citation among sample articles. The initial co-citation mapping shows that there are 17355 papers that have been co-cited by other papers within exploratory data. To show clear clusters but still not miss the key publications, papers with more than fifteen local citations (N) were chosen. The local citation refers to the number of times an article has been cited by other papers within the 206-paper network. Finally, 68 papers were selected to further analysis.

The nodes of a network can be divided into clusters according to the density of edges (Clauset et al., 2004; Leydesdorff, 2011). Nodes with similar density tend to be grouped and form clusters which represent a group of well-connected articles with a similar research theme, indicating a certain research theme in a literature network (Radicchi et al., 2004). In this way, co-citation analysis allows researchers to topologically analyse the co-citation network to identify and illustrate the main research themes (Blondel et al., 2008). Pejek software subsequently clustered 68 nodes into three main clusters of research on SCR which were visualized by VOSviewer (Figure 2.4). Three colours represent three clusters, and the size of the nodes represents the citation weight of each vertex[1]. The bigger the size of a node which means the greater the citation weight, the more influential it is in the cluster. The number of papers is respectively 30 articles for Cluster one, 16 articles for Cluster two and 22 articles for Cluster three. To determine the research theme for each cluster, the leading papers of each cluster were identified and analysed (Table 2.9). Detailed content analysis of the three clusters is provided in the next section.

[1] Vertex is a singular of vertices or nodes which represent the actor or the smallest unit in a network (Nooy et al. 2011).

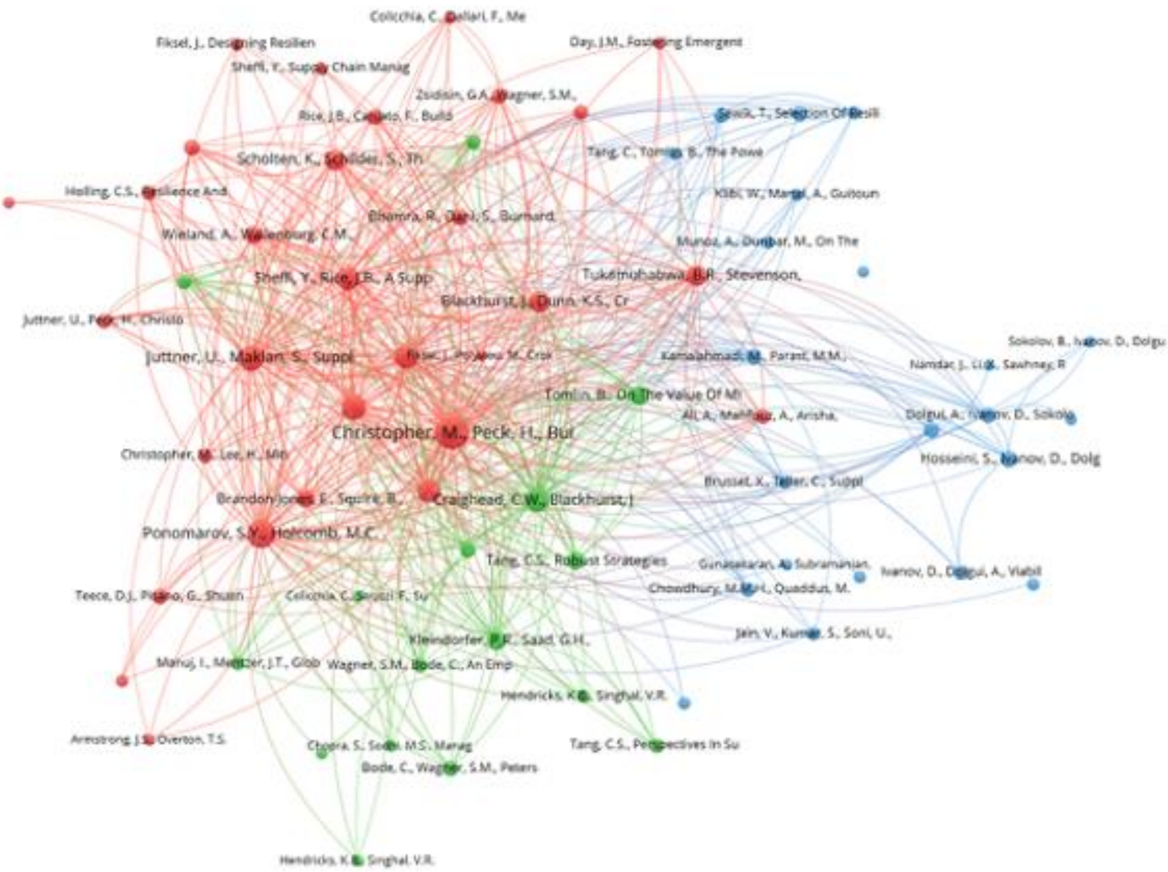

Figure 2.4 Visualization of co-citation network by Vosviewer

Cluster1（30 items）	**Cluster2（16 items）**	**Cluster3（22 items）**
Christopher and Peck, 2004	Craighead et al., 2007	Kamalahmadi and Parast, 2016
Ponomarov and Holcomb, 2009	Tomlin, 2006	Sawik, 2013
Jüttner, and Maklan, 2011	Kleindorfer and Saad, 2005	Dolgui et al., 2018
Pettit et al., 2010	Tang, 2006b	Ivanov et al., 2017
Sheffi and Rice, 2005	Peck, 2005	Carvalho et al., 2012
Pettit et al., 2013	Blackhurst et al., 2005	Hosseini et al., 2019
Blackhurst et al., 2011	Tang, 2006a	Jain et al., 2017
Ambulkar et al., 2015	Knemeyer et al., 2009	Ivanov and Dolgui, 2020
Tukamuhabwa et al., 2015	Manuj and Mentzer, 2008	Brusset and Teller, 2017
Scholten and Schilder, 2015	Wagner and Bode, 2006	Chowdhury and Quaddus, 2017
Brandon-Jones et al., 2014	Bode et al., 2011	Schmitt and Singh, 2012
Wieland and Wallenburg, 2013	Hendricks and Singhal, 2005a	Tang and Tomlin, 2008
Johnson et al., 2013	Chopra and Sodhi, 2004	Klibi et al., 2010
Zsidisin and Wagner, 2010	Colicchia and Strozzi, 2012	Ho et al., 2015
Bhamra et al., 2011	Hendricks and Singhal, 2005b	Munoz and Dunbar, 2015
Ali et al., 2017	Wagner and Bode, 2008	Ivanov, 2017
Jutter et al., 2003		Sokolov et al., 2016
Soni et al., 2014		
Christopher and Lee, 2004		

Rice and Caniato, 2003	Namdar et al., 2018
Holling, 1973	Ivanov et al., 2019
Colicchia et al., 2010	Ivanov et al., 2014
Sheffi, 2001	Gunasekaran et al., 2015
Teece, 1997	Bode and Wagner, 2015
Fiksel, 2003	
Day, 2014	
Armstrong, 1977	
Fiksel et al., 2015	
Fornell and Larcker, 1981	
Stevenson and Spring, 2007	

Table 2.9 List of leading articles for each cluster

2.3.7 Content analysis

Obtained from co-citation analysis, three major research clusters and the leading papers of each cluster were identified. To identify the research theme of each cluster and provide additional insights into SCR, the content of the leading papers in each cluster were evaluated.

Research in Cluster 1 focused on exploring the concept and principles of SCR. These studies were mostly carried out before 2015, in the earlier stage of SCR concept development. The articles can be categorized into two sub themes. The papers in the first theme are mostly literature reviews (Tukamuhabwa et al., 2015; Bhamra et al., 2011; Jutter et al., 2003) and conceptual papers (Christopher and Peck, 2004; Ponomarov and Holcomb, 2009; Sheffi and Rice, 2005; Blackhurst et al., 2011; Ali et al., 2017) which tried to understand the antecedents of SCR, propose new ideas and frameworks, and find new relationships among constructs for understanding SCR. The second theme focused on testing the relationship between specific constructs and SCR and exploring the contingent factors which affect the result of SCR. It has been highlighted that the dynamic capability view (Teece, 1997) and the Structural equation model (Fornell and Larcker, 1981) are highly cited to explore the SCR phenomena in this cluster. This may be because many researchers tried to examine and test how various SCR capabilities can serve as a catalyst in transforming resources into higher value to overcome the disturbances. The most cited resilience strategies include increasing flexibility (Stevenson and Spring, 2007), forming collaborative supply chain relationships (Scholten and Schilder, 2015) and improving relational competence (Wieland and Wallenburg, 2013).

The papers in Cluster 2 mainly focus on approaches and methods to identify, assess, mitigate, and control risks and disruptions. Most papers followed the traditional risk management approach, emphasizing identifying and classifying supply chain risks, predicting the frequency and impact of risks, and then developing strategies to mitigate the consequences of supply chain disruptions. The primary risk sources and various isomorphic pressures embedded in the supply chain and relevant influence have been extensively explored (Hendricks and Singhal, 2005a; Tang, 2006a; Chopra and Sodhi, 2004). Notably, supply chain vulnerability was highlighted in this literature (Peck, 2005, Wagner and Bode, 2006). Wagner and Bode (2006) asserted that the identification of areas and types of potential vulnerability in the supply chain is the precondition of supply chain risk management. Mitigation and contingency strategies for managing supply chain risks were also explored (Tomlin, 2006; Tang, 2006b), such as proactive planning (Knemeyer et al., 2009).

Research in Cluster 3 is mainly concerned with developing quantitative analysis methods for SCR (Schmitt and Singh, 2012; Munoz and Dunbar, 2015; Hosseini et al., 2019; Jain et al., 2017) and supply network design under uncertainty. Notably, most of the papers in this cluster were published from 2015 onwards, which were relatively new. In this cluster, modelling is the dominant method adopted. Since suppliers disruption can be one of the common external risks in modern supply chains, optimal supplier selection strategy becomes one of the focuses. Supply portfolio management (Sawik, 2013) and sourcing strategy under risks (Namdar et al., 2018) were heavily cited. There was also a surge in academic attention to understand the effect of risks on supply chain networks such as the ripple effect (Ivanov, 2017; Ivanov et al., 2014; Ivanov et al., 2019; Dolgui et al., 2018; Sokolov et al., 2016). Network Strategies were developed to respond to disruptions both in the design (Klibi et al., 2010; Carvalho et al., 2012) and operation stage. Network complexities were fully considered (Gunasekaran et al., 2015; Bode and Wagner, 2015). Network visibility (Ivanov and Dolgui, 2020) and structural flexibility (Tang and Tomlin, 2008) under uncertainty were heavily emphasized. Table 2.10 summarized the key area of research focus in each cluster.

Cluster	**Number of papers**	**Area of research focus**
1	30	The concept and principles of Supply chain resilience;
2	16	Identify, assess, mitigate, and control risks; traditional risk management;
3	22	Develop quantitative analysis methods for SCR and supply network design under uncertainty.

Table 2.10 Literature classification: the primary research clusters (N=68)

2.3.8 Discussion and future research directions

Based on the results of bibliometric, co-citation and content analyses, some implications for future SCR research can be drawn.

Firstly, among 206 sample articles, it is found that more than half of SCR research is modelling (75) and survey-based research (56) (as shown in Figure 2.3), indicating a gap for high-quality case study-based studies. Case studies can be useful to investigate the SCR phenomena intensively and systematically by obtaining great in-depth insights. It can provide a greater opportunity to specify the causal mechanisms in SCR (Fearon and Laitin, 2008).

Secondly, as our findings revealed, existing research on SCR tends to underpin a single theoretical perspective. Researchers have so far primarily relied on a limited number of theories such as resourced based theory, dynamic capability view, and system theory. Nonetheless, it is claimed that applying a single theory is not sufficient to understand the SCR concept due to its multifaceted nature (Tukamuhabwa et al., 2016). To better comprehend the multi-dimensional issues of SCR, multi theoretical lenses could be adopted to illustrate the whole mechanism of SCR and further explore the complementary characteristics (the missing traits).

Thirdly, derived from the analysis of three major clusters, further research is necessary to advance a fuller understanding of SCR. As the analysis reveals, Cluster 1 focuses on exploring the concept and principles of SCR. Although various resilience elements have been identified and examined in the literature, it is still highly fragmented. The key constructs identified provide partial solutions to a whole jigsaw puzzle. There is a lack of a holistic framework to explain the fundamental mechanisms of how resilience is built in the supply chain. In cluster 2, most of the research still focuses on risk sources identification, classification and mitigation which follows the traditional risk management approach. As discussed before, the traditional risk management approach has limitations when risks are sudden events and unpredictable. Also, SCR does not necessarily stem from mechanistic processes (Ali and Gölgeci, 2019). Agents who are embedded in the supply chain play important roles. The current literature largely emphasized the mechanical relationship between risks and mitigation strategies. Behavioural variables that are germane to decision makers are an area of weakness in the current literature (Gölgeci and Kuivalainen, 2020). Thus, there is a call for more behavioural research in SCR. Finally, the research in Cluster 3 mainly focuses on supply network design under uncertainty. Most of the studies in Cluster 3 were conducted from taking engineering resilience perspective, which is static. These studies tend to have the assumption that production should go back to the status before risks happen. The efficiency of recovering to normality, original performance of production and inventory and original financial performance were commonly used as resilience performance measurements. Thus, the supply chain network is designed to achieve the supply chain performance measurement before risks happen. However, the supply chains may not be able to return to their original status following a disruption. The supply chain may evolve through time creating new emergent properties and with the sensibility to initial conditions. Resilience enables the supply chain not only to respond or react to change, but also proactively generate new ways of operating, and new systemic relationships (Nilsson, 2003). New resources, capabilities or structures may emerge during the adaptation process (Choi et al., 2001). Given the evolving dominant focus on the dynamic social ecological perspective of SCR, there is further room to explore what factors could lead to SCR and how supply chain networks co-evolve with external environments during the risk events.

2.4 Theoretical Perspective

Helfat and Peteraf (2003) define a resource as "an asset or input to production (tangible or intangible) that an organization owns, controls, or has access to on a semi-permanent basis". Organizations are where resources are gathered and can be regarded as a resource caravan. Organizations need to utilize and mobilize available resources to ensure the business runs smoothly and achieve the best possible performance. Following the resources perspective, in this research, two theoretical perspectives (Conservation of resources theory and Ambidexterity theory) have been identified to capture the dynamic mechanism change of SCR and explain the co-evolvement process of a resilient supply chain and the environment it operates. Conservation of resources theory (COR) was used to explain what motivates organizations to invest in resilience strategies and reveal how organizations build and maintain their resource reservoirs to survive when facing turbulence. Ambidexterity theory was used to explore how organizations can activate capabilities, specific resources, structures, and processes to respond to different types of disruptions and how the Chinese pig supply chain dynamically co-evolves with its environment.

2.4.1 Conservation of resources theory

Hobfoll's conservation of resources (COR) theory is a motivational theory which focuses on the prediction of stress and resilience. COR theory was originally used to understand life stress

(Freedy et al., 1992; Kaiser et al., 1996; Benight et al., 1999), then developed to explore burnout (Freedy and Hobfoll, 1994; Hobfoll, 2002; Hobfoll and Freedy, 1993).

The research found that organizations strive to engage in reducing negative strain (Monsen and Boss, 2009), particularly strain due to potential, or actual, resource loss (Hobfoll, 2011). The importance of actual resources (Barney, 1991), potential resources (Elbe, 2011), and the effects of both on organizations that are under stressful conditions (Crook et al., 2011; Ndofor et al., 2011) have been explored by various researchers. COR theory is built on the foundation of the resource study and explains organizational behaviour based on the evolutionary need to acquire and conserve resources for survival.

COR theory begins with the tenet that “individuals strive to obtain, retain, foster, and protect those things they centrally value” (Hobfoll, 1988: 518; 1989). Hence, the primary motivation for an organization to build and preserve resources is to prevent resource loss. Organizations are motivated to manage, invest, and acquire new resources to protect their valued resources. The value of resources comes from their potential to acquire more desirable resources for organizations. In addition, different organizations may value resources in their way.

Hobfoll et al. (2018) discovered that resources are employed by the organization not only to respond to stress but also to build a reservoir of sustaining resources for times of future need. Two principles and four corollaries of COR theory (Table 2.10) were summarized to understand the complex process of resource conservation and investment (Hobfoll, 1998; 2001).

	Description
Principle 1	*The primacy of resource loss.* Resource loss is disproportionately more salient than resource gain
Principle 2	*Resource Investment.* People must invest resources in order to protect against resource loss, recover from losses, and gain resources.
Corollary 1	Those with greater resources are less vulnerable to resource loss and more capable of orchestrating resource gain. Those with fewer resources are more vulnerable to resource loss and less capable of resource gain.
Corollary 2	Initial resource losses lead to future resource losses.
Corollary 3	Initial resource gains lead to future resource gains.
Corollary 4	Lack of resources leads to defensive attempts to conserve remaining resources.

Table 2.11 Principles and corollaries of Conservation of resources theory

(Source: Halbesleben et al., 2014)

Hobfoll (2001: 349) developed the notion of resource caravans where resources exist and occur together in a certain pattern. This definition is akin to SCR where pre-existing resource caravans define the capacity for resilience. While SCR is demonstrated through the organization's behaviour in response to adversity. Some resilience researchers have started to recognize that capacity is necessary for stressful circumstances. Taking the social–ecological resilience view, resilience implies "concepts of adaptation, transformation, innovation, self-organization and the capacity to perpetuate the activities over time despite the occurrence of stressors" (Adger, 2006; Folke, 2006; Cutter et al., 2008). Building on this perspective, Bene et al. (2012) recognized that resilience emerges as the result of different combinations of absorptive, adaptive, and transformative capacities, each of the combinations leading to different responses from the system: Absorptive capacity leads to persistence; Adaptive capacity leads to incremental adjustment/changes; Transformative capacity leads to total system transformation (Figure 2.5). Bene et al. (2012)'s framework revealed that building resilience would require interventions that strengthen the three types of resilience capacities. To systematically understand SCR, further research should be carried out to illustrate the internal mechanisms and specific strategies of how resilience capacities are built and evolve with external disturbance.

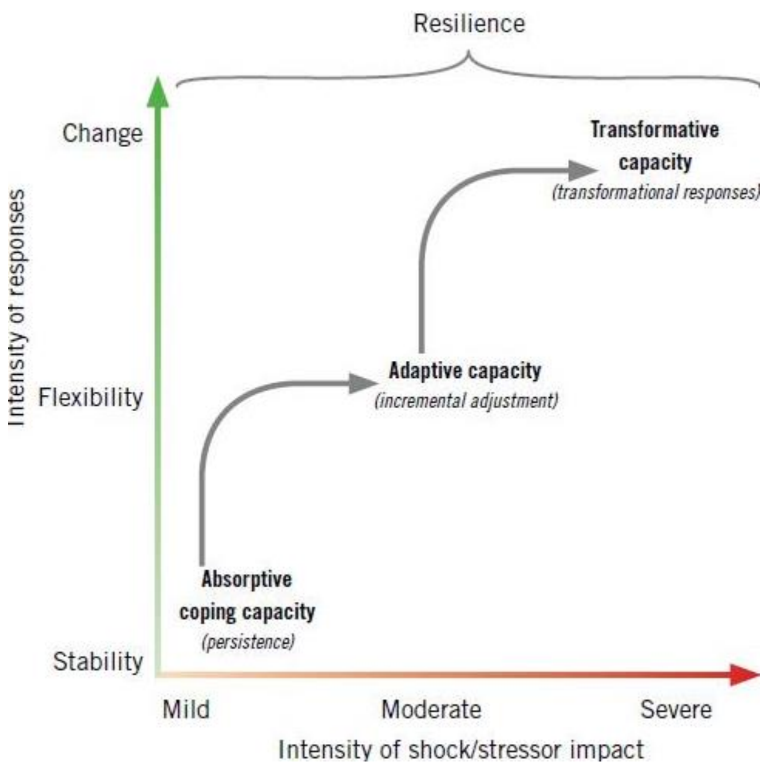

Figure 2.5 Resilience as the result of absorptive, adaptive and transformative capacities

(Source: Bene et al., 2012)

Resource investment processes, resource gains and losses have played an important role in understanding SCR. The principles and corollaries of COR are foundational for SCR research and provide a useful tool for understanding and analysing the dynamic resource change within organizations in adverse circumstances. Subject to resource constraints, an organization's resilience investment and change pattern can be predicted by COR theory (Bardoel and Drago, 2021). The COR theory acknowledges "the behaviour of acquiring, protecting, and developing resources as the coping mechanism for attenuating some of the negative effects caused by strain inherent in resource loss" (Hobfoll, 1989:519). Such a mechanism can be useful for explaining why some organizations can cope with stress due to current or potential resource loss caused by external disturbance, while others may fail.

By adopting COR's principles and corollaries on an understanding of the fundamental evolutionary requirements to build, protect, and invest resources for survival, this study tried to explore how an organization cope with stress and builds its resilience by tracing the dynamic process of the organization's resource accumulation and loss.

2.4.2 Ambidexterity perspective

Teece et al. (1997) described Dynamic capabilities (DC) as "the key role of strategic management in appropriately adapting, integrating, and reconfiguring internal and external organizational skills, resources, and functional competencies to match the requirements of a changing environment". DC perspective can be used to study how a supply chain may change its resource configurations in a dynamic environment and develop resilient capabilities to mobilize the resources to overcome the risks (Wang and Ahmed, 2007). Through learning from experience and self-configuration, organizations develop a broad and varied repertoire of routines for responding to uncertainty and complexity. Dynamic capabilities create value indirectly by changing functional capabilities and are embedded in organizational and managerial processes that enable the organization to transform and reconfigure with its dynamic environment change (Teece et al., 1997; Ambrosini and Bowman, 2009; Yao and Meurier, 2012). Pettit et al. (2010) claimed that a balanced resilience may result from a fit between vulnerability (Figure 2.6) and supply chain capabilities. These capabilities could help organizations prepare for unexpected disruption, mitigate the effects of a disruption, or enable adaptation following a disruption. Pettit et al.'s framework revealed that the vulnerabilities could be offset by capabilities, which shed the light for later researchers to further explore what capabilities organizations may require to cope with different levels of disturbances.

□

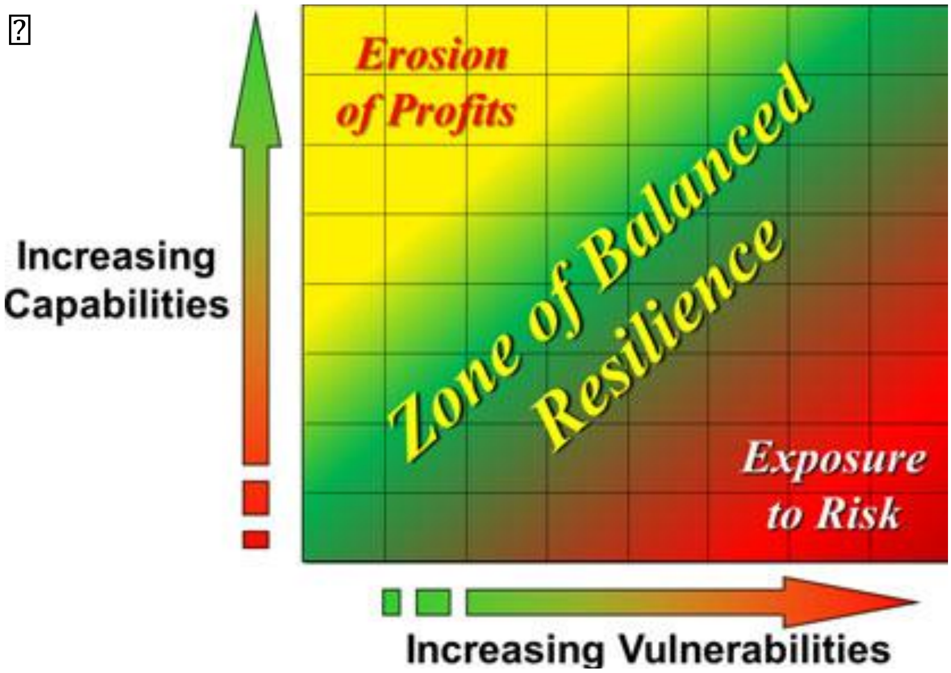

Figure 2.6 Resilience fitness space (Source: Pettit et al. 2010)

Ambidexterity is rooted in the dynamic capability (Teece, 2014) that allows firms to use their exploitation and exploration capabilities to reconfigure resources in order to adapt to a dynamic environment (Snehvrat et al., 2018; Lubatkin et al., 2006) and achieve long-term competitive advantage (Levinthal and March, 1993). The concept of exploration and exploitation was first introduced by March (1991). Exploitation refers to "selecting, refining and implementing standardized procedures to achieve efficiencies in a firm's operations" (March, 1991: 71). While exploration includes "the search for new possibilities, the discovery of innovative ideas and the flexibility to respond to new opportunities" (March, 1991:71). Exploitation and exploration serve as forces which signal and direct tangible and intangible resources and enable firms to have access to and control over those resources flowing through their network.

According to March (1991), exploration and exploitation places compete for organizational slack resources. Thus, ambidextrous organizations strive to make the trade off by attaining and sustaining the balance between these two approaches. The general agreement in this literature is that an ambidextrous firm can both exploit value from existing resources and competency to guarantee contemporary practicality and explore new opportunities to warrant future feasibility to achieve firm performance and competitiveness (Cao et al., 2009). Later the notion of ambidexterity has been applied to the supply chain level (Blome, et al., 2013; Kristal et al., 2010). Supply chain ambidexterity was defined as a firm's effort to simultaneously pursue both refining/extending its existing resources to achieve efficiency (exploitation) and developing new supply chain competencies to achieve flexibility (exploration) to yield performance benefits (Kristal et al., 2010).

Taking these two approaches, some researchers focused on exploitation orientation and tried to improve the supply chain's reliability through routines, standardization and pre-disaster planning to well control the supply chain's operations and achieve efficient response (Weick, 1993; Weick and Sutcliffe, 2015). In this vein, the concepts of agility (Liu et al., 2018; Abdelilah et al., 2018), disaster planning, velocity (Carvalho et al., 2011; Scholten and Schilder, 2015) and process reengineering were well explored. And conversely, other researchers took an exploration orientation and recommended improving flexibility and adaptability (Hamel and Valikangas, 2003) to identify opportunities and develop new processes and ideas to recover from crises. Following this track, flexibility (Tang and Tomlin, 2008; Chowdhury and Quaddus, 2017) and innovation were extensively studied.

However, the majority of research on ambidexterity is either conceptual or was carried out in resource-rich organizations that develop ambidexterity by creating separate units specializing in exploration and exploitation (O 'Reilly and Tushman, 2004). Such a strategy can be too costly, time consuming and difficult to implement when organizations experience resource constraints (Gilbert, 2005; Lubatkin et al., 2006). A predominant issue for organizations facing unexpected risks is that organizations are required to develop strategies to deal with sudden resource disruption with limited resources and capabilities to support and respond in a short time. The constrain of resources and capabilities, and the pressure of time has raised the question if organizations are still able to develop ambidexterity by balancing exploration and exploitation for better supply chain performance under such unexpected disruption.

It is highlighted that understanding how to manage exploration and exploitation activities in a supply chain with an uncertain milieu and limiting resource utilization remains underdeveloped. Resilience building operations require stability, refinement, reliability, responsiveness, agility and adaptation, flexibility, or redundancy. Ambidexterity allows firms to reconfigure the mix of resources, they are the means through which firms modify their resource base over time, allowing them to overcome risks and exploit opportunities in their environment. However, how organizations under significant resource constraints manage exploitation and exploration activities in their supply chains to achieve resilience is still unsolved. In this research, March's (1991) concept of differentiating between exploitation and exploration was adopted to identify if such a theoretical underpinning is beneficial in explaining organizational' response facing unforeseen crises and how supply chain resilience may be enacted.

2.5 Research Gaps and Research Questions

2.5.1 Research gaps

Following the literature review, the research gaps in the literature were identified and summarized below:

Firstly, given the currently dominant focus on antecedents of SCR, there is a lack of a holistic framework to understand the underlying mechanisms of why and how to promote the enablement and development of SCR.

Secondly, to advance a fuller understanding of SCR which is multi-dimensional in nature, applying a single theory may not be sufficient. Thus, multi-theoretical lenses could be adopted to illustrate the whole picture of the SCR mechanism and its characteristics.

Thirdly, the traditional risk management approach has limitations when risks are sudden events and unpredictable and agents' roles are largely missing in resilience research. There is further room to explore what factors managers take into consideration when making the resilience investment decision facing unforeseen crises.

Fourthly, most of the existing SCR studies took a static engineering resilience perspective, neglecting supply chain co-evolution and adaptation characteristics. The investigation of resilience from a dynamic social-ecological resilience perspective is needed.

Fifthly, empirical research on SCR is fragmented (Van Der Vegt et al., 2015). This may be due to the diversity of supply chains and networks, as well as the number of actors involved. It is difficult to capture the dynamic interaction among the multi-agents along the entire supply chain. Accessing resources whenever required is crucial, specifically during times of adversity and uncertainty (Kantur and Iseri-Say, 2012). Case studies that account for the dynamics of resource change in the evolution and deployment of SCR may enrich the understanding of how firms respond to adverse change.

Sixthly, most empirical studies carried out to date are mainly cross-industry and confined to large firms in a developed country context (Benjamin et al. 2015). However, "developing countries are more vulnerable to particular supply chain threats such as political turmoil, including rebel activities and post-election violence, and bribery, corruption and other unethical business practices" (Transparency International, 2013). Furthermore, the cultural, social, and economic differences between developed and developing economies may lead to different perceptions and responses to threats (Benjamin et al., 2015). Meanwhile, different development levels of the supply chains may mean that in certain developing countries, supply chains are more diversified than in developed countries. Thus, investigating how to develop SCR in developing countries is timely and may bring significant contributions to SCR literature.

Finally, developed from empirical data from the manufacturing industry, Christopher and Peck (2004) provide a comprehensive list of resilience principles/capabilities. It is questionable for its generalisability for all industries. Agricultural supply chains are less industrialised and standardised than their manufacturing counterparts and contain a large number of suppliers.

2.5.2 Research questions

In summary, the research gaps outlined above in the extant literature limit the current understanding of SCR, as well as its role in untangling the supply chain ambidexterity dilemma. Hence, in an attempt to address these research gaps, the following research questions are tentatively developed:

a. How organizations make decisions on resource investment and build SCR capabilities during risk recovery?

b. How supply chain co-evolves with its environment in terms of SCR building through analysing the organization's resources investment configuration strategies?

For RQ a, we attempt to explore how agricultural organizations can activate resilience, and the specific resources, structures and processes they need to respond to different types of disruption.

For RQ b, we try to advance the understanding of how various organizational resources and SCR capabilities inter-relate on the condition of different risks to create different resilience capacity configurations which change during each risk recovery.

Taking a social-ecological resilience perspective, this study aims to explore the supply chain resilience building mechanism and the process by integrating the Conservation of resources theory and ambidexterity theory and build a theory of **Resilient Resource Based View (RRBV)** contributing to the SCR literature.

2.6 Summary of Literature Review

This chapter used a systematic literature review method combined with citation and co-citation analyses to gain insights into the knowledge structure of SCR research. From the evolution of SCR research, it can be noticed that SCR has been a widely discussed research area and the number of publications is increasing over time. The knowledge structure identified illustrated three main themes which are the concept and principles of Supply chain resilience: identification, assessment, mitigation, and control of risks and quantitative analysis methods for SCR and supply network design under uncertainty. Based on bibliometric, network and content analyses, a few research gaps were identified which put forward the research questions of this study. Taking resource management as the angle to study organizational behaviour in risk events, the two theoretical lenses, conservation of resources theory and ambidexterity perspectives were also explored. The next chapter explains the methodology of the thesis.

Chapter 3. Research Methodology

In light of the research objectives outlined in Chapter One introduction section. The main purpose of this chapter is to display the methodological approach adopted in this study to ensure its validity. The literature review chapter highlights that the knowledge of resilience in the agricultural supply chain is not well understood or clearly defined, especially from social-ecological perspectives. As a response, this research aims to explore and advance understanding of the resilience-building mechanism which is relatively new and complex.

This chapter first provides justification for the researcher's philosophic position in Section 3.1. Section 3.2 discusses the chosen research method. Sections 3.3, 3.4, and 3.5 detail the research techniques and choices made in this study including the case selection process, the implementation plan for data collection and data analysis. Before the final summary, the reliability and validity issues are explained.

3.1 Research Philosophy

Research philosophy refers to "*a system of beliefs and assumptions about the development of knowledge*" (Saunders et al., 2015: 124). It underpins the assumption, knowledge, and nature of a study (Saunders et al. 2015). In other words, philosophical paradigms reflect a researcher's thoughts and beliefs towards the nature of truth and knowledge, as well as their acquisition (Cohen and Morrison, 2007), and serve as the base to guide the approach, strategy, and methods to conduct the research (Collis and Hussey, 2009). More specifically, a researcher's philosophical paradigm may determine the choices of research strategy, research problem formulation, data collection, processing, and analysis adopted in the research (Guba and Lincoln, 1994).

In this section, three types of research assumptions to distinguish research philosophies are discussed first before the philosophical stance the author hold is explained. Then, the approach to theory development which is interlinked with the chosen research paradigm is discussed.

3.1.1 The philosophy of management research

Burrell and Morgan, (1979), Saunders et al. (2015) and Easterby-Smith et al. (2008) classify three types of research assumptions to distinguish research philosophies: ontology (the nature of reality), epistemology (the nature of knowledge), and axiology (human nature). To be specific, **ontology** is referred to the general assumptions created to perceive the real nature of human behaviour and the status of social reality (Saunders et al., 2015). A researcher's ontological assumptions determine the way how one sees the research phenomena. **Epistemology** refers to “the study of the criteria by which we determine what does and does not constitute warranted or valid knowledge” (Gill and Johnson 1997: 177). It concerns what types of information count as “knowledge” and the appropriate research methods. Saunders et al. (2015) believe that what we consider legitimate for a particular area of study is governed by our epistemological assumptions. **Axiology** refers to “the role of values and ethics within the research process” (Saunders et al., 2015: 125). The research process including the choice of topic, data collection techniques, and ways of pursuing the research reflects the researchers’ position on the research and their values. Researchers demonstrate axiological skills by articulating their values as a basis for making judgments about the research contents and how to conduct it.

Saunders et al. (2015) further point out that varying philosophical positions are scattered along a multidimensional continuum between two opposites: objectivism and subjectivism. **Objectivism** believes that “social entities exist in reality external to social actors concerned with their existence” (Saunders *et al.*, 2015:128). This means that, from an objectivist perspective, social and physical phenomena and their meaning exist independently of our perceptual or cognitive structures (Bryman, 2012). On the contrary, **subjectivism** emphasizes that “social phenomena are made from the perceptions and consequent actions of social actors concerned with their existence” (Saunders *et al.*, 2015:130). This social phenomenon is constantly getting revised through continuous social interaction processes (Saunders et al., 2015).

3.1.2 The author’s philosophical paradigm - Pragmatism

The three types of research assumptions discussed in the previous section can be used to describe the research philosophical paradigms which are positivism, critical realism, interpretivism, postmodernism and pragmatism. The philosophical paradigms guide a researcher to determine which methods should be adopted and why (Guba and Lincoln, 1994).

Positivism refers to “*working with an observable social reality to produce law-like generalizations, as is the case with physical or natural scientists*” (Saunders et al., 2015, p. 135). The positivist philosophy approach emphasizes that the research is separated from the social reality which can be investigated thoroughly by observing the objective facts (Remenyi et al., 1998; Blumberg et al., 2008). Thus, methodologies associated with positivism tend to take quantifiable observations and be highly structured involving rigorous hypotheses testing.

Critical realism emphasizes on "the truth of reality and the existence of the objects are prevalent independently in the human mind" (Saunders et al., 2015:138). The core concept of critical realism is that objective exists independently of human thoughts and beliefs but is interpreted through what we see and experience (Saunders et al., 2015). **Interpretivism** is based on the understanding that "*humans are different from physical phenomena because they create meaning*" (Saunders *et al.*, 2015: 140). From an interpretivism perspective, rather than to quantify the phenomenon (Longino, 1990), qualitative methodologies are applied to interact with individuals to describe and investigate the meaning of reality (Rowlands, 2005) **Postmodernism** attributes "*the role of language and power relations, seeking to question accepted ways of thinking and give voice to alternative marginalized views*" (Saunders *et al.*, 2015:141). Postmodernist recognizes that knowledge creation is shaped by the power relations between the researcher and research subjects (Saunders et al., 2015). More recently, the paradigm of **pragmatism** tries to reconcile both objectivism and subjectivism by emphasizing that "concepts are only relevant where they support action" (Saunders et al., 2015:143). Pragmatism is premised on the idea that research can avoid the debates about the nature of truth and reality and focus instead on "practical understandings" of concrete, real-world issues (Patton, 2015:153). From a pragmatism perspective, it is recognized that individuals within social settings can experience different actions, and thus flexible research techniques are encouraged to adopt (Onwuegbuzie and Leech, 2005).

A comparison of the five major philosophical paradigms within a business and management context was made by Saunders et al. (2015). Table 3.1 presents each paradigm, comparing the differences in theoretical assumptions of ontology, epistemology, axiology, and typical methods used.

	Ontology (nature of reality or being)	Epistemology (what constitutes acceptable knowledge)	Axiology (role of values)	Typical methods
Positivism	Real, external, independent; One true reality (universalism); Granular (things); Ordered;	Scientific method; Observable and measureable facts; Law-like generalisations; Numbers; Causal explanation and prediction as contribution;	Value-free research; Researcher is detached, neutral and independent of what is researched; Researcher maintains objective stance;	Typically deductive, highly structured, large samples. Measurement, typically quantitative methods of analysis, but a range of data can be analysed;
Critical realism	Stratified/layered (the empirical, the actual and the real); External, independent; Intransient; Objective structures; Casual mechanisms;	Epistemological relativism; Knowledge historically situated and transient; Facts are social constructions; Historical causal explanation as contribution;	Value-laden research; Researcher acknowledges bias by world views, cultural experience and upbringing; Researcher tries to minimise bias and errors; Researcher is as objective as possible;	Retroductive, in-depth historically situated analysis of pre-existing structures and emerging agency. Range of methods and data types to fit subject matter;
Interpretivism	Complex, rich; Socially constructed through culture and language; Multiple meanings, interpretations, realities; Flux of processes, experiences, practices	Theories and concepts too simplistic; Focus on narratives, stories, perceptions and interpretations; New understandings and worldviews as contribution;	Value-bound research; Researchers are part of what is researched, subjective; Researcher interpretations key to contribution; Researcher reflexive	Typically inductive. Small samples, in-depth investigations, qualitative methods of analysis, but a range of data can be interpreted
Postmodernism	Nominal; Complex, rich; Socially constructed through power relations; Some meanings, interpretations, realities and dominated and silenced by other; Flux of processes, experiences, practices;	What counts as 'truth' and 'knowledge' is decided by dominant ideologies; Focus on absences, silences, and oppressed/repressed meanings, interpretations and voices; Exposure of power relations and challenge of dominant views as contribution;	Value-constituted research; Researcher and research embedded in power relations; Some research narratives are repressed and silenced at the expense of others; Researcher radically reflexive;	Typically deconstructive - reading texts and realities against themselves; In-depth investigations of anomalies, silences and absences; Range of data types, typically qualitative methods of analysis;
Pragmatism	Complex, rich, external; 'Reality' is the practical consequences of ideas; Flux of processes, experiences and practices.	Practical meaning of knowledge in specific contexts; 'True' theories and knowledge are those that enable successful action; Focus on problems, practices and relevance; Problem solving and informed future practice as contribution.	Value-driven research; Research initiated and sustained by researcher's doubts and beliefs; Researcher reflexive.	Following research problem and research question; Range of methods: mixed, multiple, qualitative, quantitative, action research; Emphasis on practical solutions and outcomes.

Table 3.1 Comparison of five philosophical paradigms in business and management research (Source: Saunders et al., 2015:136)

Based on the previous discussion and comparison, this research adopted the paradigm of pragmatism. Pragmatism rejects the traditional assumptions about the nature of reality, knowledge, and inquiry (Biesta, 2010). Instead, it accepts that there can be single or multiple realities that are open to empirical inquiry (Creswell and Clark, 2011). Pragmatism refuses to locate itself in a traditional epistemological space and instead replaces the metaphysical dualism of realism and relativism with an entirely different worldview, which emphasizes the linkage between beliefs and action (Morgan, 2020). Rather than arguing about whether something is true or not, pragmatists focus on the consequences of acting on a set of beliefs. For pragmatists, the reality is true as far as it helps us to get into satisfactory relations with other parts of our experiences (James, 2000). Truth is whatever proves itself good or what has stood the scrutiny of individual use over time (Baker and Schaltegger, 2015; James, 2000; Ray, 2004). Pragmatist researchers' choice of one version of reality over another is governed by how well that choice results in anticipated or desired outcomes (Tashakkori and Teddlie, 2008).

A major underpinning of pragmatist epistemology is that knowledge is always based on experience. Pragmatist epistemology does not view knowledge as reality (Rorty, 1980). Rather, it is constructed with the purpose of better managing one's existence and taking part in the world (Goldkuhl, 2012). Pragmatists believe that the process of acquiring knowledge is a continuum rather than two opposing and mutually exclusive poles of objectivity or subjectivity (Goles and Hirschheim, 2000). Thus, pragmatism is situated somewhere in the centre of the paradigm continuum in terms of the mode of inquiry. In adopting this stance, the pragmatist researcher is able to select the research design and the methodology that are most appropriate to address the research question. As Bougie et al. (2020: 24) pointed out, "Pragmatists do not take a particular position on what makes good research. They feel that research on both objective, observable phenomena and subjective meanings can produce useful knowledge, depending on the problem that initiated the study."

Pragmatism rejects high-minded metaphysics in favour of understanding the everyday practicalities of living in an ever-changing world (Simpson and den Hond, 2022). Pragmatism argues that experience is the only admissible source of practical and moral knowledge. Pragmatists acknowledge the pluralist and relational nature of life and its evolutionary dynamics, a commitment to selves that are social and continuously emergent, and a desire to improve on the present experience. This is especially appealing to those scholars more interested in exploring what organizing may accomplish than in finding out what organizations are (Simpson and den Hond, 2022). As a research paradigm, pragmatism orients itself toward solving practical problems in the real world. It emerged as a method of inquiry for more practical-minded researchers (Creswell and Clark, 2011; Rorty, 2000). Pragmatism also appeals to me because it is concerned about how to proceed in an unpredictable world in which we are nevertheless required to act – surely a perennial issue for all managers in their daily practice.

This study focuses on the organization’s behaviour on resilience building through resource management strategies within the virtual uncertain environment. Through the perspective of identifying the major themes of these strategies, this study presents the ideas or theories to gain a further understanding of an organization’s resilience-building process in the virtual world. This goes indeed in line with the pragmatism that Bougie et al. (2020) have mentioned that pragmatism is focusing on practical and applied research. During the research, different viewpoints from case companies are presented to help in solving the business problem (how to mitigate the risks through forming resilience). Moreover, pragmatism is describing research as a process where the concepts and meanings (theory) are generalizations of past actions and experiences and of interactions that people have with the environment. Adopting pragmatism, the researcher usually explains what is happening through different ideas.

Additionally, we consider that the research result is provisional truth as we live in a dynamic world which is full of uncertainty, therefore, the perceptions of resilience-building strategies will always change and develop over time. Here again, this is in line with pragmatism which underlines that pragmatism “views the current truth as tentative and changing over time” (Bougie et al., 2020:24). Finally, we believe it is important to combine the theory and concepts with the practical cases to find the real world that we live in. Moreover, we value the research from its practical relevance and keep the purpose of the theory by informing the practical actions. This connects with pragmatism that “stresses the relationship between theory and practice. For a pragmatist, the theory is derived from the practice and then applied back to practice to achieve intelligent practice (Bougie et al., 2020:24).”

The research question of “How to sustain resilience toward vulnerable environmental in agriculture supply chains" is originally derived from the observation of the practical problem. As Saunders et al. (2015: 143) suggest that as a pragmatist, "research starts with a problem, and aims to contribute practical solutions that inform future practice". As a researcher, I believe that research should be closely intertwined with how knowledge is produced. The generalization of our understanding of reality should come from real practice and its link with the existing theories. By identifying both theoretical and knowledge gaps from practice, we are enabled to inform and refine the research objectives. The outcome of this research should not only contribute to theory development but could also contribute to real practices. In addition, it is recognized that researchers may explore the relations between knowledge and action in complex contexts using pragmatism (Kelly and Cordeiro, 2020). The resilience-building process in the organization context is complex and dynamic, requiring adopting multiple perspectives. Given the complexity of the resilience phenomenon, a pragmatist approach, with a focus on the inquiry process and practicality is more appropriate to be adopted for research design. Because it "offers an alternative, flexible, and more reflexive guide to research design and grounded research" (Feilzer, 2010:7). Multiple or mixed methods tend to be adopted by pragmatists in the research to enable the credible, reliable, and relevant data to be collected to advance the research (Kelemen and Rumens, 2008).

3.1.3 Approaches adopted for theory development

Interlinked with the chosen research paradigm, the approach to be adopted for theory development is often determined by the level of knowledge of theory at the beginning of the research. It is portrayed by three types of approaches to the reasoning adopted: deductive, inductive, and abductive (Ketokivi and Mantere, 2010). Blumberg et al. (2008) suggest that the deductive approach seeks to draw valid conclusions from initial premises and is concerned with testing theory. The deductive approach starts with hypothesis generation based on existing practical and theoretical knowledge. The hypothesis is then tested with data (Saunders et al., 2015). While the inductive approach draws a general conclusion from research observations and aims at generating new theories emerging from the data (Saunders et al., 2015). Finally, abductive reasoning takes an alternating inductive and deductive perspective to produce reflective thoughts by moving back and forth between empirical data and literature (Miles et al., 2013).

The inductive approach begins by collecting data to explore research phenomena to build theories. Inductive is more suitable for the relatively new phenomenon and with little available literature (Saunders et al., 2015). The essential characteristics of inductive logic are tentative, local and instrumental (Da Costa and French, 1989). Tentative in that inductive inferences aim only for pragmatic truth; local in the sense that the induction is circumscribed by the relevant conditions of the situation under consideration; and instrumental in the sense that induction should be regarded as merely a device for arriving at pragmatic truth and our system is only one of many possibilities (Da Costa and French, 1989). The tentative nature of the inductive inferences is expressed in the claim such inferences do not aim for the truth, as such, but for 'pragmatic' or 'quasi-' truth (Da Costa and French, 1989). It is then reflected in my attitudes towards the acceptance of scientific theories and in this research. In this research, local, in the sense that the analysis of an organization's resilience-building decisions needs to take account of its relevant peculiarities. Finally, it is recognized that the role of the researcher is essentially instrumental, in the sense that induction is regarded as merely a device for achieving 'quasi-truth' and should be evaluated from this perspective.

In appreciation of the scant existing literature on resilience-building in the context of the agriculture supply chain, this study adopts an inductive approach. An inductive approach lends itself to case study research where the researcher is close to the phenomenon under study and the source of the data. Given the exploratory nature, this research aims to gain insight into the resilience phenomenon to bring new theories through the analysis. The research starts with collecting data from major pig production companies on their resilience-building processes. Patterns in the data are then identified to formulate a more general set of propositions which are finally developed into resilience theory development.

The resilient supply chain may be constructed with choices among various decisions and possibilities being dictated by pragmatic as well as logical considerations. The notion of intentionality relates to the definition of resilience, which implies a desire to contribute to the preservation of a certain system. Research concerned with being resilient is research that seeks to contribute to the pursuit of being resilient rather than simply provide accounts about resilience. Research addressing the risk challenge is bound to look into specific practical issues and pathways to improvement towards a resilient state. Intention and practicality become interrelated and, in that sense, researching resilience phenomena cannot be detached from addressing real-world issues.

For pragmatists, the best method is the one that is most effective in producing the desired consequences of the inquiry. Overall, the central tenets of pragmatism and inductive reasoning go against the traditional positivist value-free stance, rejecting the separation object-subject instantiated by the researcher-observer. And they could be the integration of theory and practice and the reintroduction of values in the realm of scientific inquiry.

3.2 Research Methods

Guided by the pragmatic paradigm of research and given its exploratory nature, the research design of this study is accordingly qualitative. The case study is selected as the research strategy to achieve the research objective. This section justifies choosing case study methods.

A case study "explores a research topic or phenomenon within its context or many real-life contexts" (Yin, 2008:13). Case study could be a powerful method in operations research (Voss *et al.*, 2002), particularly for developing new theories not only tpo investigate the phenomena but also to understand them within a particular context (Yin, 2013). According to Benbasat, et al. (1987), the case study methodology allows the researcher to (1) explore the phenomenon in its natural setting and relevant theory that can be generated from observing the real practice; (2) answer the question of why, what and how; that is, to understand the nature and complexity of the processes taking place; (3) find new variables, relationships, and develop a theory in an area that is relatively new and complex, and the phenomenon not at all understood (Meredith, 1998: 444).

In this research, organizations are under constantly changing pressures leading to coevolution. From social-ecological perspective, being resilient is an adaptive and ongoing process, making it difficult to be predicted or measured objectively. Moreover, some prior studies have indicated that resilience is a socially constructed phenomenon that is also difficult to describe objectively (e.g., Ungar, 2004; Walker et al, 2004). This implies that the resilience phenomenon can be best studied using constructionist methods, such as qualitative case studies. This suggestion is supported by McCarthy et al. (2006), who suggest a case study approach when investigating a complex dynamic phenomenon. In this research, I conceive of agriculture supply chains and organizations as complex adaptive systems (Surana et al., 2005) and, consequently, apply the dynamic form of resilience to them.

As Voss et al. (2002) and Barratt et al. (2011) suggest, the case study is particularly suitable for theory building and extension. Among the main streams of resilience research, many resilience capabilities have been identified, however, it is surprising that little is known about the relationship between resilience capabilities and how they work together to deal with different levels of vulnerabilities in an emerging economy context. In addition, the underlying principle of how resources are mobilized and changed in risk events is largely missing. The development of this theory in this research involves theory elaboration, and the application of resources theory to illustrate the co-evolving interactions between resilient organizations and their environment might generate new sparking findings. In addition, the case study has been advocated by academics in the fields of supply chain management (e.g., Taylor, 2005; Leat and Revoredo-Giha, 2008) and particularly, the agri-food supply chain (Hingley 2005; Bonney et al., 2007).

A multiple case study approach (Eisenhardt, 1989) incorporating four Chinese leading pig production organizations was adopted to conduct this study to address the research questions. The multiple case study allows the researcher to explore the four case organizations within their contextual situation. Also, the common theoretical artefacts can be observed systematically across cases to build theory.

The case study is often criticized for lack of rigour (Stuart *et al.*, 2002). Yin (2013) argues that social science research should not follow statistical generalization which is not the only legitimate method of scientific inquiry, which values more on enumerating frequencies. Instead, a case study emphasizes more on analytic generalization and amplifies the external validity and replicability of the research (Yin, 2013). To ensure the rigour of the research, a case study needs to be conducted following a well-structured process (Eisenhardt, 1989). Its methodological rigorousness is ensured by explicitly discussing the justification and reasoning of the research process (Barratt et al., 2011). Eisenhardt (1989) suggests an eight-step case study research process, which includes (1) clearly defining research questions; (2) case selection; (3) developing research protocols and instruments; (4) collecting data; (5) conducting both within and cross-case analysis to extract patterns; (6) developing hypothesis; (7) comparing with existing literature and (8) closure. In addition, Ketokivi and Choi (2014) emphasize the importance of transparency in the research process and outcomes, claiming to enable logical consistency and plausibility. Finally, the adoption of multiple cases in this research could further enhance external validity and guard against the researcher's personal bias (Voss et al., 2002).

3.3 Case Selection

The case organizations were selected from the Chinese pig production industry. China has become the world's largest pig production and consumption country since the early 1990s. While at the same time, Chinese pig production companies have been constantly buffeted by a range of risks, including pig disease, price fluctuation, policy intervention, consumption pattern change, food safety problems, and environmental pollution.

A two-stage sampling approach was adopted in this study. Firstly, a purposive sampling strategy for the identification and selection of information-rich cases was adopted (Coyne, 1997; Patton, 2015). Secondly, snowball sampling was adopted within each case study to identify the relevant participants. Saunders et al. (2012) suggest that the purposeful sample technique is suitable for selecting a small number of cases, and this allows for information-rich and informative participants to be selected (Patton, 2015). Cases were selected according to specified selection criteria, including (1) leading organizations in pig production in the region; (2) experienced risks before the research carries; (3) having experiences in successful risk recovery; (4) representing the best practice in resilience building. Besides the above criteria, these companies should also be cooperative and willing to provide comprehensive data access to researchers in this research. The case selection followed a five-step framework (as shown in Figure 3.1).

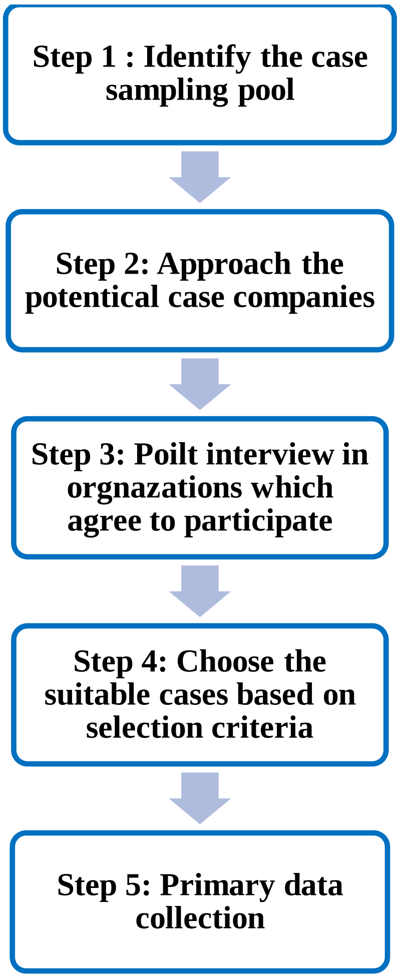

Figure 3.1 The five-step case selection framework

Following the above framework, the initial sampling pool of cases for this study was identified through the researcher's personal link, the Nanjing Agricultural University Business School, and the China Animal Agricultural Association. The China Animal Agricultural Association is a national industry association composed of enterprises engaged in livestock production. It has wide connections with all levels of pig production organizations. The Nanjing Agricultural University Business School provides executive training to senior managers in livestock farming companies. Many pig production companies have been working with the Nanjing Agricultural University Business School for a long time.

Using referral by the Nanjing Agricultural University Business School and the China Animal Agricultural Association, initial contact was made with the senior executives of major pig production organizations through emails. This was followed by presenting each participant with a research cover letter (Appendix A), which explains the purpose of the research and identifies the companies' willingness to participate in the research.

The research received enthusiastic responses from nine organizations. Then face-to-face interviews with key personnel who are directly involved in dealing with risk mitigation in these nine organizations were requested. Three organizations were dropped after the pilot interviews either because the organizations could not fully meet the case selection criteria or could not provide full data access to the research.

To meet the research objectives of this study and in line with the intended interpretation of the data, the case selection was carefully devised. The focus of this study is on the phenomenon of supply chain resilience, of which resource management is the cornerstone of risk management and precedes the building of processes and capabilities within organizations. To achieve resilience, a firm may leverage its fixed and mobile resources to build resilience capabilities, which in turn mitigates the risks. This study aims to examine the resource management of pig production companies in China to demonstrate its importance. Although the context of this study is within the pig production industry, this research also focuses on exploring the pig production organizations within their contextual situations. The remaining six organizations were further screened based on their resource combinations (Fixed resources vs. variable resources). Finally, four organizations (Muyuan, Lihua, Hanshiwei, Nanchuanhe) are selected for the case study considering their resource configuration (as shown in Figure 3.2). As Eisenhardt (1989) recommends that between four and ten cases are appropriate for multiple case studies. Too many cases may generate overwhelming volumes of data for the researcher to process, while too few make it difficult to generate the theory with complexity. Four cases are sufficient to provide in-depth data within each pig production company to compare their management practices. Limiting the sample to four cases enabled the researcher to build trustworthy relationships with participants, and subsequently carry out in-depth interviews. The background of the four organizations is presented in single case analysis chapters.

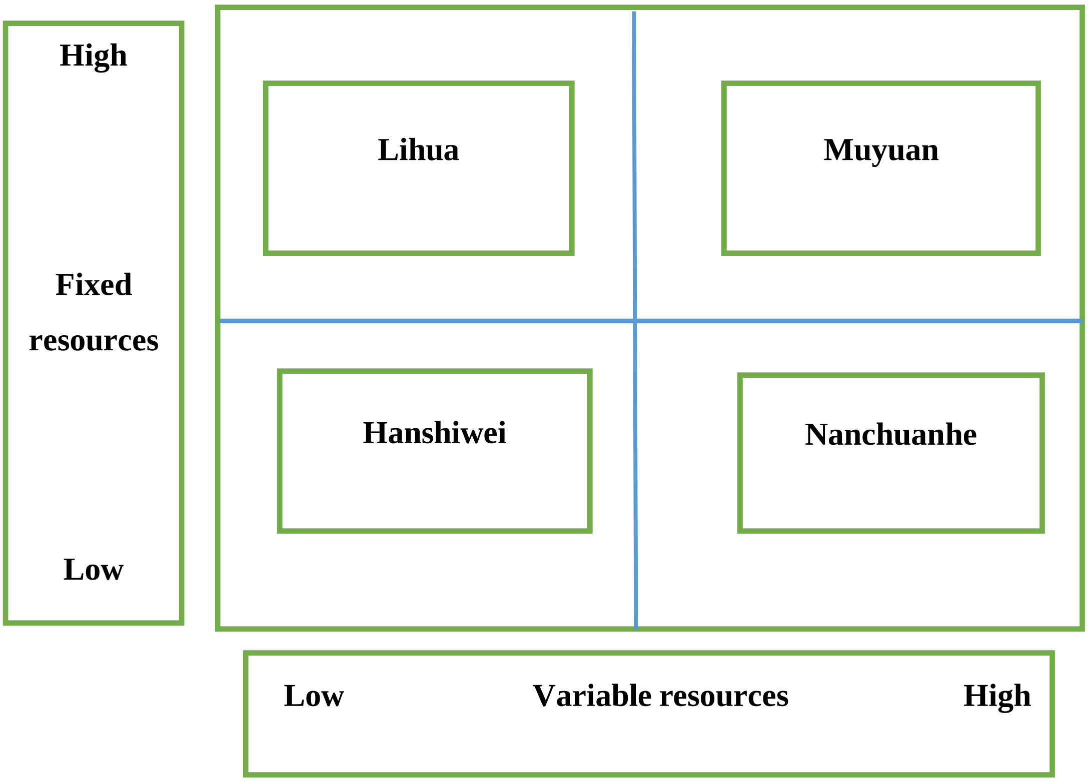

Figure 3.2 Case selection based on different resource configurations

Primary data collection was carried out with these four organizations. Within each case, snowball sampling was conducted to identify participants who are relevant to the organization's risk mitigation process. The research samples were identified through the referral made among people who share or possess characteristics that are of some research interests (Biernacki and Waldorf, 1981).

3.4 Data Collection

The data collection of this research includes multiple resources. The primary data was decided to be collected through in-depth semi-structured interviews. In answering the "how" and "why" research questions, the interview is an efficient method to collect richer empirical data, especially when the phenomenon of interest is highly episodic and infrequent which is tacitly stored in the interviewees' minds. (Eisenhardt and Graebner, 2007). The open-ended nature of the data collection allows the researcher to "dig deeper into the mind of the interviewee" (Blumberg *et al.*, 2008). This research adopts in-depth semi-structured interviews to explore the organizations' specific risk mitigation processes in considerable depth while giving the interviewees opportunities to provide valuable insights.

An interview protocol (see Appendix B) was designed to guide the interview process and systematically organize and manage all the interviews. The interview protocol was developed to align with the research objectives. The interview questions include introductory questions to open the research topics and get the background information of the organizations, direct questions to obtain the interviewees' thoughts on his/her organization's risk mitigation process; and follow-up questions to give the interviewees opportunities to elaborate further. To minimize the research bias, multiple interviewees from different professional levels from senior to junior level were interviewed to provide multiple perspectives. Interviewees include both senior managers and frontline personnel from the case organizations who are directly involved in resilience building or risk management, such as managing directors, department heads, and pig-raising technicians. In addition, interviewing multiple respondents including those actors that are located outside of the organizations but within the pig supply chain (e.g., farmers, research institutions, government) provides a more balanced and comprehensive picture of the phenomena being investigated and helps the researchers triangulate the data (Yin, 2013).

Face-to-face interviews were conducted, and the durations are on average between 15 and 240 minutes. Two major rounds of data collection were conducted. In total, 73 formal interviews were conducted for the four cases. The first round of interviews was carried out between May and June 2018. There was a significant pig price decrease from early 2017 and started to increase in the middle of 2018. Thus, a second round of data collection was conducted between October and November 2018 to further capture the whole process of how the organizations dealt with the price fluctuation. Finally, additional data were collected through either telephone or email communication as a supplement. This research benefits from the extensive access given by the four case organizations. All the interviews were conducted in Chinese, and all the participants agreed to be named in future research outputs. The interview stopped when the theoretical saturation reached (Eisenhardt, 1989). Key information from the interviews is displayed in Table 3.2.

Organization	Participant	Job Description	Date	Location	Duration
Muyuan	Mr. Tian	Senior Director	06/06/2018	Nanyang, Henan	83 mins
			02/11/2018	Nanyang, Henan	78 mins
	Mr. Li	Feeds plant Manager	08/06/2018	Nanyang, Henan	37 mins
	Mr. Wang	Feeds plants buyer	02/11/2018	Nanyang, Henan	30 mins
	Mr. Jie	Head of Production department	07/06/2018	Nanyang, Henan	48 mins
			03/11/2018	Nanyang, Henan	51 mins
	Mr. Yao	Head of Finance department	07/06/2018	Nanyang, Henan	25 mins
	Mr. Xiao	Head of Sales department	06/06/2018	Nanyang, Henan	36 mins
	Miss Zhen	Head of R&D centre	06/06/2018	Nanyang, Henan	49 mins
	Mr. Liu	Pig raising Technician	08/06/2018	Nanyang, Henan	65 mins
	Mr. Zhang	Researcher in nutrition team	08/06/2018	Nanyang, Henan	47 mins
Lihua	Mr. An	Director of Marketing department	24/05/2018	Changzhou, Jiangsu	70 mins
			19/11/2018	Suqian, Jiangsu	60 mins
	Mr. Li	Managing Director of Pig farming department	24/05/2018	Suqian, Jiangsu	118 mins
			19/11/2018	Suqian, Jiangsu	84 mins
	Mr. Li	Director of Procurement department	25/05/2018	Changzhou, Jiangsu	60 mins
	Mr. Zhang	Head of Finance	25/05/2018	Changzhou,	45 mins

		department		Jiangsu	
	Mr. Li	Buyer	26/05/2018	Changzhou, Jiangsu	40 mins
			20/11/2018	Suqian, Jiangsu	30 mins
	Mr. Shen	Director of Technology department	26/05/2018	Changzhou, Jiangsu	45 mins
			20/11/2018	Suqian, Jiangsu	40 mins
	Mr. Li	Manager of administration department	26/05/2018	Changzhou, Jiangsu	47 mins
	Mr. Wang	Manager of risk management department	24/05/2018	Changzhou, Jiangsu	89 mins
	Mr. Gu	Director of production department	24/05/2018	Changzhou, Jiangsu	91 mins
			20/11/2018	Suqian, Jiangsu	78 mins
	Mr. Huang	Sow farm technician	27/05/2018	Suqian, Jiangsu	29 mins
	Mr. Xiao	Fattening team technician	27/05/2018	Suqian, Jiangsu	41 mins
	Mr. Liu	Farmer	27/05/2018	Suqian, Jiangsu	30 mins
	Mr. Zhou	Farmer	21/11/2018	Suqian, Jiangsu	25 mins
	Dr. Ji	Director of R&D Centre	25/05/2018	Changzhou, Jiangsu	52 mins
	Mr. Gu	Officer of Changzhou Bureau of Animal Husbandry	27/05/2018	Changzhou, Jiangsu	60 mins
Hanshiwei	Mr. Lee	Head of Farmer service department	15/05/2018	Bangpu, Anhui	98 mins
			10/10/2018	Bangpu,	119 mins

			Anhui	
Dr. Wei	Managing director	15/05/2018	Nanjing, Jiangsu	240 mins
		10/10/2018	Bangpu, Anhui	216 mins
Mr. Ye	Farmer	17/05/2018	Bangpu, Anhui	65 mins
Mr. Bai	Purchasing manager	16/05/2018	Bangpu, Anhui	49 mins
Mr. Zeng	Sales manager	17/05/2018	Bangpu, Anhui	43 mins
		10/10/2018	Bangpu, Anhui	128 mins
Mr. Huang	Head of production department	15/05/2018	Bangpu, Anhui	187 mins
		10/10/2018	Bangpu, Anhui	160 mins
Mr. Ma	Deputy Managing director	17/05/2018	Bangpu, Anhui	100 mins
Mr. Zhou	Marketing manager	19/05/2018	Bangpu, Anhui	40 mins
Mr. Zhong	Farmer	11/10/2018	Bangpu, Anhui	26 mins
Mr. Qian	Farmer (head of villager)	17/05/2018	Bangpu, Anhui	55 mins
Mr. Wang	Farmer	11/10/2018	Bangpu, Anhui	19 mins
Mr. Li	Production manager in Feeds plant	18/05/2018	Bangpu, Anhui	48 mins
Mr. Zeng	Buyer	18/05/2018	Bangpu, Anhui	30 mins
Mr. Li	Pig raising technician	16/05/2018	Bangpu, Anhui	77 mins
Ms. Wang	Finance manager	18/05/2018	Bangpu, Anhui	65 mins

	Dr. Li.	Nanjing Agricultural University	16/05/2018	Nanjing, Jiangsu	35 mins
	Mr. Wu	Officer in Anhui Bureau of Animal Husbandry	19/05/2018	Bangpu, Anhui	50 mins
	Mr. Guo	Buyer of slaughterhouse	18/05/2018	Bangpu, Anhui	200 minis
Nanchuanhe	Mr. Gan	President of Nanchuanhe	08/05/2018	Liuyang, Hunan	148 mins
			14/10/2018	Liuyang, Hunan	190 mins
	Mr. Wang	Farmer; villager head	14/10/2018	Liuyang, Hunan	60 mins
	Mr. Xiao	Officer in business department	08/05/2018	Liuyang, Hunan	52 mins
	Mr. Wang	Officer in information department	08/05/2018	Liuyang, Hunan	52 mins
	Mr. Li	Farmer	10/05/2018	Liuyang, Hunan	20 mins
	Mr. Wang	Farmer	10/05/2018	Liuyang, Hunan	26 mins
	Mr. Yang	Piglet supplier	16/10/2018	ChangSha, Hunan	40 mins
	Mr. Cheng	Famer	15/10/2018	Liuyang, Hunan	30 mins
	Mr. Chen	Farmer	16/10/2018	Liuyang, Hunan	32 mins
	Mr. Zhu	Pig broker	09/05/2018	Liuyang, Hunan	94 mins
	Mr. Xi	Manager of Animal husbandry station	15/10/2018	Liuyang, Hunan	43 mins
	Mr. Zhong	Officer in pig	09/05/2018	Liuyang,	77 mins

	production team		Hunan	
		15/10/2018	Liuyang, Hunan	50 mins
Mr. Hu	Officer in Environmental protection team	09/05/2018	Liuyang, Hunan	62 mins
Mr. Huang	Officer in administration department	10/05/2018	Liuyang, Hunan	45 mins
Mr. Zhang	Manager in Jiangsu Yibin Environmental Protection Company	09/05/2018	Liuyang, Hunan	55 mins
Mr. Zhang	Managing Director of Hunan Jiabiangou food Ltd	17/10/2018	Changsha, Hunan	119 mins
Dr. Sun	Hunan Agricultural University	11/05/2018	Changsha, Hunan	60 mins
Dr. Li	Hunan University	17/10/2018	Changsha, Hunan	35 mins

Table 3.2 Summary of the interview list

All the interviews were recorded and later transcribed in Chinese. From the 73 interviews, I transcribed 21, with the remaining transcribed by the professional transcription company with a signed confidential and data security agreement.

As suggested by Eisenhardt (1989), data from multiple sources may better triangulate the information collected. Besides the formal interviews, observations are made during the fieldwork. I visited the pig farm and plant, attending case organizations' internal meetings. Personal bias was carefully managed by taking notes and constantly reflecting. Documentary evidence was collected to complement the interview. Given that much contextual data on the pig industry can be found as secondary data, in this study, government policies and regulations, official publications and industry news were collected and used to better understand the key features of the pig production industry. For document review, archival data adopted include internal company documents, companies' annual financial reports, company websites, and press releases to establish the companies' profile and understand their resilience-building strategy. All these helped the researcher to triangulate the data and ensure the validity and reliability of this research.

Ethics issues have been carefully considered in this research. This research was conducted under the terms of ethical approval by the ethical committee of the University of Sheffield and was approved prior to the start of the research. Interviewed participants and organizations were informed that their information and company data will be used only for the purpose of research and will not be disclosed to any other parties, and they have the right to withdraw from the research at any time. All the collected data have been treated as confidential and documented properly. All the data have been stored in password-protected computers and documents have been kept in locked file cabinets.

3.5 Data Analysis

After data collection, the qualitative data were coded and analysed. This study analyses the data through the thematic analysis method (Braun and Clarke, 2006), which follows an iterative process to "summarise the data into related themes, to identify the relationships among these patterns and to develop explanations for these relationships" (Jordan and Gibson, 2004: 226). This study also follows the Miles and Huberman (2013) method to guide the data analysis. Within-case analysis was conducted first, followed by a cross-case analysis. The unit of analysis of this research is the risk mitigation process within each case organization.

3.5.1 Coding

Case descriptions for the risk mitigation process of each case organization were first developed. Meanwhile, content analysis was implemented to enable the researcher to investigate explorative questions through manually coded transcripts (Blumberg *et al.*, 2008) and to allow emergent categorises to come out of the data systematically (Saunders *et al.*,2012). Content analysis was conducted manually on both the interview transcripts and archival data. An open, inductive coding process was carried out by the researcher by reading the transcripts multiple times while noting and marking phrases and passages to identify significant features in the resilience building process within each case organization. Keywords and quotations were coded to answer the research questions. Special attention was given to phrases and terminologies related to risks, resource management and resilience capability building. For example, the changing organization's resources configuration before, during and after the risks event reflects the organization's resilience-building strategy. Resilience capabilities such as learning, reengineering, flexibility, and redundancy were also coded to show the capability development process.

Next, axial coding was applied to regroup the data and codes into categories and themes, this is applied to the phenomena of resilience. Because resilience research is in its infancy, especially studying resilience from a resource management perspective, while previous resilience research mostly adopts the dynamic capability view. Resources are mobilized through created capabilities, which were coded in this research. Also, through regrouping the code and data, new themes such as Resource availability, valence, and complementarity were obtained to code the data as well. In this way, the case organizations' resource management behaviours under risk events which could reflect the second-order constructs were coded and then put under their corresponding first order constructs. Finally, tables were made to compare the four case organizations' resilience behaviour and performance.

3.5.2 Case analysis

The case analysis includes both within-case and cross-case analysis (Miles and Huberman, 2013). Within case analysis enables the researcher to investigate explorative questions in a single context before theorising and allows emergent constructs and categorises to come out of the data from each case (Saunders et al., 2012), which is a way to sort, sharpen and discard data (Miles and Huberman, 1994). In this research, the within case analysis is presented in a story-telling narrative (Chapters 5,6,7,8) and structured into the background of the case companies, resource caravan, and risk mitigation process.

The cross-case analysis aims at searching for meanings and patterns in different settings to create categorises and themes (Miles and Huberman, 2013). Comparisons among four case organizations were made to obtain the similarities and differences in their resilience-building processes. Through categorization and pattern matching, themes are created and relationships between constructs are validated. As suggested by Eisenhardt (1989), the whole process simultaneously compares with extant literature to ensure that research findings make novel theoretic contributions.

During the analysis, this study adopted a few analytical techniques (Miles and Huberman, 2013; Ghauri, 2004)):

- Creating data display (for example, create pig supply chain mapping; make Company's organization structure or production process);
- Chronologies (organize company's development milestone, make field notes);
- Make a matrix of categories (within and cross case analysis);
- Compare patterns (cross case analysis).

3.6 Reliability and Validity of This Research

Four tests suggested by Yin (2008) were used to ensure the reliability and validity of the research. These proactive measures were taken during the research process, which is summarized in Table 3.3.

Test	Strategy	Measures
Construct validity	Use multiple sources of evidence	Interview multiple respondents; Collect data from other sources (reports, company meetings);
	Maintain chains of evidence	Develop research sub questions; Establish case profile;
	Review findings by uninvolved professionals	Discuss the findings with experienced academics; Get feedback from case organizations;
Internal validity	Structure research design	Structured and transparent coding and data analysis process; Rigorous logic to generate propositions based on evidence; Constantly compare with extant literature;
External validity	Sampling approach	Purposeful selection of the cases;
	Rich data	Choose multiple cases;
	Physical visit	Visit the organizations; Participate in internal meetings;
Reliability	Use case study protocol	Use interview protocol to guide fieldwork and data analysis;
	Develop case profile	Comprehensively document the research process.

Table 3.3 Reliability and validity measures (Source: Yin, 2008)

3.7 Chapter Summary

This chapter provided the explanation and justification for the methodological choices of this research. The overall aim of this research is to explore how organizations achieve their resilience, by addressing which this study can bring new insights to the underdeveloped resilience theory. In appreciation of the under explored resilience study especially from a resource management perspective, this study adopts an inductive approach. Given the exploratory nature of this research and its contexts, a qualitative approach was selected. More specifically, multiple case study was adopted. Four leading pig production organizations were selected to understand the specific resilience building mechanisms. Semi-structured interviews complemented by observation and archive data provide rich and in-depth data. In the following chapters, the data collected are analysed and presented in single case and cross case forms.

Chapter 4. Pig Supply Chains in China

A pork supply chain is relatively long, starting with pig production, then goes to pig slaughtering and processing, pork products retailing and wholesaling until pork products consumption. The boundary of this research is the pig production supply chain which involves feed/ veterinary drug producers and pig farmers/producers. There are two main reasons why the pig supply chain is the focus of the research. Firstly, Pig production is continuously exposed to change and risks. Most of the risks embedded in the pork supply chains such as disease and price fluctuation happen on the production side. Secondly, in China, the pork industry is still a predominantly producer-dominated industry. The number of pig supply is the key factor to meet the high customer demand and also determines the price of pork.

The processes of industrialization in China's other livestock sectors (such as chicken, dairy, beef, and aquaculture) share similar goals, logic, and actors, so analysing pig supply chains provide a lens on the trajectory of China's livestock industry more broadly. This is not to say each livestock sector is identical, rather, the pig supply chain is a representative case to understand the complex factors driving the Chinese agrifood supply chain development, and it is the sector with the most pressing environmental and social implications to date.

Based on statistical data, this chapter presents the background of the Chinese pig industry (Section 4.1) and the structure of a typical Chinese pork supply chain (Section 4.2). Major risks embedded in the pig supply chain are identified (Section 4.3). This provides the foundation for understanding case organizations' resilience-building processes and strategies.

4.1 Overview of The Development of the Chinese Pig Production Industry

China is the world's biggest producer, importer, and consumer of pork and Chinese agribusiness firms have become key players in both domestic and international markets (Rose, 2015). China has a population of 1.3 billion people and is home to over 20% of the world's population. Since 1978, China has been highly successful in achieving self-sufficiency in food, regardless of China only boasts 9% of the world's arable land and 6% of the world's surface freshwater supply (China State Council, 2011). Pork has been a part of agriculture and food consumption in China for a long tradition. As a key source of protein in China, pork is China's leading meat category in terms of popularity, production, and consumption. Pork accounted for 66 per cent of China's total meat output in 2001, and from 1985 to 2001, pork consumption increased by 148% (Liu, 2009). Table 4.1 shows that in 2017, China's total live pigs' output reaches 702.021 million, and the pork meat output reaches 54.518 million tons, accounting for 49.6% of the global pork consumption. Pork consumption occupies 60% to 80% of the total meat consumption and is the major meat consumption in China (National Bureau of Statistics of China, 2018). Although in recent years, the produce and consumption of beef, mutton and poultry meat have increased rapidly, the produce and consumption of pork still maintain steady growth in China. In addition, Figure 4.1 shows that China imported 1,216,800 tons and exported 51,300 tons of fresh and frozen pork in 2017. The net import of pork only accounted for 2.14% of the total domestic production. In general, the supply of live pigs in China is self-sufficient and the proportion of imports is extremely low, which can be negligible.

Meat Type	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Meat consumption per capita of urban residents (Kg)										
Meat	25.5	32.83	34.72	35.17	35.71	28.5	28.4	28.9	29	29.2
Pork	16.73	20.15	20.73	20.63	21.23	20.4	20.8	20.7	20.4	20.6
Beef & Lamb	3.33	3.71	3.78	3.95	3.73	3.3	3.4	3.9	4.3	4.2
Poultry	5.44	8.97	10.21	10.59	10.75	8.1	9.1	9.4	10.2	9.7
Meat consumption per capita of rural residents (Kg)										
Meat	18.3	22.42	22.15	23.3	23.45	22.4	22.5	23.1	22.7	23.6
Pork	13.28	15.62	14.4	14.42	14.4	19.1	19.2	19.5	18.7	19.5
Beef & Lamb	1.13	1.47	1.43	1.9	1.96	1.5	1.5	1.7	2	1.9
Poultry	2.81	3.67	4.17	4.54	4.49	6.2	6.7	7.1	7.9	7.9

Table 4.1 Meat consumption of Chinese residents (Source: National Bureau of Statistics of China, 2013; 2018)

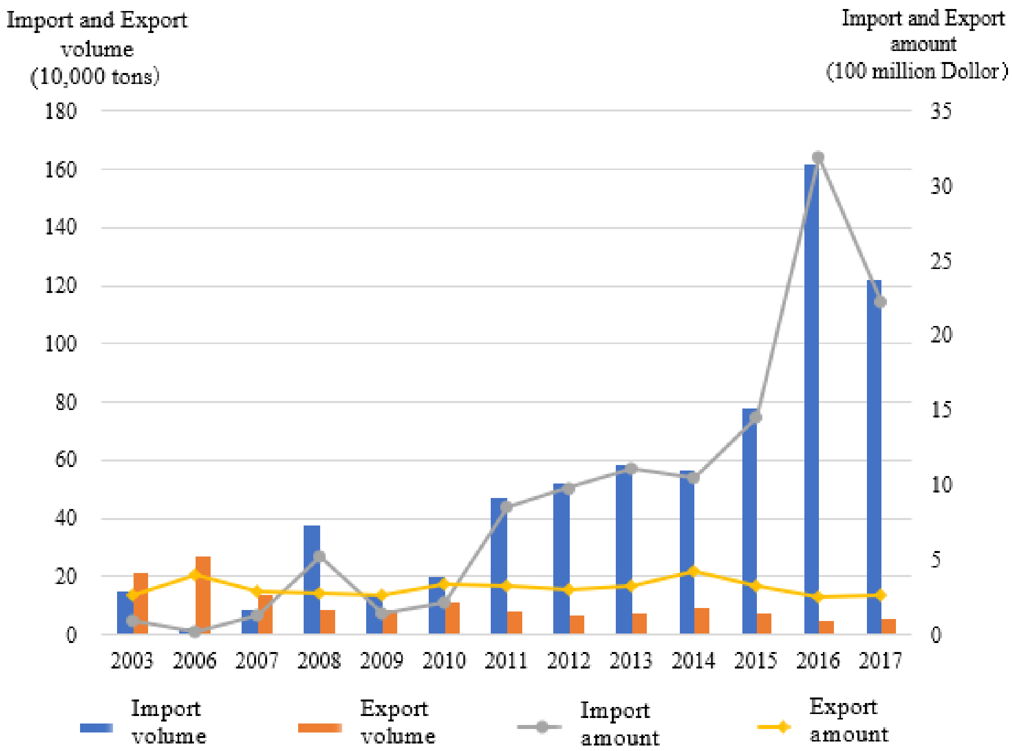

Figure 4.1 China's pork import and export from 2003 to 2017 (Source: National Bureau of Statistics of China, 2013; 2018)

Table 4.2 shows that pork production accounts for 60% to 70% of total meat production between 2005 to 2017, showing that pig farming is the most important part of China's meat production.

Year	Total Pig Production (10,000 Heads)	Total Meat Production (10,000 Tons)	Total Pork Production (10,000 Tons)	Ratio
2000	52673.3	6124.60	4031.40	65.82%
2005	66098.6	7743.09	5010.61	64.71%
2006	68050.36	8051.45	5197.17	64.55%
2007	56508.27	6865.72	4287.82	62.45%
2008	61016.6	7278.70	4620.50	63.48%
2009	64538.6	7649.70	4890.80	63.93%
2010	66686.43	7925.82	5071.24	63.98%
2011	66170.31	7957.84	5053.13	63.50%
2012	69789.5	8387.20	5342.70	63.70%
2013	71557.3	8535.00	5493.00	64.36%
2014	73510.4	8706.70	5671.40	65.14%
2015	70825	8625.00	5486.50	63.61%
2016	68502	8537.80	5299.10	62.07%
2017	70202.1	8654.40	5451.80	62.99%

Table 4.2 China's pig and pork production volume between 2005-2017 (Source: China Animal Husbandry and Veterinary Yearbook 2000-2018)

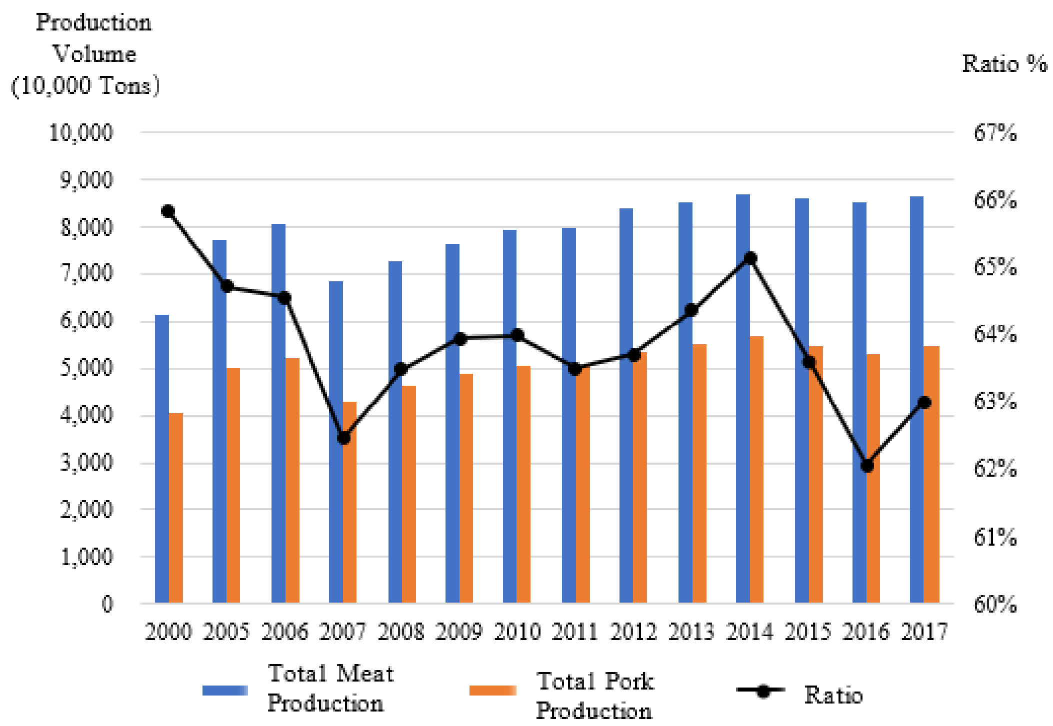

Figure 4.2 China's pork production between 2005 to 2017 (Source: adapted from China Animal Husbandry and Veterinary Yearbook 2000-2018)

It can be seen in Figure 4.2. that from 2000 to 2017, the trend of changes in total pork production is aligned with the total meat production, showing steady growth. During this period, the fluctuation of pork production can be divided into three stages:

(1) From 2003 to 2006, there is a significant increase in production due to the continuous increase in live pig sale prices. The overall Chinese pork production reaches 51.9717 million tons at the peak.

(2) From 2006 to 2011, there is a decrease in production. This is because the continuous increase in pig supply in previous years leads to a drop in pig prices. Farmers lost the motivation to raise pigs. Affected by multiple factors such as the long-term low sale price of live pigs, the increasing cost of feeds and the outbreak of highly pathogenic porcine blue-ear disease, pork production dropped to 42.8782 million tons in 2007. In 2011, affected by the “Clenbuterol” incident, the production of pork dropped to 50.5313 million tons and began to gradually recover in 2012.

(3) Since 2014, the pork price continues to decline. This is because the government started tightening environmental policies and regulations. The environmental protection requirements towards pig plants have increased. The pig plants with outdated

environmental equipment gradually withdrew from the market.

4.2 The Structure of the Pork Supply Chain

A typical pork supply chain (Figure 4.3 below) starts with pig production, then it goes to pig slaughtering and processing, pork products retailing and wholesaling until pork products consumption. It takes many different chain agents, such as feed producers, pig farmers/producers, slaughterhouses, pork processing companies, and various kinds of pork distributors before it reaches end pork consumers.

The pork supply chains are relatively long, involving multiple stakeholders such as feed production companies, animal health (veterinary drug) companies, breeding companies, fattening companies and farms, pig brokers, and slaughtering and meat processing companies. A dynamic coexistence system is formed among stakeholders through the interaction of resources such as capital, information, and materials.

Breeders in the pork chain breed pigs and sell piglets. They choose breeds with the best reproductive and biological characteristics to produce good piglet breeds. China mainly relies on imported foreign breeds, such as Duroc and Yorkshire, and then crosses breeding with Chinese pig breeds (Tang et al., 2013).

Feed producers are companies that produce feed products for livestock. The feed industry is highly competitive, and the feed producers mainly compete in price.

Veterinary drug producers develop and produce veterinary biological products. They provide buyers in the pig breeding and fattening sectors with professional technical services and animal disease prevention and control products. As veterinary medicines are key for the prevention, diagnosis, control, and treatment of pig diseases, quality and scientific use is crucial for high-quality and efficient pig raising.

Facility manufacturers provide all kinds of pig raising related facilities and equipment including automatic feeding, and environmental control devices (ventilation, temperature control, disinfection, cleaning, manure treatment, etc.). Advanced facilities and equipment may not only increase pig production efficiency but also reduce the environmental risks in the pig breeding process (Tokach et al., 2016).

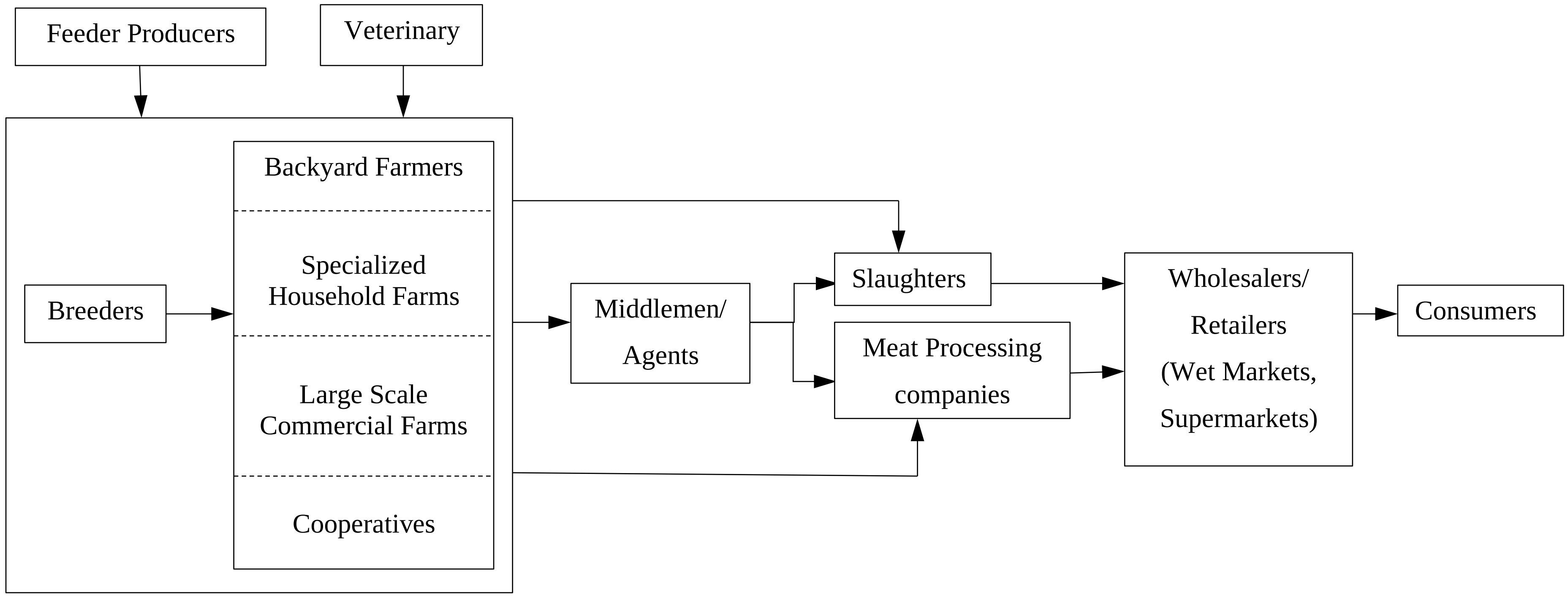

Figure 4.3 Typical structure of Chinese pork supply chain

Pig producers are farmers who are responsible for fattening pigs. In the Chinese pig industry, farms with a production scale smaller than 50 heads of fattened pigs per annum are called backyard farms, between 50 and 500 heads are called specialized household farms, and more than 500 heads are called large-scale commercial farms (Heimann et al., 2012) (as shown Table 4.3). The number of backyard farmers and their share of production have declined precipitously as state policies and investments support industrial operations that have catapulted China's pig production to its current world dominant position. Especially, after the Porcine reproductive and respiratory syndrome (PRRS)epidemic in 2006, the number of rural households that raise pigs dropped by 50 per cent (Schneider, 2011).

Type	**Production Scales**
Backyard farms	<50 heads
Specialized household farms	50-500 heads
Large-scale commercial farms or companies	more than 500 heads

Table 4.3 Pig producer classification in China (adopted from Heimann et al., 2012)

In between smallholders and large-scale commercial farms are so-called specialized household farms. The general idea of the specialized household farm is that pig raising is a professional endeavour based on production for sale instead of self-consumption (Schneider, 2014). Operations may be run by individual families, by small-scale companies, or by several backyard farmers who have come together to focus on pig raising more exclusively. Some specialized household farmers produce under contract with large commercial farms, while others sell piglets and meat pigs to local dealers who then sell pigs to slaughter, processing, and retailers. The government incentivizes the specialized household scale of production primarily through investments in infrastructure (Schneider, 2011).

The government has encouraged the development of Large-scale commercial farms and supports those mega farms to work in concert with specialized household farms (Schneider, 2014). All kinds of subsidies have been provided to support the modernization of infrastructure, the introduction of good breeds and loan interests (Ji et al., 2016). These commercial farms have established highly integrated pork supply chains including breed, feed, rear, slaughter, process, and market pigs and pork. They do so in a variety of ways, from being specialized in one particular phase of production to operating in some or all phases, to managing contracts with other farms and companies to produce and sell an end product. The annual scale of production on these farms typically ranges from 500 to 50,000 pigs but is rapidly growing

(Schneider, 2014).

Many of the largest expansions stem from the increased vertical integration of the top Chinese meat processing companies into production (Schneider, 2014). The top 20 mega pig farms are all with a production capacity of over 1 million heads in 2021 (Nong Cai Bao Dian, 2022). China Oil and Foodstuffs Corporation (COFCO), China's largest grain trader has seen the potential of the pork industry and aims to develop as the country's top pig producer with a production capacity of 10 to 15 million pigs per year. COFCO will also invest 570 million US dollars in slaughter facilities so that it can process the livestock that it raises (Schneider, 2014).

Slaughterhouses are companies that slaughter live pigs and cut these into meat products. In China, companies wanting to operate in this industry must obtain a slaughterhouse permit, which is difficult to acquire. Slaughterhouses or slaughtering points are responsible for slaughtering live pigs and dividing them into pork meat; while the processing industry converts the meat into end products, such as sausage and bacon. In China, typical processing companies include Shuanghui, Yurun and Delis. Compared to pig raising companies, slaughterhouses and processing companies are stronger in capital resources and tend to play the central role in the pork supply chain as they collaborate with pig farmers upstream in the chain to ensure pig supply and safety and work with retailers downstream in the chain for branding and marketing. They may adopt more than one type of relationship with pig producers simultaneously. For example, a company may vertically integrate pig farmers to produce pigs in their bases, purchase pigs from brokers (middleman relationship) who source pigs from backyard farmers, specialized household farms or large-scale commercial farms; use contract farming and sign contracts with pig producers.

Pig broker (intermediaries) is a critical role in the pork supply chain between pig production and slaughterhouse. Pig brokers collect commissions, buy pigs from pig companies and farmers, and sell them to slaughterhouses. In China, pig production still largely relies on small-scale farmers and cooperatives which are in remote rural areas. Pig brokers can go to each farm and collect the pigs and send them to the slaughterhouses. In China, live pig transportation is still common. In some industrialized cities, pigs can be only supplied from other agricultural intensive regions. Pig transportation is considered one of the causes of the transmission of pig diseases, due to unhygienic transport conditions and the virus spread from sick to healthy pigs during transportation.

4.3 The Challenges in the Chinese Pig Supply Chain

China's pig industry is constantly buffeted by a range of influences, "including food safety concerns, pig/pork price vulnerability, environmental stress and fragmented pig production, disease epidemics, feed prices, policy interventions, seasonal consumption patterns, demand for other meats and macroeconomic factors" (The Pig site, 2012). The degree of volatility appears to have increased since the record-high pig prices in 2007, and together with the consequence of extensive intervention from government and private investment, the whole port industry has experienced significant structural changes (The Pig site, 2012).

4.3.1. Highly fragmented production

Pig production is highly fragmented in China. Small-scale pig farming is still dominating the Chinese pig market. Though the number of large-scale and commercialized farms is increasing, more than 60% of the pig production comes from small and backyard pig producers (McOrist, et al., 2011). However, due to the limited resources and capabilities, those small-scale pig producers are highly vulnerable to many risks. Due to the government's national and regional industrial structure adjustments, the increase in consumer food safety concerns, price fluctuations in raw materials, and increased disease risks, many small-scale backyard farmers (less than 50 heads) withdraw from the pig market.

Year	The number of pig farms					
	50-99 heads	**100-499 heads**	**500-2999 heads**	**3000-9999 heads**	**10000-49999 heads**	**Over 50000 heads**
2007	1577645	542014	113784	9004	1803	50
2008	1623484	633791	148686	12916	2432	69
2009	1653865	689739	175798	15459	3083	96
2010	1685279	742772	199051	17636	3558	121
2011	1724703	782338	215216	18488	3937	162
2012	1726108	817834	231271	19735	4364	187
2013	1619877	827262	241021	20492	4567	202
2014	1571123	810448	241679	20976	4526	226
2015	1479624	758834	239246	20685	4388	261
2016	1428631	718590	231660	20380	4261	311
2017	1209265	603091	191973	18988	4134	407

Table 4.4 The number of pig farms with different production scales in China between 2005 to 2015 (Source: adapted from China Animal Husbandry and Veterinary Yearbook)

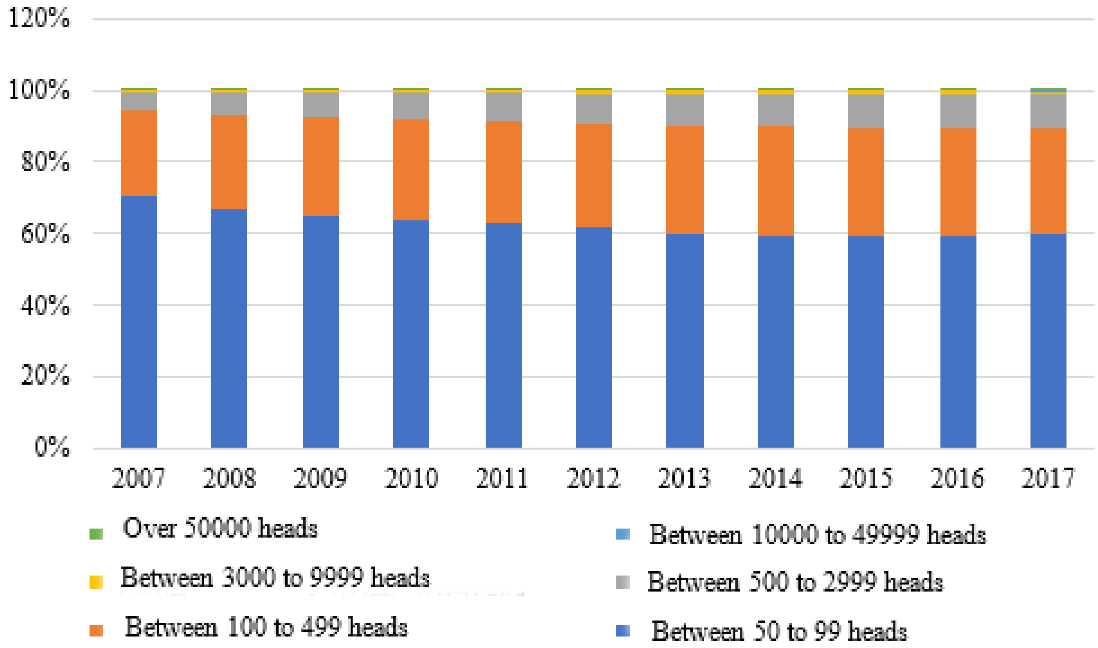

Figure 4.4 Pig farms percentage in China between 2005 to 2015 (Source: adapted from China Animal Husbandry and Veterinary Yearbook)

In Table 4.4 and Figure 4.4, it can be seen that the number of farms with an annual production of 50-499 heads has been decreasing year by year, but still occupies more than 90% of the total number of total pig production. The number of large-scale farmers with an annual output of more than 3,000 heads grows slowly.

	2005	2007	2010	2011	2012	2013	2014	2015
Production Volume (10,000 heads)	28291.50	38938.99	60250.40	57242.70	63800.58	68324.41	72214.59	69725.81
Percentage of overall production	42.80%	68.91%	90.35%	86.51%	91.42%	95.48%	98.24%	98.45%

Table 4.5 Pigs produced from farms with production scale more than 50 heads between 2005 to 2015 (Source: adapted from China Animal Husbandry and Veterinary Yearbook)

Between 2005 to 2015, the number of live pigs sold by farmers with a production scale of more than 50 heads increased from 282.2915 million to 697.2581 million, increasing from 42.8% to 98.45% of total pig production (see Table 4.5). This is because farmers with a production scale of more than 50 heads are mostly backyard farmers who are more financially vulnerable to pig price change and do not have sufficient capitals to invest in manure treatment equipment to meet the governmental environmental regulations. Gradually, they either withdrew from the market or started to work with pig production companies to produce pigs. The pig production companies helped them to upgrade their production scales.

Table 4.6 below shows that from 2005 to 2015, the number of live pigs produced by farmers with an annual production volume of 50-99 heads continued to increase. However, its percentage in total pig production decreased. This is because the large pig production companies increased their production capacity rapidly and started to take the leading role in pig production. Live pigs produced by farmers with an annual production volume of over 100 had a clear increase in terms of both numbers and percentage of pigs produced in China. Especially, live pigs produced from farms with a production scale between 500 to 2,999 heads increased significantly from less than 10% of the total annual pig production in 2005 to 27.44% in 2015. There is a clear tendency that farmers with large scales are more resilient and can have a higher chance of surviving in the market.

Year	**Annual Number of pig production (10,000 heads)**					
	50-99 heads	100-499 heads	500-2999 heads	3000-9999 heads	10000-49999 heads	Over 50000 heads
2005	9490.67	8810.05	5344.90	2500.89	1848.41	296.58
2006	10565.82	10375.64	6066.56	2792.83	2045.56	296.59
2007	10424.39	10995.64	10293.90	4110.20	2736.14	378.72
2008	11086.02	13498.77	13287.90	5888.53	3665.94	546.34
2009	11394.69	14743.69	15523.94	7067.36	4570.54	730.75
2010	11900.90	16087.20	17874.90	8190.60	5269.70	927.10
2011	10813.83	15527.82	16667.46	7899.33	5255.95	1078.30
2012	11573.90	17506.09	18218.23	8993.67	6164.75	1343.94
2013	12171.28	18807.26	19227.53	9784.55	6789.57	1544.22
2014	12628.98	19851.27	20126.80	10547.39	7237.44	1822.71
2015	12276.71	18797.91	19435.57	10219.16	6980.53	2015.92

Table 4.6 Pig farms and production volume in China between 2005 to 2015 (Source: adapted from China Animal Husbandry and Veterinary Yearbook)

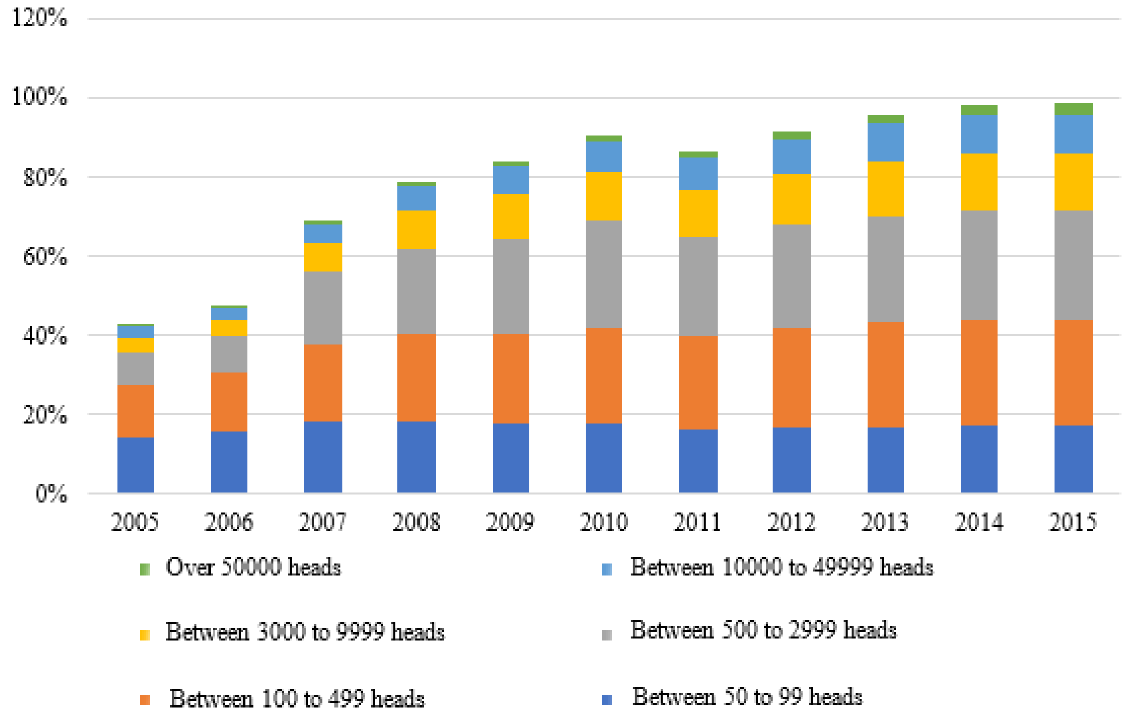

Figure 4.5 Annual Pig farms and production percentage in China between 2005 to 2015

(Source: adapted from China Animal Husbandry and Veterinary Yearbook)

4.3.2 Price fluctuation

It can be seen from Figure 4.6 that the price of pork in China has fluctuated heavily over the years. The pig price decreased in 2016, reached the bottom in the middle of 2018 and then started to increase significantly until 2020. From 2020. There are various small fluctuations, and the price starts dropping heavily in 2021.

There are various factors which contribute to the price fluctuations such as changes in feed prices, seasonal consumption patterns, disease outbreaks, and the general economy. But meat from livestock production is especially volatile and pig price fluctuation poses a significant risk for pig producers, this is because: first, with a long pig production period (6-7 months at least), pig producers are not able to respond to market demand and price fluctuation quickly; second, unlike cattle or sheep, reproductive pigs procreate 8-10 piglets at once (cattle with one cub once and sheep with 3 cubs once maximum, the supply of pigs may enlarge fast which leads to even bigger economic lose.

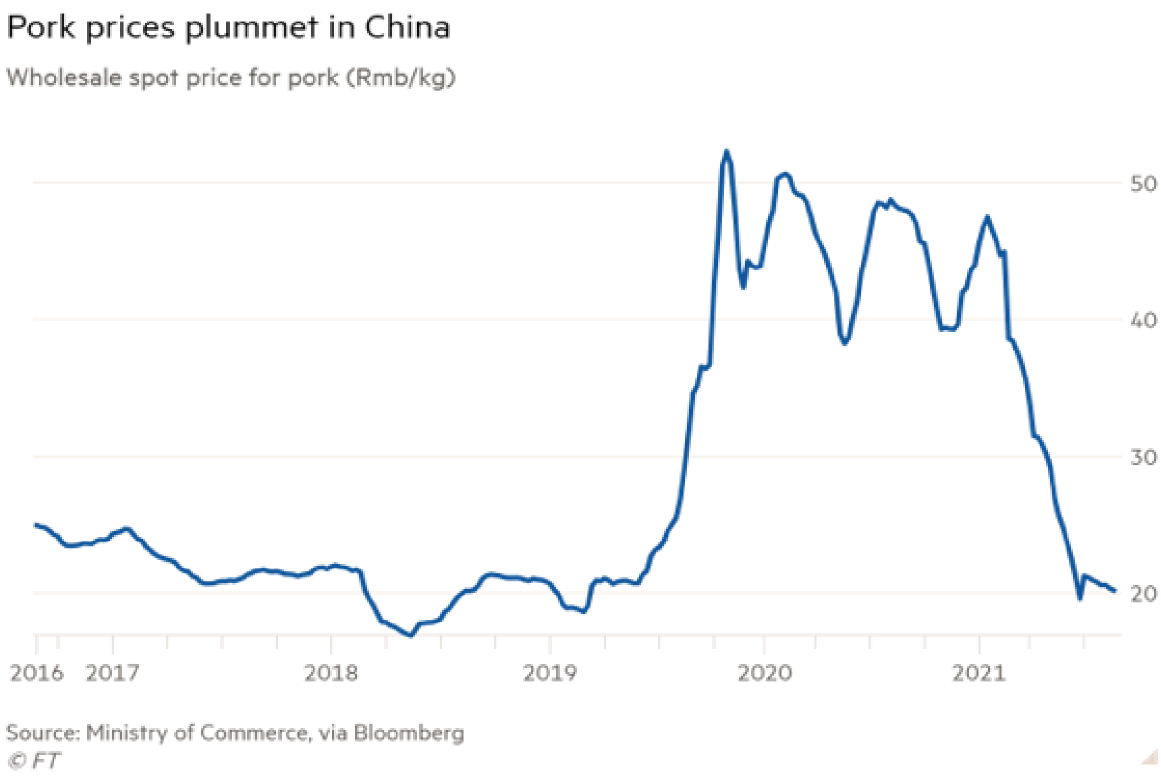

Figure 4.6 Pork price in China between 2016 to 2021

4.3.3 Pig disease

Food safety and pig disease are another concern. For example, between 2005 and 2007, several pig epidemic diseases attacked China, which caused significant pig death. More recently, African swine fever broke out in 2018 and almost decimated half of China's pigs by the end of 2019. A quarter of the breeding animals were taken by the disease, limiting their ability to rebuild the herd. Furthermore, the use of clenbuterol and other illegal feed additives, the slaughter of sick pigs, the pumping of potentially contaminated water into pigs before slaughter and the contamination of feed with heavy metals concerns Chinese consumers. Chinese consumers respond to food safety scares by making dramatic shifts in consumption of one meat to another. The sudden decrease in pork consumption leads to further economic loss for pig producers. Compared to large-scale pig producers, small farmers often suffered more due to limited available resources and capabilities (such as public funds and technologies) to cope with and recover from the disaster. Lots of small pig producers have been driven out of the market, which leads to the sudden shortage of live pig supply and disruption of the supply chain. However, adequate, and timely supply is a prerequisite for producers' and suppliers' value creation, making it possible for producers to reach their service targets and allow the supplier to stay in business.

4.3.4 Environmental policy uncertainty

Finally, pig production has created environmental stress, which has drawn lots of central and local government attention. Small farms rarely treat manure, but large farms are usually required to invest in treatment facilities. Waste often washes into streams and rivers. In China annual production of pig manure reached 600 million tons in 2018, occupying one-third of the total livestock waste generated (Science and Technology Daily, 2018). A census of pollution released in 2009 found that livestock waste was a chief cause of water pollution in China (China Ministry of Environmental Protection, 2010). To prevent and control pollution from livestock production, and encourage the best utilization of livestock manure, China government has aggressively promulgated a series of regulations and policies nationally and locally (as shown in table 4.7). Also, Chinese officials are taking steps to address the problems by closing small-scale farms and encouraging large-scale farms that have the capabilities to deal with pollution. However, the livelihood of those small-scale pig farms has become hugely uncertain. Some of the small pig producers tried to find the resource to scare up and others gradually faded out from the market.

Standards	Content
Technical Specification for Livestock Pollution Prevention and Control	Specifies the requirements for production site selection, layout, manure removal process, livestock manure storage, sewage treatment, solid manure treatment and utilization, feed and feeding management, treatment and disposal of dead livestock and poultry carcasses, pollutant monitoring, etc. Basic technical requirements for pollution prevention and control.
Pollutant Discharge Standard for Livestock and Poultry Raising Industry	According to the different scales of livestock and poultry production, regulates the maximum allowable daily average discharge concentration and maximum allowable drainage volume of water pollutants and malodorous gases, and sets up harmless environmental standards for livestock and poultry breeding waste residues.
Technical Specification for Livestock Pollution Control updates	Specifies the technical requirements for the design, construction, acceptance and operation and maintenance of pollution control projects in intensive livestock and poultry farms.
Standard for Environmental Assessment in the Livestock production industry	Set up the evaluation indicators, limit values, monitoring and evaluation methods of water environment quality, soil environment quality, ambient air quality and acoustic environment quality of various livestock and poultry breeding areas. It is suitable for environmental quality evaluation and management of livestock and poultry farms, breeding communities and grazing areas across the country.

Technical Policy on Pollution Prevention and Control in Livestock and Poultry Breeding Industry	It applies to the prevention and control of environmental pollution in the livestock and poultry breeding industry within the territory of the People's Republic of China. Development, promotion and application of prevention and control technologies.

Table 4.7 National environmental standards for livestock pollution prevention and control

Source: adapted from National Environmental Standards for Livestock Pollution Prevention and Control (Ministry of Environmental Protection & Ministry of Agriculture, 2013).

The establishment of regulations for pollution prevention and control of livestock in China started late. Many of the standards and regulations are still in the development stage and have not been accurately described. During the implementation of the regulations, some local governments do not consider the pig growth cycle, which means the production cannot be stopped immediately. Many companies do not have time to adapt and have been fined heavily and even shut down. Furthermore, different government departments have an inconsistent understanding of environmental protection provisions, which has a great impact on pig production companies. For example, it is required that each pig farm must be equipped with a sewage treatment plant, which most small and medium size companies are not able to afford. Typically, a pig plant which can breed 8,500 sows will need a total investment of 24 million RMB on environmental protection facilities and equipment, which is great financial pressure for pig production companies.

In addition, some local governments arbitrarily expanded restricted and prohibited areas for pig production, and even suddenly change the land that is planned for agricultural land into industrial land. Even if the farms in some areas fully meet the environmental protection requirements, the local government still shuts down or forcibly relocates pig farms. Until 2017, the government set 49,000 livestock and poultry breeding prohibited areas, covering an area of 636,000 square kilometres, accounting for about 17.3% of the overall Chinese pig production breeding area. This has caused great losses to enterprises that have been engaged in breeding for many years and have made a lot of investments.

Finally, the frequent updates/changes of the regulation make it difficult for pig companies to keep up with. After pig farms pass the environmental assessment, they often face continuous rectification in the operation process, resulting in continuous additional investment in environmental protection. The high investment in environmental protection construction and operating costs put many companies under great pressure.

4.3.5 Uncertainties embedded in supply chain relationships

Within the pig supply chain, the instability of relationships among chain members has also posed a significant vulnerability towards the pig supply chain. Chain members may not commit to each other and barely share information. There is very low trust among members in the four case organizations. Breaching contracts are quite common. Companies may take advantage of incomplete contracts to buy pigs from farmers at a lower price instead of contracted prices Since there is no punishment for breaching contracts. Farmers may also choose to sell pigs to anyone who provides higher prices. Secondly, farmers may sell pigs with potential safety problems to companies. Thirdly, with very low negotiating power towards big meat producers, small pig producers get the least profits in the Chinese pig supply chain but always bear the most economic loss.

4.4 Chapter Summary

This chapter reviews the status of the Chinese pig industry. It shows that accounting for nearly half of the world's pig production and consumption, China's potential to affect the world market derives from the size and volatility of its domestic pig market. The typical structure of the pork supply chain is presented which includes pig production, pig slaughtering, processing, pork products retailing and wholesaling and final pork products consumption. The challenges the pig industry is facing have been analysed such as pig price vulnerability, environmental uncertainties and fragmented pig production, and disease epidemics. This analysis in this chapter provides the evidence to support the justification to focus on the pig supply chain in China in this research.

The background information presented in this chapter provided a solid context for understanding the single case analysis which will be carried out in the next chapter.

Chapter 5. The Case of Muyuan

In this chapter, the case of Muyuan is presented. Firstly, the background of the company is introduced. Then the single case analysis is carried out to illustrate Muyuan's resources and resilience building strategy facing major risks in the pig supply chain. The other three single cases (Lihua, Hanshiwei and Nanchuanhe) follow the same structure. The four single case analysis identified how each case company mobilize its resources to overcome various risks and build its resilience. The data were analysed by the author by reading the transcripts multiple times to identify significant features for risk mitigation. This is to lay the foundation for identifying the common and notable patterns and constructs across the four cases.

5.1 Background of Muyuan

Muyuan Co., Ltd. (Muyuan) is a leading enterprise in integrated pig breeding in China. Its business activities include scientific research, feed processing, pig breeding and distribution. The Company's main products consist of piglets, boars, and commodity pigs. Muyuan was founded in 1992 as a small family pig breeding company by Dr Yinglin Qin and his wife Ying Qian and has been developing rapidly as one of the largest pig production companies in China. In the past 10 years, Muyuan's overall annual sales have increased from 1.134 billion RMB in 2011 to 56.277 billion RMB in 2020. Even in the worse year, there is still a 15% growth rate in sales (Figure 5.1).

Figure 5.1 Muyuan's sales between 2011 to 2021(Third quarter) (Billion RMB) (Adapted from Muyuan's annual report 2021)

From 2011 to 2020, Muyuan's net profit increased from 357 million to 30.375 billion, and the 10-year compound growth rate is as high as 64% (Figure 5.2).

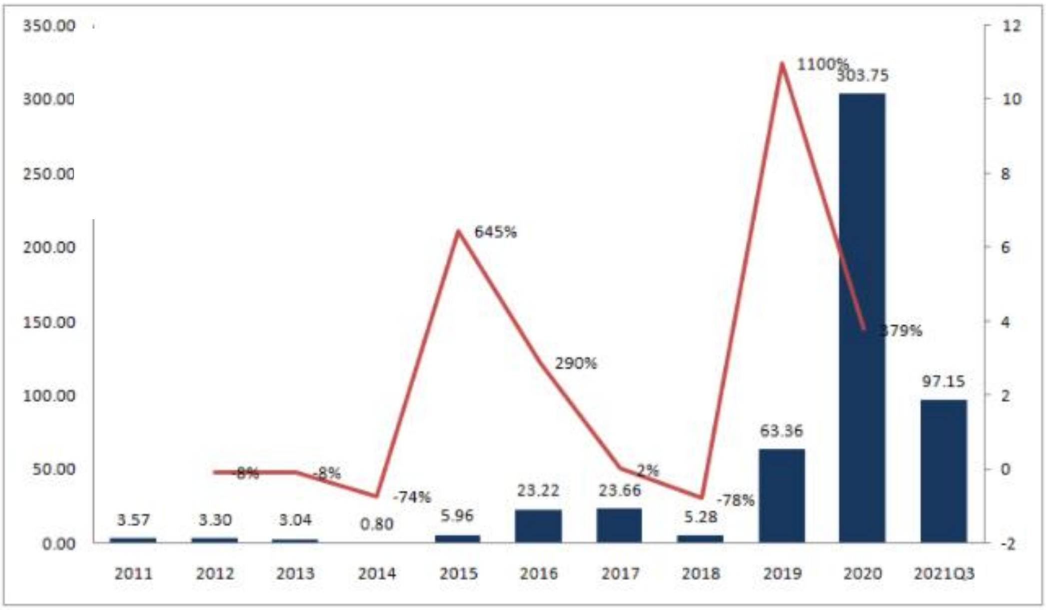

Figure 5.2 Muyuan's net profit between 2011 to 2021 (Third quarter) (100 million RMB) (Adapted from Muyuan's annual report 2021)

In 2020, Muyuan owns 90 subsidiary companies (most are swine farms) across the country, has more than 120,000 employees across its locations and produced 18.11 million commodity pigs annually.

Table 5.1 summarizes Muyuan's chief business development milestones.

Year	Milestones
1992	Started with 22 pigs
2000	Muyuan pig production Co., Ltd is founded
2004	Expanded pig production capacity to 200,000 heads
2001	Started building a self-owned feed factory to avoid the problem of Clenbuterol putting in the outsourced feeds.
2004	Mr Qin Yinglin and his technicians invented the early isolation weaning technology, which shortened the piglets' weaning period from 22 days to 14 days.
2005	Imported 470 great-grandfather breeding pigs from Canada and built the largest core breeding farm in China
2006	In September 2006, the Clenbuterol incident broke out in Shanghai, and more than 300 people were poisoned at the same time. Muyuan's took advantage of its strict

	quality control and successfully won the contract from big meat processing companies.
2007	The sixth biogas project was successfully put into use, marked as the full launch of Muyuan's clean development mechanism project.
2009	Henan Longda Muyuan meat food co., Ltd was founded as a subsidiary of the Muyuan group which has annual 1 million heads of slaughtering capacity.
2014	Was listed on the Shenzhen stock exchange. The market value of its shares exceeded 30 billion.
2017	Produced 7.2 million pigs and was ranked the second-largest pig production company in China
2018	Sold more than 11 million live pigs and was ranked the biggest large-scale breeding company in China

Table 5.1 Milestones of Muyuan (Adopted by Muyuan annual report, 2020)

Muyuan has a full spectrum of departments to manage each production process (as shown in Figure 5.3).

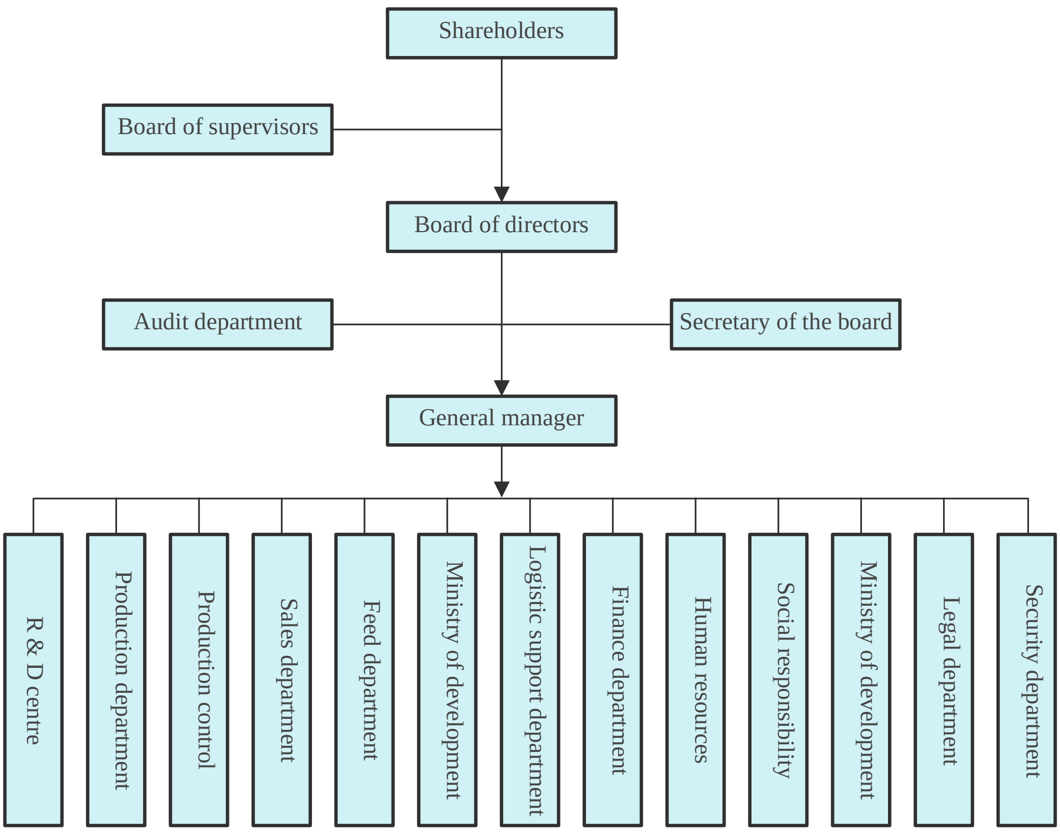

Figure 5.3 Organization structure of Muyuan

5.2 Muyuan's Organizational Resources

Pig production is inherent with various risks. Muyuan's resource development and capability building are embedded in each risk mitigation process.

Muyuan is the biggest vertical integrated pig production company in China. All pig production processes are carried out internally, which integrates scientific research, feed production, pig breeding, pig fattening, live pig slaughtering, and sales. Under the integrated business model, all resources in the production process are under the control of the company, which reduces the transaction costs between each process and enhances the company's resistance to risks. Muyuan tries to standardize the operation of each production process, and trace the whole process information from feed production, breeding, fattening, and slaughtering to enable efficient production operations.

In this section, firstly Muyuan's existing resources are analysed and then how Muyuan mobiles its resources to mitigate the major risks are presented.

5.2.1 Material resources

Feeds account for over 70% of the total cost of pig production. The pig feeds are mainly composed of corn and wheat. Muyuan's headquarter is located in Henan Province which is the largest grain production area. MuYuan takes a vertical supply chain integration approach to improve its resilience. To effectively avoid the shortage and price increase of the feeds in the market, Muyuan built its own feed production company and source from Henan province. All of Muyuan's pig fattening plants are equipped with feed production plants nearby which supply self-made pig feeds. This setting is also to eliminate the use of Clenbuterol. As the manager of Muyuan's feeds plant, Mr Li said,

"In 2000, the use of Clenbuterol in pig fattening was a common practice in the industry. Clenbuterol can promote the pigs to be fattened in a short time and increase the leanness of the pork meat. To quickly gain profits, not only farmers but also pig production companies use Clenbuterol in their feeds. However, pork containing Clenbuterol may cause damage to human health.

To guarantee the quality of Muyuan's pig, instead of using any Clenbuterol during the fattening process, Muyuan focuses more on improving the feeding technology to fatten pigs into reasonable leanness. But we realized that many feed companies put Clenbuterol into their feed formula. To avoid the use of Clenbuterol, we decided to stop sourcing feeds from outside and *built our own feed production factory to ensure the quality of the feeds. We have got recognition from many customers especially customers from Japan and Europe.”*

Except for sourcing from Henan Province, Muyuan rented many state-owned grain reserves across the country to store the grain. These grain reserves are close to Muyuan’s pig production factories, so Muyuan may produce the feeds locally. Local sourcing may not only reduce the raw material purchasing costs and transportation costs but also lowered the possibility of feed mildew.

In addition to feeds, in 2018, Muyuan built its own veterinary drug company to research and manufacture livestock veterinary drugs, which may reduce the cost of veterinary drugs.

Managing over 550,000 sows, the company also owns two nationally designated Great Grandparent farms plus three Grandparent farms with over 8000 purebred sows. This ensures Muyuan has a sufficient supply of piglets.

5.2.2 Facility resources

Muyuan’s headquarter is a modern building equipped with advanced laboratories, a large library, staff dormitories, and recreation areas. The company’s self-built pig plants reach the top standards at the national level. Muyuan has patents on its pig house design. Pig houses are designed differently according to the local temperature and humidity conditions. The company adopts its intelligent raising system throughout the whole pig-raising process. An intelligent environmental system controls the temperature and humidity in the pig house. Pig-raising robots and automatic cleaning systems ensure the pig manure is cleaned in time, which is helpful for epidemic prevention and control. The intelligent feeding systems efficiently feed the pigs guaranteeing food safety and reducing labour costs. A comprehensive environmental management mechanism including an advanced manure treatment facility has been established to effectively manage pollution in the process of pig production. The circular economy model not only equips MuYuan with the capability to be more resilient to the change of government environmental policy but also gains an environmental-friendly reputation which is helpful when MuYuan expands its business in other areas.

As Senior Director Mr Tian said,

“Muyuan believes the adoption of the advanced facilities may not only help to increase the efficiency and reduce the cost of pig raising but also prevent and control swine disease. In small farms, normally, 30 technicians are required to look after 10,000 pigs. Comparatively,

Muyuan only needs 3 technicians with the support of our intelligent raising system. All our pig houses are equipped with a self-cleaning system to guarantee hygiene of the pig house. In addition, we have a set of pig monitoring systems. Once the pigs with health conditions are identified, they will be removed from the pen immediately…".

"After the pig excrement is separated from wet and dry, the pig urine is transported after fermentation treatment, which happens in the biogas slurry storage tank. Biogas slurry can be used to irrigate and fertilize the land, replacing chemical fertilizers. When the nearby farmland needs to be fertilized, the biogas slurry is transported to the farmland through pipelines. According to our calculations, the use of biogas slurry for fertilization can save 200 Yuan per acre of land compared to the use of chemical fertilizers, and production can increase by 30% to 50%. In 2017, the treatment rate of biogas slurry and solid pig manure in Muyuan reached 100%, and the total length of pipelines for returning biogas slurry to the field reached 1.72 million meters. Muyuan has constructed a circular economy model integrating "breeding - biogas fertilizer - ecological agriculture", and achieves ecological, social, and economic benefits".

Figure 5.4 Muyuan's 12th generation pig house

5.2.3 Land

Due to Muyuan's vertical integration model, all pig fattening factories are equipped with feed plants. A typically integrated factory including a pig reproduction area, feeding factory, fattening factory, manure treatment plant and living area for employees covers an area of around 4,000 acres and a construction area of 400,000 square meters, which can produce 1 million head of hogs annually. Thus, a great number of lands are required during pig production. Muyuan acquired a large amount of land through lease contracts with the local government; In

2001, the company has already had 2.3 million hectares of land in stock in the different provinces all around the country. In 2022, the company has land reserves with a total production capacity of more than 100 million head of pigs.

5.2.4 Financial resources

Due to Muyuan's large production scale and integration model, Muyuan requires significant cash flow. All the pig sales need to follow the rules of "one-handed cash and one-handed delivery" which means pigs can only be collected from the pen when the payment goes into Muyuan's account. All the feeds, raw materials and veterinary drugs are received and then get paid for. In general, the company's cash flow is stable and abundant.

Due to the strong cash recovery ability and high achievement in profitability, Muyuan has high credibility in major banks and is favoured by investors.

Figure 5.5 The case flow of Muyuan from 2016 to 2020

Muyuan was listed on the Shenzhen Stock Exchange in 2014 and raised a total of 36 billion (RMB) in 2017. The market value reached 57.6 billion RMB in 2018.

5.2.5 Knowledge resources

As Senior Director, Mr Tian summarized that talented employees, advanced technology and social responsibility are the three core strategies for Muyuan to achieve rapid development.

Mr Qin, the founder of Muyuan graduated from Henan Agricultural University majoring in animal husbandry. He and his core management team all have strong academic backgrounds and rich industry experience.

Figure 5.6 shows that Muyuan continues recruiting top technical talent and backup management trainees to build up the knowledge base. In 2020, the number of employees with bachelor's degrees or above reaches 16,300. An increase of 25 times compared to 2013. The number of professional technicians has also continued to grow from 433 in 2013 to 10,444 in 2020 (Figure 5.7).

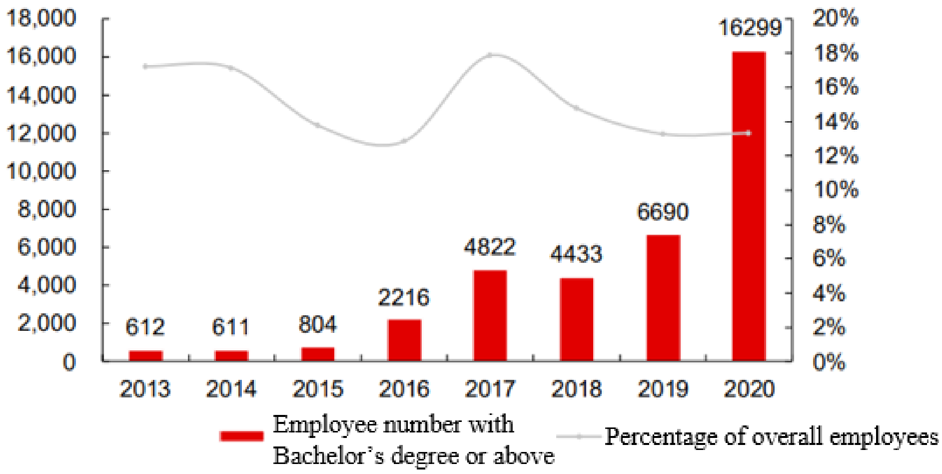

Figure 5.6 The number of employees with bachelor's degree or above

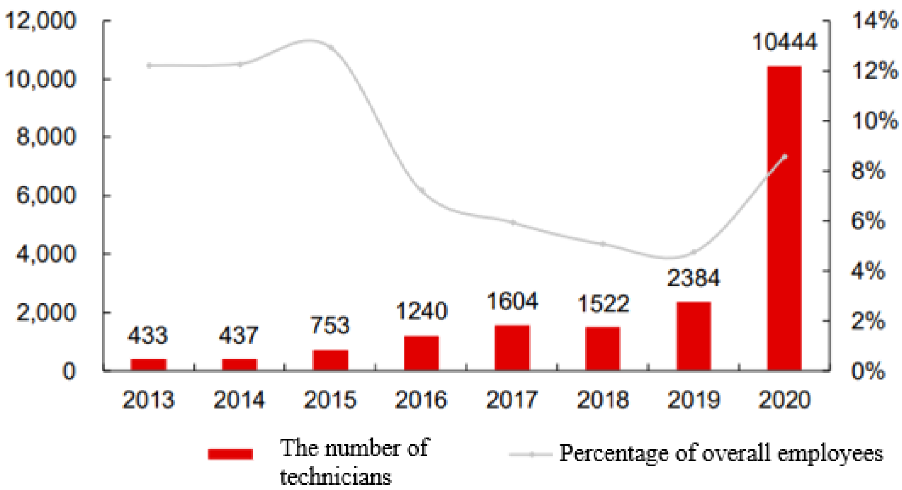

Figure 5.7 The number technicians in Muyuan

Muyuan has built a comprehensive recruitment and training system. Professionals from various disciplines are recruited. Internships are provided to college students through collaboration with universities. Students may better understand Muyuan's cooperate culture and operations and later many of them stay and get promoted in Muyuan after graduation. The new staff receives systematic training including management skills and knowledge of breeding. Each staff will be trained according to his/her interested future career path and then be evaluated. The company takes performance as the core criterion for evaluating and selecting top managers and establishes a younger, professional team.

Mr Tian gave an example,

"Muyuan would like to recruit professionals with strong technical backgrounds. In this way, knowledge can be quickly accumulated within the company. For example, the director of nutrition in our Hennan subsidiary company entered Muyuan through our internship scheme just two years ago. After she obtained her master's degree at the University, she was interested in Muyuan's advanced breeding technology, she did an internship and achieved an outstanding performance. Later, she was recruited into Muyuan and now she is the leader of the supervisor in the nutrition department."

High salaries and promotion schemes are used to attract the top talented professionals. The company motivates all employees to work hard through excellent remuneration, equity allocation, promotion, and other remuneration schemes. As Mr Tian described,

"After the African swine epidemic, we tighten the policy of technician's entrance to pig houses. Technicians who are looking after pigs are not allowed to leave the pig fattening plant for the whole 6 months. The freedom of technicians has been significantly restricted, and they have to work very hard. Such a policy brings us a lot of difficulties in recruiting top technicians.

Therefore, to better enhance the enthusiasm and sense of responsibility of employees, the company has formulated a more complete incentive mechanism and remuneration system. Muyuan values talents. Higher remuneration and perfect incentive mechanism are expected to help the company to retain more outstanding talents. And a clear promotion path will also enable more outstanding talents to stand out, thus boosting the company's long-term development. The overall turnover of the employees in Muyuan is much lower than the industry level."

By increasing the production scale, standardization and improving management level and breeding technology, Muyuan can control the production cost. Muyuan has formulated a series of standardized systems and technical specifications for the production processes from raw material procurement, feed processing, pig breeding, and pig fattening. The “standardization” of the production system promotes the company’s breeding technology development and improves production efficiency. Innovation is highly encouraged. Rewarding for technology innovation including cash and equity is provided. 436 national patents for various pig houses and related breeding equipment were obtained. The technological innovation in Muyuan mainly focused on five aspects:

1. The innovation of the pig houses and equipment. Muyuan’s pig house design has improved nine generations. The different design adapts to different climatic conditions, considering the temperature and humidity required for pig growth and meeting the requirements of large-scale and standardized modern farming style. Through the research and development of intelligent equipment such as intelligent feeding, environmental control, and pig-raising robots, the company provides a clean environment for pigs and improves the health of pigs. The continuous upgrading of pig raising equipment has greatly improved labour efficiency. In the fattening stage, one breeder technician can look after 2,700-3,600 live pigs at the same time which is the highest level of production efficiency in the pig industry.

2. The continuous improvement of breeding technology to increase the genetic performance of breeding pigs and breeding efficiency, reducing feeding costs, and improving the quality and taste of pork.

3. Feed production and Continuous improvement of formula technology. Based on the existing "corn + soybean meal" and "wheat + soybean meal" formulas, the company has developed the barley and raw material processing by-products formula and low-protein diet formula. The new patented formula not only reduces the reliance on traditional corn and soybean meal but also decreases nitrogen emissions and is more environmentally friendly. Meanwhile, Muyuan has established 59 types of dynamic nutrition models to provide pigs best nutrition. The nutrient formulae can be dynamically adjusted according to the growth of the pigs, to achieve one formula per day and a precise nutrition supply. The establishment of a nutrition information system may monitor feed intake and feed quality to guide pig feeding and reduce feed waste.

4. Upgrading and improvement of pig breeding and epidemic prevention technology, Muyuan established a pig disease prediction model through artificial intelligence technology to realize real-time monitoring and effective control of epidemic diseases, automatic collection and analysis of breeding process data, early warning of s pig diseases, and remote diagnosis to assist veterinarians.

5. Key breakthroughs in environmental protection technology. Muyuan has innovated the fourth generation of biogas treatment equipment to simultaneously deal with manure and sewage.

5.2.6 Relationship resources

Due to Muyuan's vertical integration model and large business scale, many production processes are carried out internally. Muyuan does not need to maintain a great number of relationships.

Muyuan maintains close relationships with raw material and veterinary drug suppliers to carefully sufficient supply. Most of Muyuan's pigs are sold to brokers. The company has a platform with brokers registered. Muyuan exhibits the pig information daily and the brokers can bid on the pigs through the platform. Good relationships with the government have been maintained to help with the acquisition of land. Muyuan provides job opportunities to reduce the local unemployment rate. Muyuan supports the local poverty alleviation project. Pig raising causes smells that still disturb local villagers. The publish relation department is responsible for handling the conflicts with the village. The good relationship with the village committee also mitigates the tension between the company and local people. Due to the advanced technology, Muyuan has become a role model in the industry. Regular industry meetings and visits are arranged for other pig production companies to exchange breeding technology and management experience.

5.3 Risk Management Process

Muyuan's intensification of pig production and integrated model enables the company to have more control of the production process and has advantages in risk management, food safety, epidemic prevention, and cost control. However, it also brings some problems.

5.3.1 Price fluctuation

Due to the large scale, price fluctuation causes huge pressure on the company's financial resources.

In 2021, the price of commercial pigs dropped from 26.95 yuan/kg in January to 11.88 yuan/kg in October, which decreased by almost half of the price. In turn, Muyuan's profit reduce from a profit of 10.2 billion RMB in the same period last year to a net loss of 1 billion RMB.

As Senior Director Mr Tian described:

"We did not know how long the price will keep dropping. All our management team nervously watched the price trend every morning. We had a lot of meetings to discuss what we can do and evaluate the consequence if the price keeps dropping. I received various reports on the estimation of the price trend and possibly impact on Muyuan's profits every day. We are all under great pressure. Muyuan's production scale is large which means we have staff to pay and pigs to feed daily. The more pigs we had, the more financial loss we made."

To buffer the impact of the price decrease, Muyuan took two approaches: 1) Stop selling the commercial pigs and sell sow instead; 2) Cost control.

The pig price fluctuation cycle refers to an economic phenomenon in which pig prices change cyclically. The reason for the price fluctuation is that when pig price increase, farmers actively replenish the piglets to produce more pigs, which leads to the oversupply of live pigs. When the supply is over demand, the pig price drops. The farmers will get rid of the sows to reduce the production of pigs, which lead to a shortage of pig supply in the next 6 months. So, the pig price will rise again.

As a leading vertical integrated pig production company, Muyuan builds its own sow farms to supply piglets to its pig fattening factories. The self-owned sow farms can not only provide sufficient sows and piglets but also give Muyuan the flexibility of selling piglets instead of commercial pigs when the pig price is low. Selling piglets instead of fattened pigs may save the cost of feeds and minimize the profit loss from commercial pig selling. In addition, the integrated sow farms enable Muyuan to control the speed and quantity of pig production so that Muyuan can quickly recover from the previous profit loss. After birth, sows go through nursery, fertilizing, gestation, and farrowing. It often takes 10-12 months for a sow to be able to produce piglets. Muyuan has an advanced information system which monitors the daily live pig price change, and the technicians use advanced algorithms to estimate the future tendency. Early warnings can be given when the price starts to drop. When the pig price is in an upward cycle, Muyuan increases the sow inventory to produce more piglets and produce more pigs to compensate for the profit loss in the last period and quickly gain more profits. Other pig companies also want to purchase more piglets to gain profits. When the profit of piglets is 80% higher than that of commercial pigs, Muyuan may start selling piglets.

Figure 5.8 Muyuan's advanced pig price monitor system

Cost control is another important way to mitigate price risks. The cost of pig production mainly includes raw materials (including feed, medicines, and vaccines), labour, and production/manufacturing expenses (including depreciation, energy consumption and others). The cost of raw materials accounts for the highest expense. According to Muyuan's 2021 annual report, the average annual raw material costs account for approximately 55% of its production costs. The feeds are self-supplied which provides Muyuan with the flexibility to adjust the main ingredients in the feed formula according to the market price of raw materials, effectively reducing the cost of feeds.

The advanced technology innovation further facilitates cost savings. From 2017 to 2020, the company's R&D investment increased from 73.98 million to 410 million RMB, an increase of 4.5 times. And the number of R&D employees increased from 641 to 2,362. However, these investments in knowledge building have brought significant cost reductions for Muyuan. From 2017 to 2020, the cost of medicines and vaccines per head of commercial pigs was reduced from 104 yuan to 63 yuan, a drop of about 40%. The company has built a dynamic cost assessment system including detailed measurement indexes such as profitability, production cost, production efficiency and product quality in each pig production stage. The production management information system can accurately assess the technician's performance which is directly linked to their salary. The application of no flushing and leaky floors in pig houses, improved drinking fountains, advanced high-pressure water guns for cleaning and disinfection, and computer-controlled cooling sprays reduce water consumption. The internal heat exchange system and better sealing of the pig house save the use of electricity. Any innovation on cost saving is quickly replicated and shared with other teams. Muyuan has a price monitoring system to record the historical pig price data and raw material data for analysis. As Mr Wang, the purchaser of Muyuan's feeds plants said,

"We monitor and record the historical price change of the raw material. Through comparing and analysing, we try to estimate the future trend. We will submit our estimation to the headquarter and they will incorporate other information such as the pig production information and decide on the purchasing strategy during the department head meeting. Our research team have many researchers with PhD degree. They are building price models to consider more factors which make our prediction more precise, and we can better control the cost of the feeds."

Compared to other pig production companies or the industry averages, Muyuan achieves the lowest production cost. The average production cost in the industry is about 24 RMB/Kg, and Muyuan saves 1/3 of the cost which is around 15 to 16 RMB/Kg.

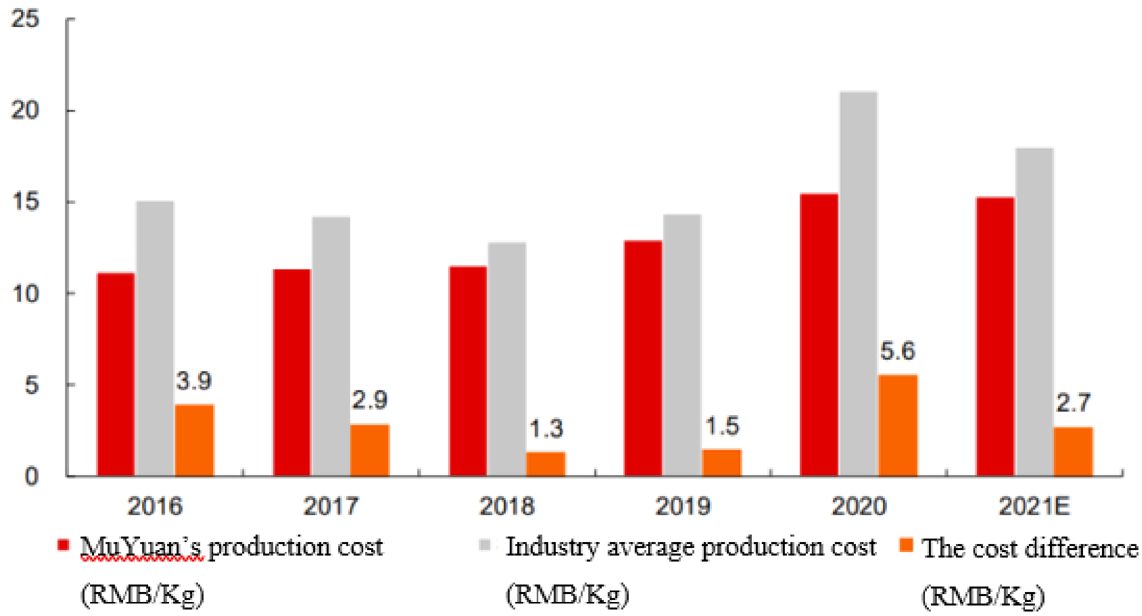

Figure 5.9 The production cost of Muyuan

The lowest production cost buffers the impact of price reduction. It enables Muyuan to achieve less profit loss when the pig price is low and gain higher profit when the price is high. So, Muyuan can either sustain or develop quickly. In 2021 winter, the five major pig-raising companies lost nearly 20 billion RMB. Among them, Muyuan is the one with the least loss.

Company	The overall profit (RMB)
Muyuan	Loss of 1 billion
TianBang	Loss of 2.05 billion
ZhengBang	Loss of 5.5 billion
XinXiWang	Loss of 2.85 billion
WenShi	Loss of 6.75 billion

Table 5.2 The profit of five major pig production companies in China from October to December 2021 (organized from companies' annual report)

The strong cash flow also enables Muyuan to not only resist the financial loss brought by the price decrease but also gives Muyuan the opportunity to invest and quickly recover from the loss when the price is increasing. Mr Tian revealed,

"Since 2019, Muyuan have raised more than 10 billion RMB through convertible bonds, medium-term notes, fixed increments, and short-term financing bills. In 2021, we released a private placement plan for major shareholders with a total scale of 6 billion yuan. Also on the same day, Muyuan shares received surveys from 24 top public and private investment institutions including Hillhouse and Gao Yi.

The strong financial status enables Muyuan to survive and resist longer in the pig price cycle. Many small pig production companies went bankrupt in the market winter. We had a profit loss; however, we lost the least compared to other companies. We still have enough capital so that we can invest heavily in our sow farms to get prepared for the coming better market. I am sure Muyuan could overcome the winter of the market and develop quickly in the next term."

5.3.2 Pig disease

At present, there are about 50-60 kinds of swine epidemics. The common ones are swine fever, swine flu and viral diarrhoea. Multiple diseases can coexist and spread rapidly. The disease may cause pig fat loss, and the death of pigs, which leads to a decrease in feed return rate and an increase in labour and medicine expenses.

As Senior Manager, Mr Tian talked about African swine flu,

"Of course, we are nervous. If one pig is infected, all the pigs will have to be culled. Each of our pig houses is large-scale. The loss will be huge."

Muyuan has developed clear procedures for preventing and controlling pig disease. The detailed procedure has been made into training material which has been distributed within the company and subsidiary companies. Regular training has been provided to pig-raising technicians to get them familiar with the typical symptom of the disease. Suspected cases are reported timely once identified. The pigs in the whole pen should be isolated immediately. The veterinary department carries out sterilizing and starts the treatment. Mr Tian said,

"Normally, the disease happens suddenly and spread widely which requires us to respond quickly. Muyuan has developed the capability to establish a set of solutions for epidemic prevention and control, plan execution and result evaluation. We are required to analyse complicated information. formulate clear procedures and standardized them to share them with other departments and strictly implement them in a short time. It is a challenge for the management team and staff.

Our advanced pig house and systematic veterinary system give us a big advantage. All our pig plants are equipped with rapid testing laboratories. The investment in a well-equipped testing laboratory is about 1 million. The rapid inspection laboratory is equipped with PCR detectors for preliminary rapid detection of epidemic diseases. And the test result can come out in about an hour. If the test result is in doubt, it will be sent to the central laboratory for further inspection. Generally speaking, the accuracy rate of disease detection can reach 98%-99%. Through timely detection, early treatment and culling, Muyuan minimizes pig loss.

Many small farmers and pig production companies lack scientific veterinary systems and misuse different kinds of veterinary drugs on the market, which leads to the outbreak of epidemics. Some of them even ignore food safety and still sell the sick pigs to the market."

The entry and exit of pig houses are unavoidable because of the delivery of live pigs and feeds. The contaminated vehicle is one of the main channels to pass the virus into pig houses. Therefore, decontamination centres are established to thoroughly clean and disinfect the people and vehicles when entering and leaving the pig houses (as shown in Figure 5.10 below).

Figure 5.10 Decontamination centre to sterilize the vehicles

Taking advantage of the vertical integration model, Muyuan’s feeds are all self-produced. The manufactory and transportation of feeds and other raw materials can be controlled. So, it can significantly reduce the number of people and vehicles in and out. In some cases, feed production is carried out within pig plants. The possibility of cross-infection can be minimized.

Each pig house manager has established an individual epidemic prevention management system. It detailed illustrates the operations in each prevention and control process with a clear flow chart. Monitoring mechanisms have been built to make sure that the implementation of disease prevention and treatment operation can be supervised. Critical risk control points in the production process are identified, highlighted, and monitored (As shown in Figure 5.11). For each production process, a special person is assigned to take charge of and deal with the problems in time. There is a comprehensive and standardized process for personnel disinfection, isolation, and entry and exit from and to different production areas.

The fully enclosed modern pig house with ventilation, temperature control, and high automation independently developed by Muyuan is sufficient to provide a clean, comfortable, and healthy growth environment for pigs. Meanwhile, Muyuan has established a pig disease prediction system through artificial intelligence technology to achieve real-time monitoring and effective control of epidemic diseases. The system can automatically collect and analyse the breeding process data, provide early warning of some pig diseases, and assist veterinarians in remote diagnosis. But it still cannot completely guarantee the isolation of the African swine fever virus from the outside. After the outbreak of African Swine Fever, Muyuan further invested nearly 3.8 billion RMB in the comprehensive renovation of the pig house. The partitioned pig house integrating air filtration, independent ventilation, air sterilization, the feeding method, and the automatic drinking system has been updated. The pig house is transformed into a partitioned house for multi-level isolation of the pigpen. The air filtration system can filter viruses with smaller molecules such as PED and blue ear in the air.

Figure 5.11 Monitor the critical points of the production

Muyuan has incentive schemes for employees based on their performance in epidemic prevention. For example, if the disease is identified in time, staff may get the rewards. And the pig raising technician may also get economic rewards if there is no epidemic happened. The economic reward mechanism can improve employees' enthusiasm for disease control and prevention.

Due to the large production scale, the loss can be huge once the epidemic occurs and is not dealt with in time. But it also brings opportunities to recover quicker than other companies. The pig loss due to the disease will be evaluated. After considering other factors such as the current pig price, Muyuan decides if the house will be kept empty or refilled with piglets immediately to offset the loss. The biggest advantage of Muyuan's integrated model is that all the production processes can be flexibly under control and the implementation of any disease control and prevention operations can be highly efficient.

5.3.3 Environmental policy uncertainty

Large-scale pig raising may produce serious pollution caused by impropriate treatment of livestock manure. Large-scale pig production companies need to fulfil social and avoid the negative impacts on the local environment while pursuing intensive production. China's first environmental management regulation for livestock production "Regulations on the Prevention and Control of Pollution from Large-scale Livestock and Poultry Breeding" was issued in November 2013. Later, many other regulations were gradually issued. Environmental standards are gradually tightened. However, many of the standards and regulations are still in the development stages and have not been clearly described. The sudden change and unclear standards pose a significant risk to the pig producers. companies which cannot reach the standards will be fined or even be informed to stop production. In addition, there are understanding deviations when the local governments enforce the new environmental protection regulations. The arbitrarily expanded restricted and prohibited areas for pig production have brought more uncertainty for Muyuan. Muyuan has to relocate the pig plant to an allowed place to avoid water pollution, which has significantly increased the production cost. The change in environmental policy has brought new challenges to the development of the pig breeding industry.

To deal with these environmental policy uncertainties, Muyuan continuously improves the company's environmental protection level not only by complying with the current laws and regulations but also by aiming at exceeding existing standards. In this way, Muyuan may minimise the impact when government increase the standard of environmental regulation. For example, there is no compulsory requirement to install pig manure anti-leakage facilities in pig houses. Since 2014, Muyuan has made it a standard to install anti-leakage facilities during the construction of every pig house to ensure that the sewage or other pollutants would not penetrate the groundwater layer and cause pollution. An environmental protection team is established to monitor the whole progress and performance of environmental protection facilities building. Those who fail to pass the inspection are not allowed to proceed to the next stage of construction. So, the anti-leakage facility has become an industry requirement later, and many pig production companies either cannot afford to install or experience difficulties adapting the facility to existing pig houses design. As Mr Tian said,

"Muyuan wants to walk a step ahead in environmental protection. For example, Odour control in pig production is a worldwide problem. The current regulation only requires pig houses to be built 500 meters away from residential areas and there is no clear requirement for odour

treatment. When selecting the site for the pig house, we comply with the standard which is higher than those set by the state and fully consider the potential impact on surrounding residents, ensuring that the pig plants are far away from densely populated areas.

In Muyuan, we have an odour prevention and control team which is responsible for researching odour treatment and taking control. Through adding live bacteria, air filtration, planting trees and other methods, Muyuan try to reduce odour to a minimum. This is also to prevent the site we choose to become a restricted pig production area. As a leading pig-raising company, Muyuan has this social responsibility. Also, when the government's regulations are tightened, we do not have to suffer from them. That is why we invest in environmental innovation heavily. In 2020 and 2021, we further invest more than 200 million RMB in environmental protection facility building."

Taking advantage of its vertical integration model, Muyuan has established a comprehensive environmental management system covering every production process and built an agricultural circular economy model that integrates "breeding - biogas fertilizer - ecological agriculture". Advanced harmless treatment plants are built close to pig houses to deal with sick and dead pigs. The closed-loop sick/dead pig disposal mechanism includes collection direct from Muyuan's pig houses, transportation to treatment plants, and disinfection to high-temperature processing. Finally, the oil residue separated will be converted into biodiesel and meat whilst bones residue will be converted into fertilizers.

Muyuan actively carries out innovative research and development in environmental protection to reduce the environmental impact on the production process. Until 2020, Muyuan has obtained more than 80 patents for environmental protection. The intelligent pig house is equipped with a computer-controlled cooling system which reduces the water usage for cooling by about 71% compared to the traditional method. High-density atomization spray is used to adsorb the odour generated in the production process, which significantly reduces the impact of odour in the field and surrounding areas. Once the innovation has been proven to be effective, it will be quickly promoted throughout the whole company. These investments in advanced facilities not only enable Muyuan to fully comply with the environmental standard but also reduce operational costs.

5.4 Case Summary

In this Chapter, firstly, Muyuan's existing resource base has been examined. Muyuan as the biggest vertical integrated pig production company occupies strong tangible resources including lands, materials, facilities, and financial resources. Muyuan's production process covers feed production, pig breeding, pig fattening, live pig slaughtering, and sales. Such a highly vertical integrated model enables Muyuan to efficiently manoeuvre all the resources to buffer the impact of risks.

Due to Muyuan's strong financial resources, Muyuan can survive in the industry during the profit loss, while many other pig production companies experience significant financial difficulty or even go bankrupt. Such a strong financial position also enables Muyuan to have the capital to invest in continuous production, knowledge and facility building to either offset the loss of the resources or quickly recover from the resource disruption.

Through analysing Muyuan's strategies in dealing with three types of major risks embedded in the pig production industry, how Muyuan builds its resilience has been revealed (Shown in Table 5.3).

<table>
<tr><th>Risks</th><th colspan="2">Resource Strategies</th></tr>
<tr><td rowspan="8">Price Fluctuation</td><td>Build own sow farms to supply piglets to its pig fattening factories which gives Muyuan the flexibility of selling piglets instead of commercial pigs when pig price is low</td><td rowspan="3">Vertical integration to provide flexibility and efficient control of the production process</td></tr>
<tr><td>Integrate sow farms enable Muyuan to control the speed and quantity of pig production</td></tr>
<tr><td>Build own feeds factory provides Muyuan with the flexibility to adjust the main ingredients in the feed formula according to the market price of raw materials, effectively reducing the cost of feeds</td></tr>
<tr><td>Acquire lands to get prepare for the expansion of production</td><td rowspan="3">Accumulate physical and financial resources to buffer the risks</td></tr>
<tr><td>Keep a strong cash flow</td></tr>
<tr><td>Invest in water and energy saving system</td></tr>
<tr><td>Invest in dynamic cost assessment and pig price monitoring system to have a clear measure and control of the production cost and profits</td><td rowspan="2">Internal Knowledge building to control the production costs</td></tr>
<tr><td>Invest production management information system to assess the technician's performance</td></tr>
<tr><td rowspan="2">Pig Disease</td><td>Self-own feeds factory to minimize the cross infection</td><td>Vertical integration to flexibly implement disease control and prevention operations</td></tr>
<tr><td>Establish decontamination centre</td><td>Accumulate physical resources</td></tr>
</table>

	Clear procedures for preventing and controlling the pig disease	Internal Knowledge building
	Invest on high tech pig houses to provide a healthy environment for pigs	
	Invest on high tech disease prediction and diagnosis system	
	Provide incentive schemes for the employees to prevent the epidemic	
Environmental Policy Uncertainties	Acquire more land to enable the relocation of pig plants	Accumulate land to buffer the risks
	Establish a comprehensive environmental management system covering every production process and built an agricultural circular economy model	Internal Knowledge building to build high environmental standard which exceeds existing standards to buffer the policy change uncertainty
	Application of high-tech environmental protection equipment	
	Carry out innovative research and development in environmental protection	

Table 5.3 Muyuan's resource management strategies to deal with the risks

To buffer against price fluctuation, Muyuan focus on reducing production costs. Muyuan takes advantage of its vertical integration structure to control the cost in each production process and coordinate the material, information, and financial flow to achieve efficient production. The heavy investment in knowledge building further facilitates cost reduction. Thus, Muyuan would be able to achieve fewer profit losses when the pig price is low. And when the pig price increase, Muyuan would be able to not only resume production but also carry out efficient production and recover quickly. More profit can be gained to compensate for the lost profits.

The investment in knowledge building and technological innovation helps Muyuan to prevent and control pig disease. Still, with benefits from the vertical integration model, Muyuan would be able to minimize the disease spread across each production stage. Muyuan's large production scale may lead to huge losses if the epidemic is not dealt with timely. It also gives opportunities to quickly resume production and efficiently recover from pig loss.

Through carrying out innovative research and development in environmental protection, standardizing environmental protection procedures across the company and investing in the company's environmental protection facility building, Muyuan achieves higher environmental standards ahead of national requirements, which can significantly reduce the rectification, shutdown, fines, and disputes caused by environmental problems. The increasing production scale can greatly share the cost of environmental protection investment.

Chapter 6. The Case of Lihua

This chapter explores Lihua's resilience-building strategy. Firstly, the business development of Lihua and its existing resources are presented, followed by analyses of how Lihua mitigates the three major risks embedded in the pig production industry, revealing its resilience building process. This chapter ends with the case summary.

6.1 Background of Lihua

Jiangsu Lihua Animal Husbandry Co., Ltd was established in 1997 with registered capital of CNY (Chinese Yuan) 403.88 million. Its main products are commercial yellow feather broiler chicken, commercial pigs, and geese. Lihua has more than 60 wholly self-owned subsidiaries, located across twelve provinces in China. In 2011, the company began to develop the pig breeding business. Figures 6.1 and 6.2 show Lihua's pig sales from 2013 to 2018.

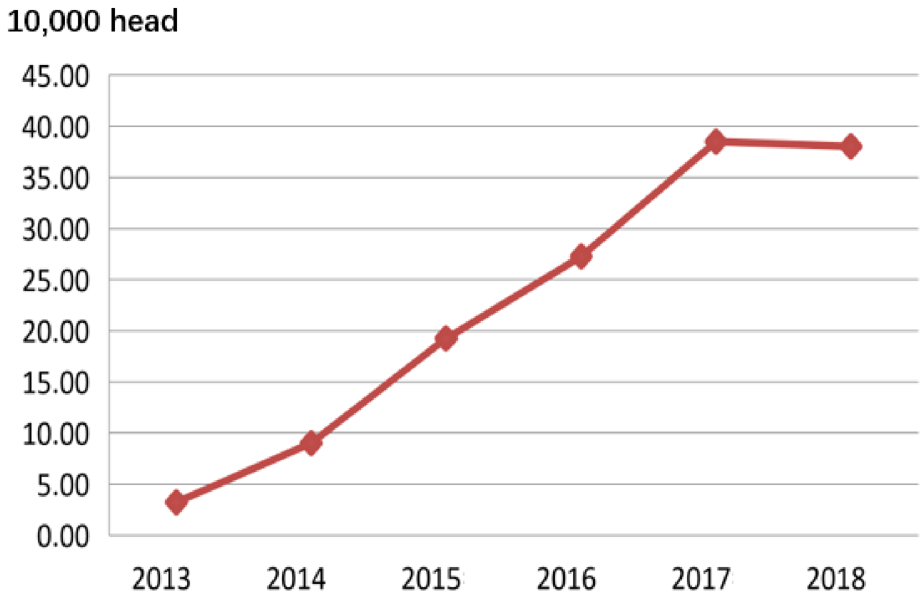

Figure 6.1 Lihua's sales volume of commercial pigs 2013 – 2018 (Lihua annual report, 2020)

It can be seen that Lihua's production volume and sales have significantly increased in these five years (Figure 6.1). In 2020, the company produced 184,200 commercial pigs, and the sales of pigs reached 669 million CNY (as shown in figure 6.2). Lihua has accelerated the expansion of existing pig farms in Anhui, Shandong, North Jiangsu and other provinces. Meanwhile, the company has started establishing pig breeding subsidiaries in Changzhou, Suzhou, Yangzhou, Nanjing, Heze, and Bozhou provinces which may further expand pig farming capacity. With a further 920 million CNY investment, it is planned that feed factories with an annual output of 180,000 tons, 6 breeding farms, and 15 commercial pig farms will be built.

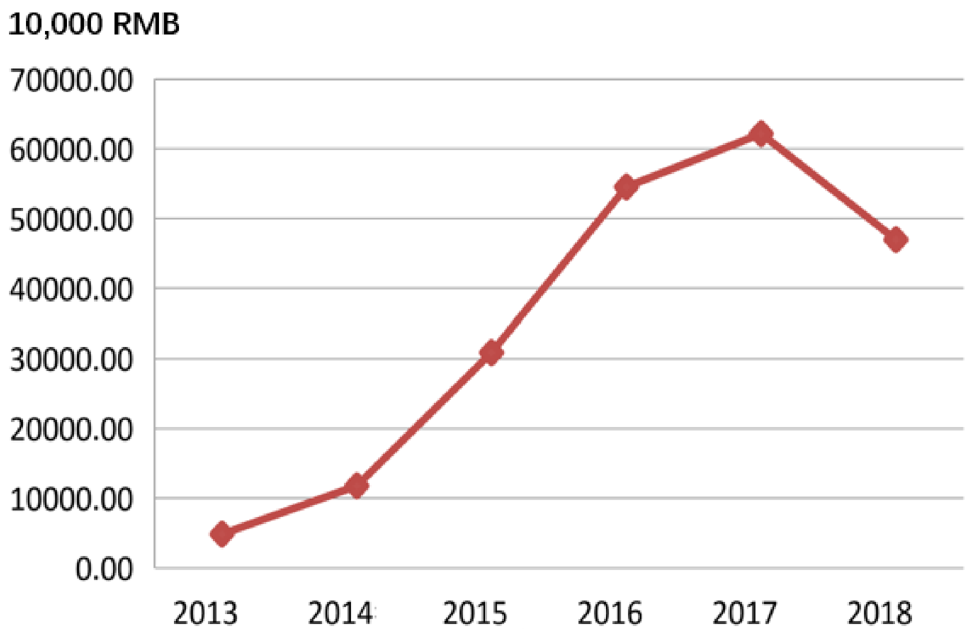

Figure 6.2 Lihua's sales of commercial pigs 2013 - 2018 (Lihua annual report, 2020)

Table 6.1 summarizes Lihua's development milestone in pig production.

Year	Milestones
1997	In June 1997, Lihua Livestock and Poultry Co., Ltd. was established.
2003	In April 2003, the first subsidiary, Hefei Lihua Livestock and Poultry Co., Ltd., was established.
2003	In June 2003, Lihua was identified as "Jiangsu Provincial Leading Agricultural Industrialization Enterprise" by the People's Government of Jiangsu Province.
2010	In April 2010, the academician workstation of Changzhou Lihua Livestock and Poultry Co., Ltd. was established.
2011	In March 2011, Suqian Lihua Animal Husbandry Co., Ltd. was established. Formally enter into the pig production industry.
2011	Cooperated with Legend Capital, a subsidiary of Lenovo, to introduce foreign capital of 30 million US dollars.
2013	The first batch of pigs of Suqian Company was successfully launched.
2019	Was listed on the Shenzhen stock exchange. The market value of its shares exceeded 11.85 billion RMB.
2019	In July 2019, Anhui Lihua Biological breeding Industry Co., Ltd. was established.

Table 6.1 Lihua's development milestone in pig production

Lihua’s pig farming operations mainly cover pig breeding, feed production, pig fattening, and sales. Figure 6.3 shows Lihua’s main business process.

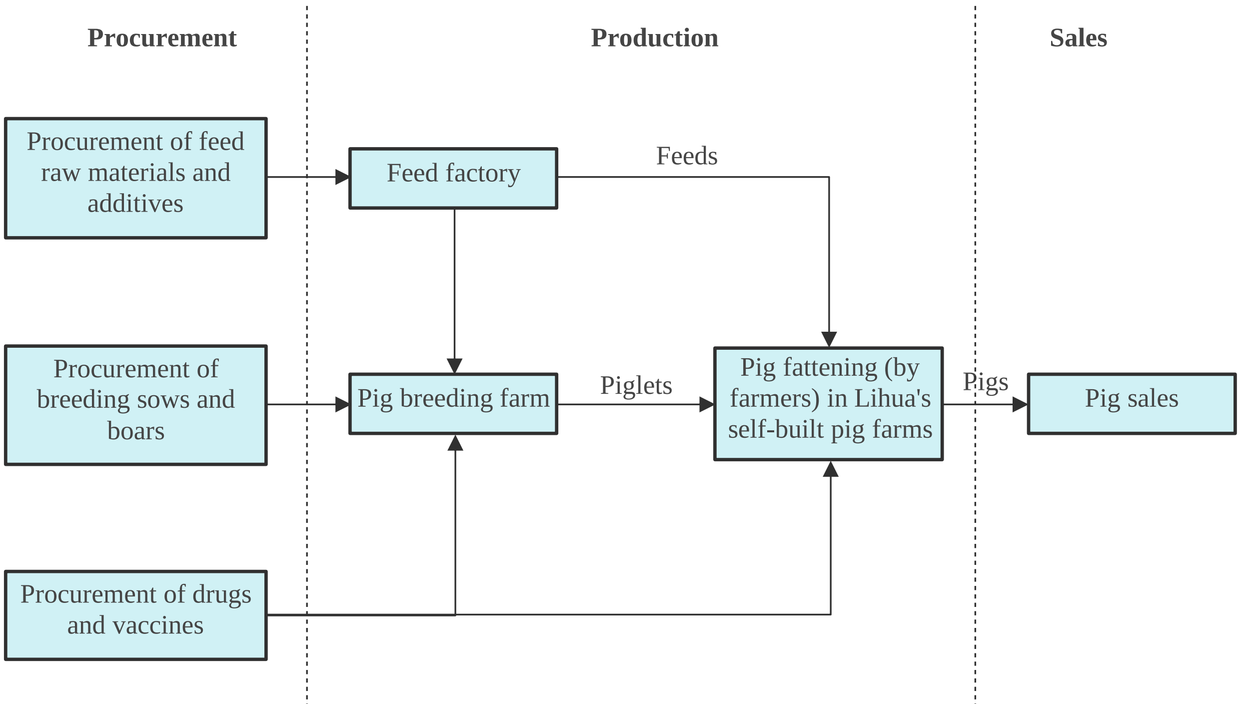

Figure 6.3 Lihua’s main business process

In the pig production process, Lihua promotes the operation mode called “company + base + farmers”. Figure 6.4 explains Lihua’s pig production model.

Two stages models:

- **Pig Breeding**
- **Piglet weaning** — **Raised by Lihua (stage 1)**
- **Pigs fattening** → **Raised by farmers (Stage 2)**

Figure 6.4 Lihua’s pig farming model

Lihua rents land from either local authorities or farmers to build its own high-quality and large-scale pig farms. Lihua is responsible for feed production, pig breeding and piglet weaning, and then hands over piglets to farmers for fattening in the company’s self-built farms. Farmers rent pig houses from Lihua, and the company’s production service department is responsible for managing the farmers. The company provides one-stop products and services for farmers who rent pig farms, which include: pig pens with unified standards, piglet supply with guaranteed quality, unified supply of feed, medicines and vaccines, pig raising and epidemic prevention technology, and pig sales. Lihua chooses collaborative farmers who have strong financial backgrounds, rich pig farming experience, and a sense of responsibility to work with. Farmers pay a certain deposit and monthly rent to Lihua when signing the contracts. Farmers are mainly responsible for providing labour forces and raising pigs according to Lihua's standardized procedures.

The collaborated farmers are responsible for fattening piglets provided by the company. The collaborated farming households shall deliver the commercial pigs entrusted to be bred to the company according to the contract. In the end, the company pays the farming income to the farmers based on their performance, after deducting the settlement amount for production materials such as piglets, feed, medicines, and the cost of water, and electricity shared by the commercial pig breeding base. The company gives farmers internal prices for materials such as piglets, feed, and drugs which are lower than the market price.

The overall production cycle of pigs is around 150 days, of which the fattening period is about 110-130 days. When pigs reach the weight for sale, Lihua's marketing and sales department sells the pigs to pig brokers or slaughterhouses. Then the company pays the farmers based on their performance (such as the ratio between the pig's weight and feeds used, the number of dead pigs, etc.) after deducting the cost of piglets, feed, medicines and used water and electricity. As the Managing Director of the pig farming department, Mr Li said,

"Lihua's self-built pig houses are contracted to farmers, and farmers who let us land are given priority to rent pig houses. In this way, farmers cannot only have stable incomes from land rent but also income from pig raising. Lihua carries out unified farmer management. Each pig house can accommodate 1,000 pigs and each year 2.5 batches can be raised. Thus, 2,500 pigs can be raised annually. Roughly farmers can earn 40 RMB for each pig. Farmers can achieve a net income of over 100,000 RMB per year. Even if the raised pigs have not met the technical requirements such as the ratio of meat to raw material, there is a profit guarantee of 60,000 RMB for farmers. So, the farmers only make money and never lose money."

Lihua provides farmers with high-standard pig farms with fully automated equipment and facilities installed, which improves pig production efficiency compared to traditional small-scale pig farming. The locations Lihua chooses to build the pig farms are normally far away from human crowded areas and other pig breeding sites, which may reduce environmental and noise pollution to residents. The company's unified disinfection and immunization process can further reduce the risk of disease transmission among pigs in different stages and batches. In addition, Lihua can monitor farmers' operations in real-time, which greatly reduces the risks of farmers' behaviours in violation of the regulations and production procedures such as the private sale of feeds and pigs.

In Lihua's production model, the risk of capital return shortage can be reduced, and the company can fully control the production process. In its self-built large-scale pig farms, higher-level epidemic prevention equipment can be installed. However, this model requires a heavy investment into fixed assets and occupies a lot of land. So, the speed of scaling up is restricted. As the Managing Director of the pig farming department, M. Li said,

"In the future, due to the adjustment of government policies, the outbreak of major epidemics, and the fierce market competition, it will become more difficult to find new collaborated farmers, and the existing collaborated farmers may also withdraw from the cooperation. It is getting more and more difficult to have sustainable growth in terms of the farmer number. It is a question whether Lihua's model can be continuously replicated long term."

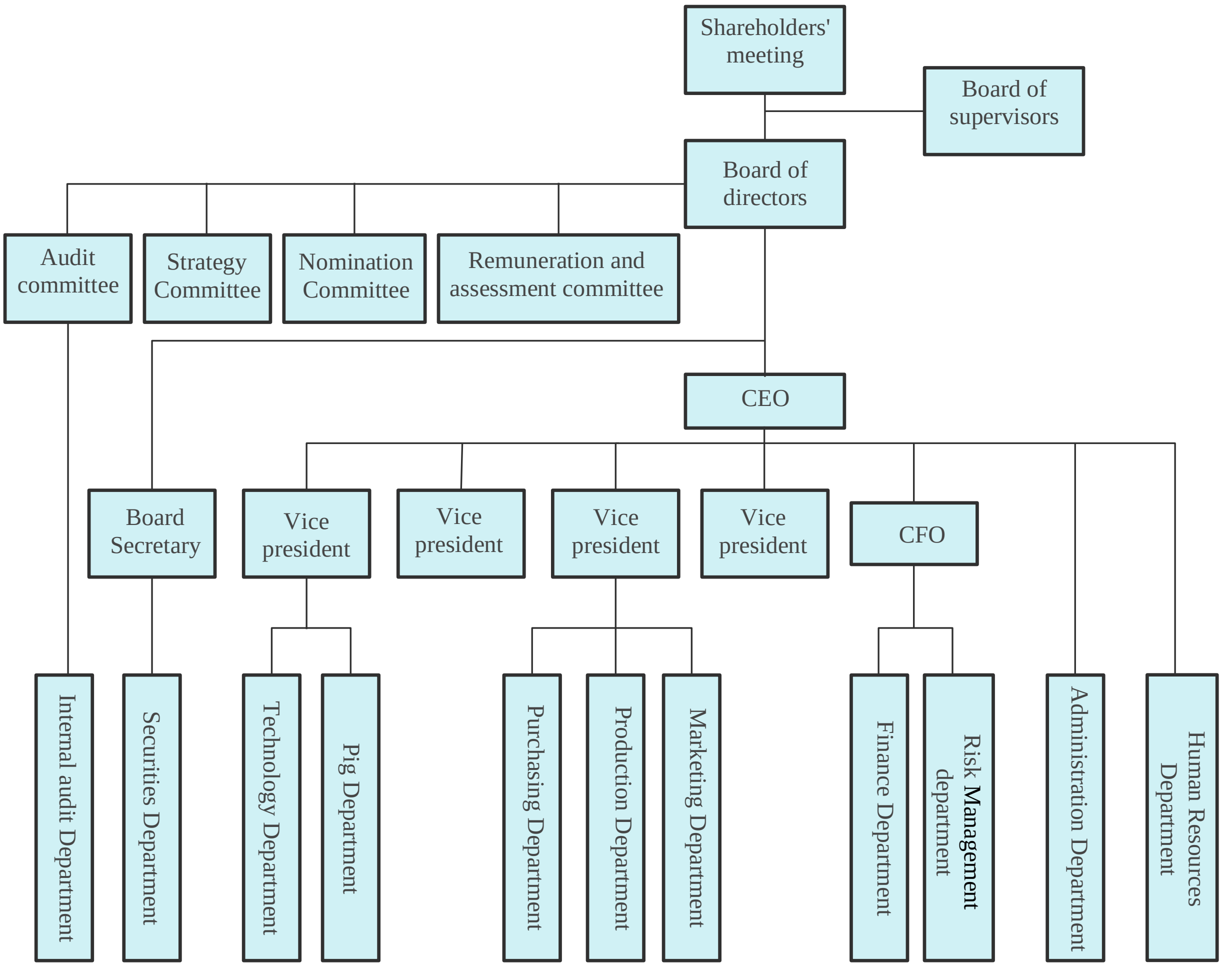

Figure 6.5 Organization structure of Lihua

Figure 6.5 shows Lihua's organizational structure. Lihua has a functional organizational structure. The employees are grouped based on their specified roles and skills which form different departments such as production, finance, marketing, etc. Each separate department is managed independently. This structure encourages employees to specialize in their field to achieve significant efficiencies. However, it may also have the disadvantage of a lack of coordination among the different functional departments.

6.2 Lihua's Organizational Resources

6.2.1 Material resources

To ensure the best genetic potential for the company's hog operation, Lihua imported 1,000 high-quality French great-grandfather breeding boars from AXIOM, which is the worldwide leading company in swine genetics with 30 years of experience in genetic research. The piglets produced may have the advantage of quick growth, and high meat output with low feed usage. Lihua builds its pig breeding farms. Due to the genetic advantage of Lihua's piglets, most of the breeding piglets produced in the company's breeding farms are not sold to the outside. The qualified breeding piglets are transferred to the breeding farms. And those that do not meet the breeding standards are transferred to the fattening farm bases to be fattened with other commercial piglets.

The feed required for the company is mainly developed and produced by itself independently. Lihua has its own pig feed factory, which has a total production capacity of 270,000 tons each year. Benefiting from Lihua's rich experience in chicken feed production, the company can provide sufficient top-quality feeds to meet the needs of the different feeding stages of pigs. Generally, corn, soybean and wheat are the main raw ingredients of the feeds, which respectively account for 36.09%, 38.42%, and 42.27%, and together they make up 35.62% of the total cost of pig production. Lihua adjusts its feed formula according to the cost of procurement and availability. Overall, the production cost of hog feeds has decreased due to the increase in Lihua's production scale.

The drugs and vaccines required during the production process are centralized purchased from domestic drug and vaccine manufacturers by Lihua's purchasing department in the headquarter. The procurement of raw materials mainly considers existing stocks, consumption, and market conditions to keep proper inventory while keeping the procurement costs under control. In July 2019, Lihua established its own biological breeding company and started to produce its vaccines.

In addition to the supply of piglets, feeds, vaccines, and other materials, Lihua is also responsible for the feeding technology. Lihua has also built management systems and technical standards required for live pig production operations. The ownership of the pig houses, piglets, feed, medicines, and vaccines provided to farmers belongs to Lihua, and the farmers cannot sell or use them without authorization.

6.2.2 Facility resources

Lihua adopts the "company + base + farmer" production model, which means the company builds the feed factory and pig houses. Farmers then rent the pig pen in the company's self-built farms to raise the pigs. Lihua has built its feed production factory and further invested CNY 400 million in Shuyang County to build three breeding pig farms which can produce over 20,000 breeding pigs, two nursery pig farms and eight pig fattening farms.

The company has set up internal environment monitoring systems in all the pig houses, collecting environmental-related data such as humidity and wind. It also can make self-adjustment according to the environmental situation. In pig fattening farms, the feeding, humidification, blasting, and manure scraping all have been automated and mechanized, which has greatly improved production efficiency. The wind speed and ventilation frequency in the pig house have been carefully designed considering the local meteorological records to meet the needs of the pigs. Each pig house adopts the intelligent environment control system independently developed by Lihua. Through the auto control of fans, pumps and shutters, the control system can automatically adjust the environment in the pig house and facilitate better pig growth. Figure 6.6 are photos taken in Lihua's advanced farms, and Figure 6.7 displays some examples of Lihua's automatic feeding equipment.

Figure 6.6 Lihua's advanced farms

Figure 6.7 Lihua's automatic feeding equipment

Based on its own pig producing process, Lihua has developed an EAS (Enterprise Application Suite) information system. The EAS is a platform for centralized management, covering financial management, human resource management, customer relationship management, and supplier relationship management. Lihua has designed the EAS operation process and compiled the "Manual for EAS Operation Process" for the production and sales of pigs. The application of EAS is to achieve a full digitalization of the pig production process and cost management, pig sales and farmer management. The EAS information system enables real-time data monitoring, analysis and feedback on production and sales. Figure 6.7 shows the farmer management system and the early warning system of Lihua's EAS. As the Managing Director of the pig farming department, Mr Li said,

"We have an internal self-developed system. We used to recruit external consultant companies and use their system. It did not work. Since their system was not compatible with our pig production process. There were always problems. So, we decided to develop ours. The current EAS is comprehensive. For example, in the farmer management section, I can quickly find out the information of each farmer regarding how many pigs they are raising, how many feeds they have ordered and used, and the number of hog deaths. The system also sends you reminders on the vaccination due dates of different batches of pigs. So, we can prepare and order the vaccine in advance and our technician can go and facilitate the farmers to vaccinate the pigs. If the pig death number is high in certain pig houses, the system gives warnings. We carry out investigations to see if it is the farmer privately sells the pigs and reports them as pig death or if there is a disease. Thus, the system can support us to diagnose the problem earlier."

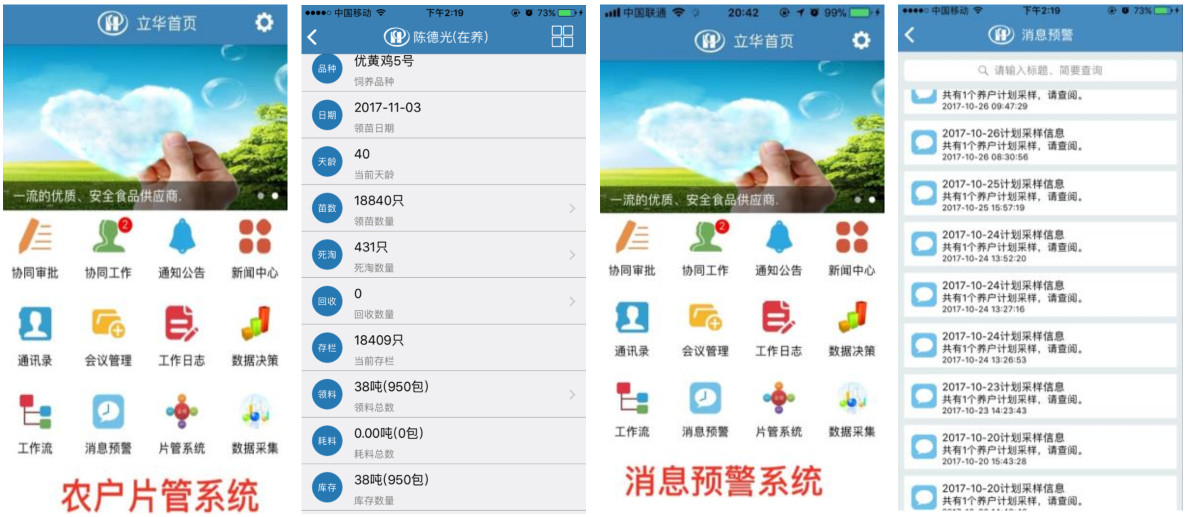

Figure 6.8 Farmer management system and early warning system of Lihua's EAS

In addition, Lihua emphasises environmental-friendly pig production. The farms are equipped with pig manure processing facilities to achieve zero pollution. The generated organic fertilizers are used in local farmland to realize the best resource utilization. Figure 6.8 shows Lihua's pig farm sewage treatment facility.

Figure 6.9 Lihua's pig farm sewage treatment facility

6.2.3 Land

Lihua's pig farms are all self-constructed and are integrated with nursery houses, mating houses, breeding houses, pregnancy homes, delivery rooms, boar stations and fattening houses. Thus, this demands a large scale of land. At present, the land Lihua is using for production and business premises is mainly through leasing and contracting of rural land from local government or farmers, following the "Law of the People's Republic of China on Rural Land Contracting". Since 2011, Lihua has acquired large land in Suqian city, Lianyungang city in Jiangsu province and Taizhou city in Zhejiang Province. Due to its rapid expansion, Lihua continuously acquires more land.

As a large-scale livestock and poultry produce company, Lihua's "company + base + farmer" model has more environmental challenges and higher requirements for the construction of breeding sites compared to small-scale pig farms. The scale-up is often constrained by the supply of land resources since idle scattered land cannot be used. As the pig producing companies have tax exemption in China, and pig raising may cause environmental problems, the local government is not enthusiastic about welcoming such companies. In addition, the farmers sometimes breach the land leasing contract which adversely affects the production and operations of the company. As Mr Li explained,

"In some cases, Lihua signed the land leasing contract with villagers. The leasing contracts were carried out under the 'Law of the People's Republic of China on Rural Land Contracting'. We also obtained written authorization from the village committee. However, due to the development of the regional economy and the category change of land use, there is a risk of contract breach by the lessor and the contracting party. It is difficult to get the land."

6.2.4 Financial resources

Lihua has a total of CNY 362.6 million registered capital. In Feb 2019, Lihua's stock became listed on the Shenzhen Stock Exchange.

Lihua does not allow customers to overdraft when selling the pigs. Payment needs to be done at the same time as the pig sales. Some of the pig agents pay cash directly. A delay for bank transfer is only allowed for customers who have tracked history and frequently buy pigs from Lihua. In addition, Lihua collects rent and deposits from farmers before working with farmers. Therefore, this model reduces Lihua's pressure on cash flow. However, self-owned assets such as pig houses, and production facilities require relatively high investment and maintenance costs. The depreciation also affects the net profit.

6.2.5 Knowledge resources

Lihua's p has more than 4,000 employees. Among them, there are 1,087 technical personnel with a bachelor's degree, 11 with a doctoral degree, and 160 with a master's degree, which accounts for 30% of the total number of employees. Lihua has built a complete technical management team internally. The technical team covers all production units of the company. Lihua provides good financial packages to keep the talent, especially people with rich industrial experience. As Marketing Director Mr An said,

"Staff with long industrial experience is extremely important for us. Within our marketing and sales department, all our staff requires at least five years of working experience. This is determined by our sales model. In my department (marketing and sales department), I have set up a price-setting team who is responsible for reviewing daily prices and creating sales plans. The price-setting team collects the pig prices of other pig production companies in different areas for our reference and determines the price range according to our own planned yield (the price will increase if there are not many ready-to-sale pigs, and the price will be reduced if we have more to sell. Based on the customer's quotation and order plan reported by the sales department of the subsidiary company, our technician further analyses the recent market demand and supply information of other pig production companies and determines the daily final price. Thus, the price-setting process requires rigorous procedures and technicians' personal experiences. That is why we need people with long industrial experience. We are also exploring to use of mathematical models to set the price. This project is currently under research collaborating with Huazhong Agricultural University."

The company cooperates with many research institutions and universities such as Yangzhou University, Nanjing Agricultural University, Jiangsu Academy of Agricultural Sciences, China Agricultural University, and other research institutes. In 2020, Lihua established Lihua Agricultural Industry Research Institute. Lihua has an R&D team with professionals in veterinary, animal nutrition, and epidemic prevention. The core technical staff is relatively stable. By the end of June 2018, the company has a total of 64 R&D staff, accounting for 1.6 % of the total number of employees which is high compared to the industry standard (Lihua annual report). The KPI (Key Performance Indicator) of the research department is related to the number of patents applied and the economic benefits through knowledge transfer. In 2018, The R&D expenses reached CNY 15.994 million, which equals 0.22% of the overall revenue. Lihua has increased its R&D investment to 27.336 million in 2020.

Lihua focuses on reducing costs, increasing production efficiency, optimizing processes, and supervising data. Lihua established an IoT (Internet of Things) group, which is responsible for the construction of the IoT cloud platform. This platform supports IoT devices and applications needed for real-time operations and processing. It allows the employees to easily connect, securely manage data and run analytics. Through cooperation with external third-party companies, Lihua has built a big data platform. More attention has been paid to the research and application of data management and automatic data collection. The information of farmers, drivers, customers, and employees is all uploaded into the system. The company may analyse internal and external data in production and sales to better support decision-making.

6.2.6 Relationship resources

Lihua relies on the government and farmers to lease the land. So, Lihua regularly inquires about the local government regarding land availability and also policy changes in land use.

Lihua has a relatively small scale of feed production and pig breeding. Occasionally, Lihua still sources piglets and feeds. Lihua's purchasing department in the headquarter also centralized purchases of the drugs and vaccines required during the production process from qualified suppliers. There is a vendor system in Lihua's EAS system. Lihua has been purchasing raw materials from existing suppliers for many years. There is a long-established collaboration between them.

Lihua has good relations with local villagers. On one hand, Lihua rents land from them. On the other hand, the farmers may collaborate with the company to fatten the pigs. Lihua approaches the farmers through the government - local government officers or heads of villages introduce Lihua to local villagers. The information of collaborating farmers is input into the company's system. Regular meetings are organized to better communicate the problems met. Training on safety and pig-raising techniques is provided to farmers. Sometimes, there can still be conflicts between local communities and Lihua due to the water pollution and the smell from pig raising.

Most of Lihua's pigs are sold to brokers who have been trading for many years. Lihua cooperates with a few research institutes and universities to carry out technological innovation in pig breeding and feed formula optimization.

6.3 Risk Management Process

6.3.1 Price fluctuation

The price fluctuation has a significant impact on Lihua's profit and capital chain. In 2021, Lihua sold 413,000 commercial hogs, an increase of 123.9% compared to the sales of 2020. The average selling price was CNY 17.9 per kg, a decrease of 44.5% compared to the average price in 2020. Due to the continuous decline in pig prices, Lihua suffered a huge loss of CNY 590 million. Facing price fluctuation, it is relatively difficult for pig companies to raise funds, and the capital chain problem would be magnified accordingly.

The key capability of pig companies to survive is to have a continuous cash flow and emphasise cost reduction. Farmers pay deposits and rents to Lihua, which can be used as a partial capital return to offset their investment in farm building.

Lihua also has a strict budget preparation and monitoring system. The preparation of the budget is initiated by Lihua's financial department. The marketing department conducts market research in conjunction with the sales department of the subsidiary. Based on the research, the marketing department makes predictions on sales trends, prepares key budget measurements, and formulates sales plans. The Finance Department, together with the Production Department, Purchasing Department, and Marketing Department formulate annual production plans based on sales prediction and determine the annual budget. Then the budget is submitted to the board of directors for review. The board of directors together with each department head review the feasibility of the budget to ensure that the budget is reliable and coordinated with the annual production and operation plan.

Lihua regularly checks and monitors the use of budgets by its subsidiaries. The headquarter finance department collects statistical data on the budget usage of each subsidiary monthly and reports it to the president's office. Each subsidiary is responsible for collecting relevant information on market trends, production, and regulations, and reporting to the headquarters. Meetings are organized with heads of department to analyse the problems discovered when using the budget and propose improvement plans. The budget adjustment plan will be submitted to the chairman for review and approval. In accordance with the company's provisions, if there is a major budget adjustment, it must be reported to the board of directors and be discussed in the general meeting of shareholders for deliberation.

Each subsidiary or department reports the usage of the annual budget at the end of the year. Experience and deficiencies are summarised into feedback. The differences between the financial budget and the actual implementation results are analysed. Improvement report for the next year's budget will be submitted to the Marketing department, the Production department and the President's Office for review. The comprehensive budget preparation and monitoring system keeps Lihua's budget in control. The end-year summary helps to give an outline of experience and reflect on any mistakes. Such careful budget control enables Lihua to have the maximum cash flow to buffer the financial loss during pig price decrease.

To reduce production costs, Lihua has established a strict procurement procedure to control the budget. The cost of feed accounts for about 70% of the overall pig production costs. Lihua's feed for pigs is mainly self-produced. Lihua adopts the model of "centralized procurement at the headquarters and assisted by regional procurement team" to purchase feed raw materials, additives, medicines, and vaccines.

Lihua has formulated a comprehensive procurement management and monitoring system. The company has set up a procurement leader group to formulate the overall procurement plan and financial budget, which will be reviewed and determined by the President's Office. The procurement leader group meets once a month to summarize and analyse the situation of the raw material market and discuss the procurement plan for next month. The headquarter procurement department is responsible for the implementation of the procurement plan and undertakes the unified procurement. The procurement department is divided into subgroups according to different categories of raw materials which are managed by purchasing managers with professional knowledge and rich experience.

Lihua pays close attention to the national and international market trends of bulk raw materials and controls the procurement frequency and quantity. Through analysing the characteristics of price fluctuations, previous procurement experience, actual production needs, and warehouse capacity, the purchasing team decides the inventory level and procurement plan for main feed raw materials and additives. The staff inputs real-time procurement and inventory data into the EAS system. Lihua issues "Lihua Pharmaceutical Warehouse Management regulations" and "Lihua Procurement Management policy" to standardize the procurement and inventory management of drugs and vaccines.

Lihua has designed a supplier management system. A supplier selection team is established within the purchasing department to develop potential suppliers, review the suppliers, select, and establish a list of qualified suppliers. Suppliers are evaluated quarterly based on factors such as product quality, price, service, and on-time availability. For suppliers who have two major quality accidents or supply accidents that happened within three months, Lihua immediately terminates the cooperation which is listed in the contract. Lihua also tries to use hedging and other tools to buffer the procurement risks. The centralized bidding method is adopted in the procurement of medicine and vaccines, which not only reduces the purchasing costs but also guarantees the quality of purchased products.

In addition, the application of a full set of intelligent facilities such as intelligent ventilation, precision automatic feeding, and manure collection increases pig breeding efficiency. Lihua has made upgrades in raw material substitution and formula optimization, which has strengthened its cost minimization.

When the pig price falls, Lihua stops the construction of most pig houses to keep the capital and try to maintain a healthy production and operation situation. And the company often sells parts of the sows to reduce costs. When the price of pigs rises and the cash comes in, the company will expand and increase production capacity immediately.

6.3.2 Pig disease

In 2018, due to the African swine fever epidemic, the China government banned cross-province transportation of live pigs. Lihua had 58.82% sales decrease this year. Meanwhile, the cost of epidemic prevention has significantly increased, further threatening Lihua’s existence.

Lihua builds the highest standard pig farms to meet the requirements of African swine fever prevention and control. Lihua’s pig farms are far away from crowded areas and other pig breeding places, which can effectively isolate the spread of the epidemic. The self-designed pig houses fit Lihua’s production model and process, which can not only improve production efficiency but also reduce biosecurity risks. The separation of pig houses based on pigs’ growth is beneficial for controlling pigs at different stages and stopping the spreading of disease.

The company implements fully closed-off management. Based on the actual production characteristics of breeding pig farms and fattening farms, Lihua has respectively formulated the “Standards and Operational Specifications for Breeding Pigs”, “Operational Regulations for the Management of Breeders in Breeding Farms”, and “Production Management Standards and Operational Specifications of the Pig Service Department”. The company standardizes the operational procedures for disease prevention as well as the control of breeding pigs and pig fattening.

In the breeding pig houses, a comprehensive epidemic prevention system has been established. The company has set strict requirements for disinfection and epidemic prevention operations for staff living areas and production areas respectively. For the staff living area, the company requires thorough disinfection of people, vehicles, and goods; for the production area, the pig houses, pig house infrastructure, pigs, and vehicles access to and out of the pig house are required to be disinfected. The sick and dead pigs need to be sent for harmless treatment and to be turned into fertilizers.

In the fattening pig houses, Lihua has formulated detailed standardized procedures for the immunization and disinfection of fattening pigs based on its "Production Management Standards and Operational Specifications of the Pig Service Department". Before the piglets are sent into pig houses for farmers to fatten. The empty pen including the feeding equipment needs to be thoroughly disinfected. After piglets enter pens, farmers need to follow Lihua's designed procedures to conduct weekly inspections against common hog diseases, such as pseudorabies, swine fever, foot-and-mouth disease, ileitis, highly pathogenic blue-ear disease, foot-and-mouth disease, respiratory diseases.

Once the pig breeding technicians and the farmers start looking after the pigs, they are not allowed to leave the pig houses until the batch of pigs they are responsible for is sold. Such closed-off management helps the company to unify the disinfection and immunization work, which can further reduce the spread of diseases between pigs at different stages and batches. Meanwhile, the company can monitor farmers' pig fattening operations in real-time, which greatly reduces the risk of farmers' fraud and irregularity such as selling pigs privately.

Lihua has formulated standardized immunization and healthcare procedures for pigs at different stages. The company's veterinarians regularly collect pig's blood samples and send them for inspection. Based on the level of antibodies inside pig blood, veterinarians decide whether to carry out supplementary immunization. Lihua also set the pig health standards and criteria and urge farmers to observe and check the pigs on time. If the disease is identified, the sick pigs and pigs in the nearby pens will be isolated or culled. In the event of severe infectious disease of livestock, the farmers are required to thoroughly clean and disinfect the entire farm. And the dead pigs should be sent for harmless treatment. In addition, the company has formulated emergency plans such as the "Operational Procedures for the Prevention of Major Animal Diseases". The plan includes guidance and requirements on how to isolate sick pigs, disinfect pig herds and pig houses, and immunize pig herds in emergencies. The relevant information and the whole production process of each livestock are recorded in the production manual and Lihua's EAS information system. The information includes the breeds and sources of the batch of pigs, feed consumption, immunization, use of veterinary drugs, daily disinfection, number of deaths, number of culling, epidemic situation, non-harmful treatment, etc.

Lihua also puts in efforts to enhance the work efficiency and capability of employees. On the one hand, the company employs external professionals to lecture on disease prevention and control. Employees are encouraged to undertake specific training. On the other hand, an internal trainer team is set up to create a platform for internal training so that advanced knowledge and expert experience can be shared within the company. In 2020, more than 2,500 training sessions were carried out. Lihua is building a comprehensive online training system to create a more supportive learning platform for employees.

These procedures and activities have a positive result on epidemic prevention. However, it also increases the production cost. As Mr Li said,

"The production cost of pigs depends on the cost of feed, piglets, and medicines, depreciation, employee salary, and pig mortality. These variables also interact and influence each other. For example, during the period of African swine fever, to reduce the mortality rate of pigs, Lihua transformed the pig houses, added strict cleaning and disinfecting process, and heated the feeds to sanitise. The pig mortality rate decreased but the production cost increased. Therefore, the control of cost requires comprehensive management capability of the pig production company, the staff executive ability and the accumulation of experience. The formation of cost advantage requires long-term experience accumulation under a scientific system."

6.3.3 Environmental policy uncertainty

In recent years, governments at all levels have paid increasing attention to environmental protection issues in the livestock industry and successively promulgated more strict regulations. It is required that livestock and poultry breeding enterprises further strengthen the disposal of wastes such as livestock manure, corpses, and sewage. Lihua has adopted various measures to prevent and control the pollution generated during the pig farming process.

The wastewater generated in the pig farming process is mainly the flushing water of pig houses, pig urine, and domestic sewage of employees. In the production process, Lihua invests in advanced equipment to achieve clean production. The wastewater from pig farms is treated by sewage treatment facilities and used to irrigate trees on the farm and nearby farmland. Lihua has built biogas generation facilities to treat pig urine and manure, which realizes efficient utilization of waste and has good economic and environmental benefits.

The main noise sources in the company's production and operation are the traffic noise of transport trucks, the noise generated by pigs, and wastewater treatment facilities. Lihua avoids arranging deliveries in the evening. The noise from pig farming is mitigated by planting green isolation belts around the farm. The isolation belts can also help to reduce the malodorous gas generated in the production process.

The solid waste generated during pig farming mainly includes dead livestock, discarded vaccine and medicine packaging bottles, sewage sludge, manure, and domestic waste. Lihua has established its “Regulations for the Harmless Treatment of Livestock” which stipulate the steps for handling sick and dead pigs. Lihua also invests in facilities such as corpse ponds, deep burial wells, and incinerators to deep bury or incinerate the dead pigs. Waste vaccine and medicine packaging bottles are immediately sterilized and collected by the company, and then entrusted to a qualified hazardous waste disposal unit for unified treatment. Biogas fermentation and high-temperature composting facilities are adopted to turn pig manure into organic fertilizers which are sold to local farmers at a cheap price.

Still, as some of Lihua’s pig farms were built previously, updating all the pig farms requires significant investment. The environmental protection facilities in some of the farms are relatively out of date. As Mr Li described,

“Since some of the pig houses are early built and relatively old. And the terrain where the pig farm is located is relatively flat and the water level of the underground river is high. It happened that the sewage pool collapsed during excessive rainfall and the discharge manure leaked out. It was reported by the surrounding local villagers. After being investigated by the environmental protection department, this pig farm was ordered to stop production and make renovations within a time limit. The manager of the pig farm invited the environmental protection department to give guidance. A must-do list including expanding a storage tank and adding a dry and wet separator was made. The environmental protection department and the company determined and approved the rectification plan together. After the farm updates were completed, the farm was put into production again after passing the inspection.”

Lihua faces a situation where the government further increases environmental protection regulatory requirements. Lihua is consistently increasing its expenditure on environmental protection to meet the higher requirement, which affects Lihua’s operating performance and profitability.

In 2013, the State Council promulgated the “Regulations on the Prevention and Control of Pollution for Large-scale Livestock and Poultry Breeding”, which clearly defines areas where pig farming is prohibited. To avoid the risk of future forced demolition, Lihua has consulted the local animal husbandry department, environmental protection department, and land department about the relevant policies and regulations on livestock farming land use and pig farm site selection. After getting permission from the local government, Lihua went through the formal land use application and signed contracts with the government and farmers before building the pig farms. A small number of Lihua’s farms which were built earlier have been classified as prohibited areas. These farms are facing the risk of being relocated, closed, or banned. If Lihua cannot complete the relocation within the given time limit, Lihua may be fined, and the farms may be demolished. In addition, the local government is delimiting new prohibited and restricted zones. Lihua’s farms may also face the risk of relocation or closure, which may adversely disrupt the company’s production and operation.

6.4 Case Summary

In this Chapter, the case of Lihua is presented. Lihua adopts a hybrid production model. Lihua builds the pig farms and is responsible for the front pig breeding process. Farmers rent the pig houses and take care of the pig fattening. Lihua controls most of the pig production process and resources use. Through analysing Lihua’s strategies to mitigate three types of major risks, Lihua’s resilience building strategy and performance are revealed (Shown in Table 6.2).

Risks	**Resource Strategies**	
Price Fluctuation	Build own sow farms to supply piglets to provide the flexibility of selling piglets or commercial pigs	Vertical integration to provide flexibility and efficient control of the production process
	Control the speed of pig house building	
	Self-built feed factory to control the feeds costs	
	Get deposits and rents from farmers	Accumulate capital to ensure continuous cash flow to buffer the risks
	Have a strict budget preparation and monitoring system	

<table>
<tr><td rowspan="3"></td><td>Invest production management information system to assess the technician’s performance</td><td rowspan="2">Internal Knowledge building to control the production costs</td></tr>
<tr><td>Establish a strict procurement procedure to control the budget</td></tr>
<tr><td>Design a supplier management system to manage the suppliers</td><td>Manage costs through supplier management</td></tr>
<tr><td rowspan="7">Pig Disease</td><td>Fully closed-off management</td><td>Vertical integration to flexibly implement disease control and prevention operations</td></tr>
<tr><td>Establish decontamination centre</td><td rowspan="2">Accumulate physical resources to reduce biosecurity risks</td></tr>
<tr><td>Build the highest standard pig farms to separate the pig houses for controlling pigs at different stages and stopping the disease spread</td></tr>
<tr><td>Standardize the operational procedures for disease prevention, immunization, and disinfection of fattening pigs</td><td rowspan="3">Internal Knowledge building</td></tr>
<tr><td>Formulate internal Regulations</td></tr>
<tr><td>Enhance the work efficiency and capability of employees through training</td></tr>
<tr><td>Consult external professionals on disease prevention and control and train the staff</td><td>Acquire knowledge externally, also accumulate the knowledge</td></tr>
<tr><td rowspan="2">Environmental Policy Uncertainties</td><td>Application of advanced equipment to achieve clean production</td><td>Accumulate equipment to buffer the risks</td></tr>
<tr><td>Consult the local authorities about the relevant policies and regulations on livestock farming land use and pig farm site selection.</td><td>Consult external stakeholders to build the knowledge</td></tr>
</table>

Table 6.2 Lihua’s resource management strategies to deal with the risks

To buffer the impact of price fluctuations, Lihua focuses on reducing costs, increasing production efficiency, and optimizing the process. Lihua has a designated budget and strict monitoring system to keep a continuous cash flow. To reduce production costs, Lihua adopts the model of “centralized procurement at the headquarters and assisted by regional procurement team” to purchase feed raw materials, additives, medicines, and vaccines. There is clearly written down procedure and regulations to guide budget-making and procurement. Lihua also invests in developing its internal EAS information system to store and monitor real-time pig production data. Through analysing the data, Lihua aims for better production efficiency.

Lihua does not have strong financial resources to develop its own veterinary medicine, although Lihua has started to build its own drug and medicine plant recently. Lihua invests in designing and building its own pig houses. The separation of pig houses based on pigs' growth is beneficial for stopping the spread of disease. Lihua has also designed a strict disease prevention and control procedure and formulated specifications and standards for farmers and pig breeders to follow. A comprehensive epidemic prevention system has been established. Lihua also focuses on staff training either through inviting external professionals or establishing an internal learning platform.

To deal with the strict and changing environmental protection regulations, Lihua invests heavily in facility adoption to prevent and control the pollution generated during the pig farming process. Lihua also works with the government to carefully choose the land for new pig farm buildings and updates the existing pig farms to comply with the environmental protection regulations.

Lihua buffers the risks mainly through investing in internal knowledge building. However, such heavy investment also affects Lihua's operational performance and profitability.

Chapter 7. The Case of Hanshiwei

This chapter discusses Hanshiwei's resilience-building strategy. Firstly, the background of the company is introduced and Hanshiwei's existing resources are presented. The resilience building strategy will be analysed based on how Hanshiwei mobilizes its resources to overcome three major risks embedded in the pig production industry. Finally, this chapter ends with the case summary.

7.1 Background of Hanshiwei

Hanshiwei Co., Ltd. was founded in September 2013 and is a wholly owned subsidiary of Tianbang Food Co., Ltd. Hanshiwei has rapidly developed as one of the top pig production companies in China. Figure 1 shows Hanshiwei's annual live pig production between 2016 to 2021. It can be seen that Hanshiwei increased its production scale from 580,000 heads in 2016 to more than 3 million heads in 2020. In 2020, Hanshiwei was ranked sixth in the Chinese pig industry in terms of annual pig production. Until 2021, Hanshiwei owns 9 subsidiaries in 9 provinces across the country (Hanshiwei's annual reports, 2020). Table 7.1 summarizes Hanshiwei's chief development milestones.

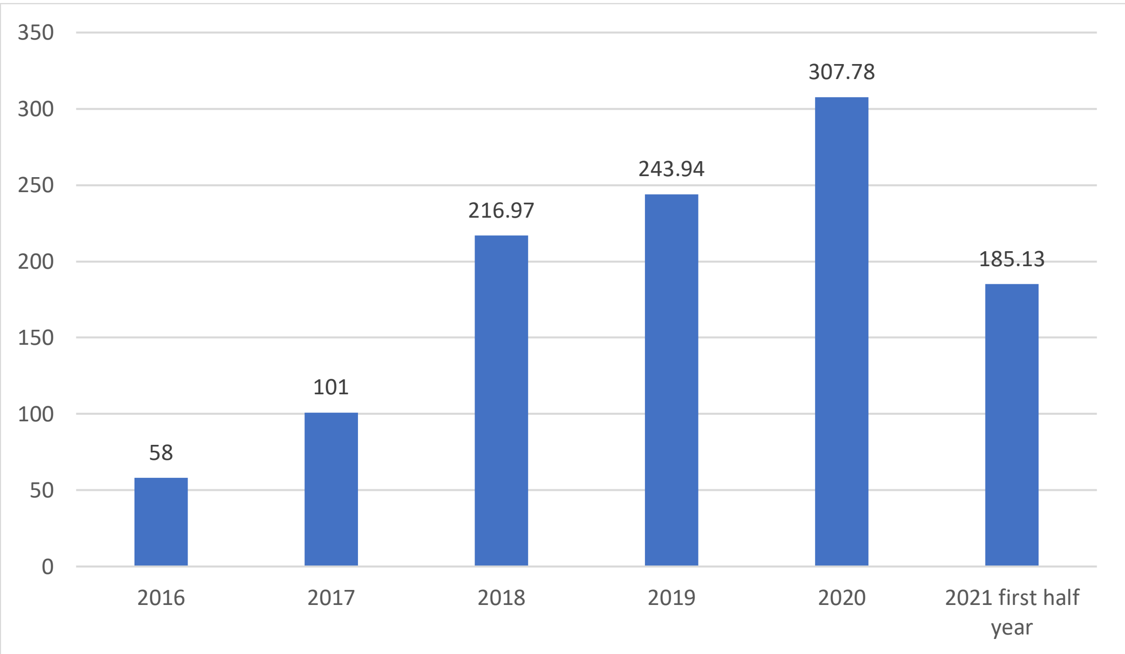

Figure 7.1 Hanshiwei's annual live pig production between 2016 to 2021 （10,000 head）

(Source: Hanshiwei's annual reports)

Year	Milestones
2013	Hanshiwei was founded.
	996 breeding pigs were imported from NewSham Choice Genetics, United States.
	Acquired the assets of Agfeed China, a NASDAQ-listed company in the United States at 280 million RMB.
2014	Invested 15 million US Dollars to acquire a 40.69% share of CG (Choice Genetics SAS), an internationally renowned breeding company
	Nine branches were established in nine provinces in China.
	Expanded pig production capacity to 300,000 heads
2016	By the end of 2016, 69,000 sows were produced and sold nearly 600,000 live pigs.
2018	Hanshiwei further imported 1,200 great-grandparents breeding pigs from Choice Genetics United States.
2021	Tianbang Co., Ltd. further invested 3 billion RMB.

Table 7.1 Hanshiwei's main development milestones

In August 2014, Hanshiwei invested 15 million US Dollars to acquire a 40.69% share of CG (Choice Genetics SAS), which is a global swine genetics company. CG currently has two R&D centres located in the United States and France. And the newly established third R&D centre will be located in China, which will provide top technical support for Hanshiwei's pig breeding business.

Hanshiwei draws on the experience of the American "two-stage" production model, which divides the pig production process into two stages: piglet production and pig fattening. More specifically, Hanshiwei is responsible for pig breeding and sow production. This is because the production processes of pig breeding and sow farrowing are more complicated and require professional technology. After the piglets are weaned, they are sent to the fattening farms to be fattened. Since the fattening process is relatively simple, Hanshiwei works with farmers to fatten the pigs. Farmers are responsible for fattening pigs for the company. Hanshiwei signs pig-raising contracts with farmers and provides farmers with piglets, feed, and vaccines. All these materials are kept in bookkeeping rather than paying cash. Farmers are responsible for farm construction. The ownership of the pigs still belongs to the company. Hanshiwei sends technicians to provide support and pig raising related services to farmers. When the fattened pigs meet the requirements, the company will collect back and pay the labour fees to farmers according to the contract price. The cost of piglets, feed, vaccines, and other expenses is directly deducted from farmers' profits.

Working with farmers, Hanshiwei does not need to acquire large land and build pig houses. This light asset model has the advantage of low fixed costs and can expand the production capacity quickly.

7.2 Hanshiwei's Organizational Resources

Hanshiwei has a relatively short history compared to other major pig production companies. However, in less than 10 years, Hanshiwei has developed into one of the top ten pig production companies with a unique resource base. During the crisis, Hanshiwei is more than ever advocating the need of enhancing adaptability through developing its resources.

7.2.1 Material resources

Hanshiwei's parent company Tianbang Group originally specialized in feed production. Tianbang's pig feeds have premium quality and only supply internally to Hanshiwei not selling to the external market. The Feeds are offered to the farmers at a higher price compared to the price of similar feeds on the market. This is to prevent farmers from selling the feeds. The technicians monitor the use of feeds. The farmer service department reports the feed plan according to each farmer's production scale. Hanshiwei arranges the delivery to farmers. The cost of feeds is calculated into the farmer's overall production cost which will be deducted from farmers' profits at the end of the fattening.

Chengdu Tianbang Biological Products Co., Ltd., a wholly owned subsidiary of Tianbang, is a high-tech enterprise specializing in the research, development, production, and sales of animal vaccines. Most of Hanshiwei's vaccines are supplied by Chengdu Tianbang. Hanshiwei also has its own vaccine vendor list to source some of the veterinary drugs which cannot be produced by Tianbang.

Hanshiwei is strong in pig breeding and sow production which may provide sustained, high-quality piglets to farmers for fattening. In 2014, Hanshiwei invested 15 million US dollars and acquired a 40.69% share in Choice Genetics (CG), a world-renowned pig breeding company. CG Company not only owns rich experience in genetic breeding research and strong multidisciplinary R&D teams but also is the only company in the world that has both genome selection and CT assay breeding technologies. The acquisition of CG significantly enhances Hanshiwei's pig genetic optimization and breeding technology. Later, Hanshiwei invested 59.18 million RMB to build the Hexian breeding farm with 6,200 sows, which is currently the largest single breeding farm in China. All these investments ensure the quality of Hanshiwei's breeding pigs. However, the difficulty in land acquisition restricts the expansion of sow farm building, which in turn affects the sufficient supply of piglets. So, Hanshiwei still needs to source piglets from other piglet suppliers. Once the piglets are weaned, they are sent to farmer's pig houses to be fattened.

7.2.2 Facility resources

Hanshiwei owns sow farms and boar stations and does not own any fattening farms. Through the acquisition of Agrfeed China, Hanshiwei took over Agrfeed's two large scale sow farms in Guangxi and Jiangxi provinces which can produce around 5,000 sows per year. Hanshiwei further invested 250 million RMB and built large-scale sow and breeding farms.

Hanshiwei adopts a different production system compared to Muyuan's vertical integration model. Hanshiwei takes each county as a unit to establish a small pig production system. Within every 100 kilometres, Hanshiwei develops farmers to collaborate and builds a sow farm and feed plant to meet the needs of farmers. Farmers are responsible for fattening the piglets. Hanshiwei supplies piglets from its sow farm and feeds from the feed plant. Figure 7.2 shows the structure of Hanshiwei's pig production system in each county.

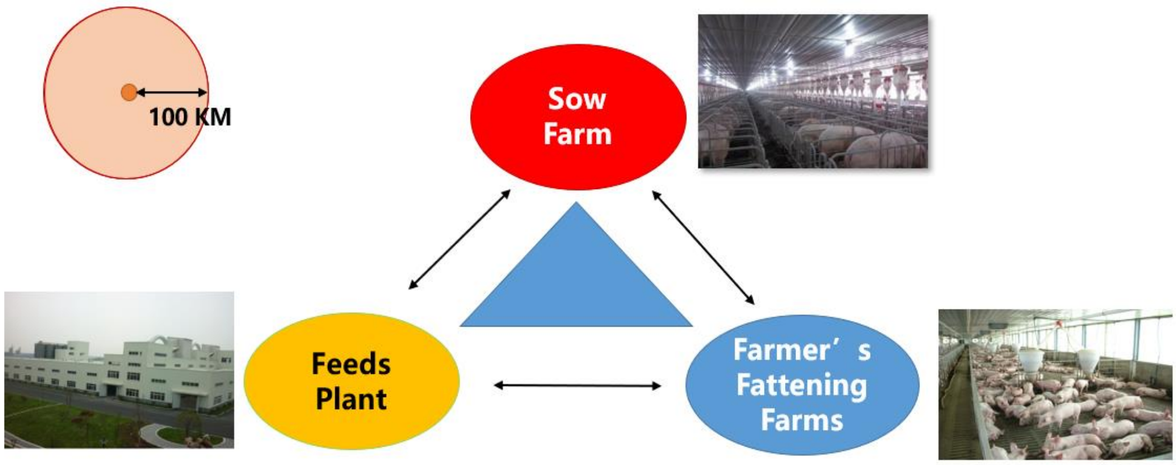

Figure 7.2 Hanshiwei's pig production system

Hanshiwei uses automated and intelligent pig-feeding equipment in its own sow farms. The sow farms are fully enclosed and equipped with automatic temperature control, automatic feeding and drinking systems. Figure 3 shows that all pig pens use central environmental control systems to precisely control temperature, light and ventilation. Hanshiwei also utilizes microbial fermentation to turn pig manure into fertilizer.

Figure 7.3 Hanshiwei’s pig feeding equipments

The fattening stage has been outsourced to farmers. Hanshiwei provides the farmers with the design of the pig house and recommends them the feeding system and manure treatment equipment. Before sending the piglets to farmers' fattening farms, the company requires the farmers to install the environmental control and protection facilities such as the insulation box required for cold protection in winter, heating systems, the sealing of the water curtain and the fan, manure scrapers, sewage pumps etc. Once all the equipment is installed and tested, the service department delivers the piglets, feeds, and veterinary drugs to qualified farms. As the head of the Service Department, Mr Lee said,

"We have requirements towards the pig farmhouse building. If the farmers cannot reach the requirement. We will not work with them. To monitor the quality and growth of the pigs, we ask the farmers to use advanced feeding systems. We give them professional advice and provide piglets, feeds, and drugs. After the outbreak of African swine fever, all materials are basically handled and disinfected by the company in a centralized manner and distributed uniformly. Farmers are responsible for the cost of the house building and equipment installation."

The company provides farmers to use handheld computers to collect pig production data. All the data in the farmers' pig houses is uploaded and transferred to Hanshiwei's pig production system. The company has begun to promote the use of chip ear tags, which can automatically scan and record the identity of pigs through equipment, which can realize pig traceability and greatly facilitate the real-time monitoring of pigs. As the Managing Director of Hanshiwei Anhui Ltd, Dr Wei said,

"Hanshiwei's core production management system has covered the entire production process, including pigs, feeds, and medicines. All data is connected to the financial system. We are developing systems such as automatic and precise environmental control systems for pig houses, livestock disease monitoring and early warning systems, and digital precision feeding management systems for breeding pigs. All the equipment can be used to support farmers' pig fattening. Intelligent breeding is the future development direction of Hanshiwei."

7.2.3 Land

Pig fattening requires a large amount of land. However, Hanshiwei outsources the pig fattening process to farmers. Farmers own the land. Hanshiwei acquires land through farmers. Through closely working with farmers, Hanshiwei rapidly expands to more than 10 provinces in China and has become one of the top ten pig production companies in China. Hanshiwei still needs some land for its sow farms and feed plants and has to compete with other pig production companies for land. As the Head of the Service Department, Mr Lee said,

"We acquire the land through farmers. Farmers have their own land. The technicians in the service department are responsible for developing farmers to fatten the pigs for us. Farmers build the pig house on their land. That's how we solve the land problem. However, we face fierce competition from other pig production companies. Hanshiwei has a good reputation, but other companies may offer higher better prices for farmers to fatten the pigs for them. Thus, if the government agrees to give us the land, we sometimes sign exclusive agreements with them and state the other pig companies are not allowed to get access to the land and farmers in this area. Also, we still need some land to build the sow farm and feed plants. In addition, pig raising still will cause pollution and bad smells. So, we are not that welcomed by the local government. It has been always a problem for us."

7.2.4 Financial resources

Hanshiwei is a wholly owned subsidiary of Tianbang Group, the parent company Tianbang Group was listed on the Shenzhen Stock Exchange in 2007. In 2021, Tianbang further invested 3 billion RMB in Hanshiwei. So, Hanshiwei may get lots of support from Tianbang. All the feeds and medicines are supplied at internal prices which are a lot cheaper than similar products on the market.

Also, due to its production model, Hanshiwei does not need to invest in the pig house building and equipment installation and maintenance. In this way, Hanshiwei outsources fixed asset investment to franchise farmers, lending banks and subsidizing governments which reduces its financial pressure. Meanwhile, farmers become Hanshiwei's pig-raising factories and franchisees, which helps the company to rapidly expand.

7.2.5 Knowledge resources

Hanshiwei accumulates strong knowledge in pig breeding and vaccination through investment merge and acquisitions. The strategic investment in Choice Genetics enables Hanshiwei to develop advanced pig Gene research technology. In Hanshiwei's sow farm, taking advantage of CG's advanced equipment, technicians can measure the sow's backfat and eye muscle thickness and upload them to CG's global database, simultaneous analysis of the sow's health status. Big data genetic evaluation, genome selection, CT scanning and automatic feeder measurement technology can be used to improve the quality of breeding pigs.

Hanshiwei also takes advantage of 12 research institutes established by Tianbang to build up its pig-raising knowledge. Hanshiwei also develops its own farm patrol system. Through this system, whether the technicians visit and provide services to the pig farmers regularly can be monitored.

Hanshiwei has carried out training programs such as pig breeding special training courses, family farm special training courses, reserve farm manager special training courses, and pig production practice special training camps for staff. The training programme focuses on cultivating and building a high-quality workforce to adapt to needs. Hanshiwei develops regulations for the daily management of family farms and formal procedures for the technicians to follow. The regulation of daily management of family farms has clear guidelines on humidity control, illumination, breeding density and other detailed requirements. There are general flow charts to guide technicians when they carry out visits to farmers' pig houses. The chart clearly states what to inspect when visiting either collaborated farmers or potential targeted farmers.

The technician department is the core team in Hanshiwei who is responsible for supporting farmers to raise pigs and developing new farmer suppliers. However, it is difficult to recruit and keep experienced technicians. The staff turnover is high. This is because the competitor companies may pay higher salaries to attract experienced technicians. If the technician leaves the company, the farmers managed by this technician will likely leave with the technician since strong trust has been built between them through day-to-day communication. So, there is a long-term shortage of experienced technicians. As the Head of the Service Department, Mr Lee said,

"We are always recruiting technicians. It is a hard-working job. And the requirement towards technicians is very high. He needs to be knowledgeable in pig raising. He also needs good communication skills. Working with farmers is difficult. Hanshiwei provides generous packages and training programs for technicians. Still, there are always other companies trying to dig our technicians away. Even our management team's turnover is very high. There is another problem. Since the value of the pigs is very high, in some cases, the technician works with collaborated farmers to secretly sell the pigs and runs away with the money. This happens many times. To stop it happen again, we regularly change the area where technicians are in charge. So, they cannot be corrupted."

7.2.6 Relationship resources

Farmers are the key stakeholder in Hanshiwei's supply chain to finish pig production. Hanshiwei manages and develops farmer suppliers through its production service department. Technician develops new farmers based on their pig-raising experience and previous credits. Once the farmers pass the first step screen, the company establishes a preliminary cooperation intention with the farmers who meet the standards and guides the farmers to build or renovate the farmhouses according to the company's technical standards. The technician carries on providing comprehensive service to farmers throughout the whole pig fattening process, including suggestions on pig house building, application of water and manure treatment facility, nutrition formula, disease prevention and treatment and financial assistance. Thus, there is a strong trust between technicians and farmers.

Except for sourcing internally from Tianbang's own feeds and veterinary drug plants, Hanshiwei has vendor lists and a central purchasing system to regularly monitor the quality of the supplies. Hanshiwei has collaborative relationships with other pig production companies. The company and farmer co-production model has been adopted by other major pig production companies. Therefore, Hanshiwei competes farmer resources with them to expand the production scale. Meanwhile, due to limited sow farm production capacity, Hanshiwei still sources from other companies to guarantee sufficient piglet supply.

The government relationship is quite important for Hanshiwei. Since the local government helps Hanshiwei to establish links with more farmers. In some cases, Hanshiwei signs exclusive contracts with the local government to prohibit its competitor companies to enter this area. Also, through a close relationship with the local government, Hanshiwei is well informed of policy changes in advance. Hanshiwei participates in poverty alleviation projects and provides job opportunities for residents, which enhances the relationship with the government.

The pig raising still brings pollution, which is not welcomed by the local community. Hanshiwei employs powerful local people to establish and manage relationships with the local community. The person is either highly respected by local people or the village head. Especially when a dispute happens, this person can well communicate with the local community and the possibility of local farmers colliding with the company can be effectively reduced.

Hanshiwei has established long-term partnerships with universities or research institutions and provides internship opportunities for students. University professors are employed as advisors to provide technical support and advanced knowledge.

To guarantee pig sales, Hanshiwei work closely with pig brokers. All the pigs fattened are sold to pig brokers in Hanshiwei. This is to get a quick cash flow return. The transaction with the pig broker follows the "payment first and then pig collection" rule. Hanshiwei chooses not to work with the slaughterhouses, because there is always a delayed payment.

7.3 Risk Management Process

There are clear advantages that outsourcing the fattening process has brought to Hanshiwei such as cost minimization in tangible resources investment and value cocreation with farmers. It has also added risks to the firm. One of the largest risks firm faces is the lack of control over processes that are no longer internally managed. Other risks include operational risks associated with communication barriers, unethical conduct, and vendors' failure to deliver the products when faced with disasters. There is a high requirement for Hanshiwei to not only manage the risks within the company but also embedded in its supply chain.

7.3.1 Price fluctuation

Price fluctuation has caused significant threats to Hanshiwei. When the pig price is decreasing, Hanshiwei loses profit since the farmer's labour cost is negotiated as a fixed cost before farmers start to fatten the piglets. According to Hanshiwei's Annual Report from 2015 to 2019, the farmer's cost occupies around 18.5% of the overall production cost. Feed costs account for about 61% and vaccines occupy 5%. When pig price increases, farmers get more profits by raising pigs themselves than by fattening the pigs for Hanshiwei. So, farmers either stop working with the firm or violate the contract. Selling the company's pigs without permission sometimes happens. In Hanshiwei's production model, the two parties sign a contract. Hanshiwei provides production materials such as piglets, feed, vaccines, and veterinary drugs. The company collects the pigs back after pigs grow to the weight for slaughtering and pays the labour fee to farmers. The cost of piglets, feed, vaccines, and other expenses will be deducted from the payment to farmers. The final amount of labour fee farmers can get is linked to farmers' pig-raising performance. If the performance reaches the company's average standard, standard labour fees will be paid. If the performance is outstanding, additional rewards will be given. Under this model, farmers do not take the risk of market price fluctuation, and the basic income is guaranteed. Hanshiwei takes all the risk of financial loss. As the Head of the Service Department, Mr Lee described,

"Farmers are risk sensitive. When pig price is low, it is difficult for us to find farmers to fatten pigs for us. Most farmers choose to withdraw from the market. They can still make a living relying on growing other crops. Some of the farmers have long-term collaborations with us. They are still willing to raise the pigs for us since we provide "protected payment" to farmers. This means no matter how the pig price decrease, Hanshiwei undertakes all the risks. Farmers just need to fatten the pigs for us, and we pay them a fixed labour fee. But if the farmers decide to quit, we can do nothing."

When the pig price is low, Hanshiwei does not encourage farmers to raise a large number of pigs. This is to avoid potentially huge financial loss. By controlling the quantity and speed of piglet supply, Hanshiwei controls the production lead time. During this period, it is unavoidable that some farmers withdraw from pig production. Hanshiwei focuses on maintaining existing farmer relationships rather than developing new collaborated farmers. The company encourages farmers to carry out technological upgrading and pig house transformation through provided subsidies. So, when the pig price increases, farmers can scale up the production and quickly acquire extra profits to compensate for the loss during the low-price period. When pig prices increase, the actual market sales price exceeds the agreed price in the contract with farmers. Hanshiwei puts great effort into developing new farmers to increase production capacity. Hanshiwei increases the payment to farmers and shares a certain percentage of profit with farmers. This is to bind the interests of farmers and achieve win-win development. Not many companies have Hanshiwei's sow production capacity. The sufficient piglets' supply capability is attractive for farmers. The spread of African swine fever has required higher requirements for the biosecurity of pig farms. Hanshiwei screened farmers, and only retained farms that could meet the biosafety requirements after transformation. As Mr Ye, one of Hanshiwei's collaborated farmers said,

"I have been working with Hanshiwei for many years. I was also contacted by Wenshi (another big pig production) to raise pigs for them. I still choose to work with them. This is because firstly, Hanshiwei provides good quality feeds; Secondly, I trust them. Thirdly, no matter whether the market price is high or low, I am guaranteed income. When the pig price is high, Hanshiwei helps us to gain more profits. Lastly, since we have been collaborating for over 5 years now. They are willing to provide me subsidiary to upgrade my pig farms and loans to

overcome the difficult period. Apart from these reasons, the technician in Hanshiwei knows me and my family well, sometimes they even help me to solve my family problem such as my kids' school entrance. Compared with fluctuating incomes, I prefer stable incomes. My family's expenditures on food, clothing, housing, and transportation are continuous. The pig cycle leads to huge profits and losses, which has a significant impact on our family in terms of living standards, financial arrangements, and psychological experience. Working with Hanshiwei, the total income remains stable, and I prefer stable income."

In addition to working with farmers to mitigate financial difficulties during price fluctuation, Hanshiwei also optimizes its internal operations to minimize production costs. When pig prices are increasing, sow farms are put into full capacity as soon as possible to produce more piglets. Technicians visit the pig farms more often and supervise the pig raising, which can increase the survival rate and quality of the pigs. When the pig price is high, some of the farmers privately sell the pigs and report pig death. Regular visits can prevent such behaviour. Through closer work with the Tianbang feed research institution, Hanshiwei optimises the feed formula and reduces the raw material procurement costs. As Purchasing Manager Mr Bai said,

"We manage and control the purchases based on the feedback from the Production Services department. They provide us with the purchase plans and usage according to the pig's growth in collaborated pig farms. We report to Tianbang Headquarters, and they will adjust the feed formula considering the price of raw materials. Tianbang then sell us the feeds based on internal prices. We provide the information, and they help us get the feeds at a lower price. We also provide them with feedback for the use of feeds to improve the formula."

There is a trade-off when Hanshiwei decide whether to invest in internal refinement or develop new farmers' collaboration. These two approaches compete for organizational resources, especially financial resources. Most organizational resources are finite (March, 1991), thus more resources devoted to investment in internal knowledge building and optimization imply fewer resources left over for recruiting technicians to develop relationships with farmers, and vice versa. This trade-off generates tensions within Hanshiwei and Hanshiwei is trying to work on both but more focusing on managing the relationship with farmers. Since working with farmers, the company does not have to invest in building pig houses and can take advantage of farmers' deposits to solve part of the capital needs to purchase feeds and medicine. Through the company + farmer cooperation model, Hanshiwei can realize the "bundled sales" of feed, vaccines, piglets, and epidemic prevention technology, to increase income. Farmers provide the land and labour. Without farmers, the company cannot even finish production.

7.3.2 Pig disease

In order to prevent the pig disease, Hanshiwei chooses farmers whose pig farms are located at least 500 meters from villages or other pig farmers, which have innated conditions to stay away from the spread of the virus. However, some farms are close to the village or other farms. Hanshiwei either stops the collaboration with farmers or suspends the contract and require the farmers to upgrade their pig farms to meet epidemic prevention requirements.

Chengdu Tianbang, a wholly owned subsidiary of Tianbang group, is a high-tech enterprise specializing in the research, development, production, and sales of animal vaccines. Chengdu Tianbang consistently provides sufficient and high-quality veterinary drugs to Hanshiwei.

In Hanshiwei's sow and piglet weaning farms, a biosecurity system has been built. Each Hanshiwei's boar station has installed a set of fluorescent quantitative detection systems. Before the semen is released every day, the original semen of all the corresponding boars is tested to prevent the vertical transmission of the virus in the semen. The sows need to be isolated in the reserve pig houses after arriving at the sow farms. People and vehicles are required to be sanitized in the decontamination centre when entering and leaving pig houses. Each decontamination centre is equipped with advanced testing equipment and specialized testing personnel. All vehicles need to be washed with hot water, disinfected, and dried. There are currently decontamination points in every service department. The fattened pigs in farmers' pig houses are required to be transported by the company's vehicles to the pig sales transfer platform for sale. Transport vehicles that deliver fattened pigs are subject to additional disinfection before pig loading. Due to the high value of sows, Hanshiwei buys insurance for all its sows.

During the fattening process, Hanshiwei sends technicians to the farmer's pig farms regularly to provide technical guidance and inspection and supervision of breeding. Hanshiwei has established clear immunization programs and health care plans according to the conditions of the pig and requires farmers to immunize the pigs. The technician guides and monitors the immunization process to ensure the effectiveness of the procedure. The technician formulates customized feeding procedures for each pig herd. On the one hand, it can improve nutrient absorption and reduce unnecessary waste of feed. On the other hand, the health of the pigs can be assessed according to the feed intake of the pigs. Thus, timely warning and treatment can be achieved if pigs are sick. Besides, Hanshiwei requires cooperative farmers to record production data such as the usage of the feeds and medication, temperature and humidity in the pig houses and the number of pigs. Based on these data, the company can manage and analyse the production data to provide better advice to farmers and quickly identify abnormal circumstances. If infected pigs are identified, the company's technicians can promptly investigate the cause and make timely decisions. As Mr Ye, one of Hanshiwei's collaborated farmers said,

"*Hanshiwei's technician comes to my farm every 2 days. I do not have to worry about it. Each pig has a recorder book. When the pigs are due for vaccinations. The technician brings the jab and comes to help vaccinate the pigs. The vaccine will be recorded. Our piglets are provided by Hanshiwei. They make sure they are healthy piglets before sending them to us. Previously, I had no knowledge. Now the technician teaches us, we can pass the virus to pigs. We are required to take a shower and change our clothes and shoes before going to the pig houses. Hanshiwei helps us install remote monitoring so that sick pigs can be quickly identified. If the sick pigs are found, we immediately report to the corresponding technician. He will come to check and decide if it is a curable disease, or if we have to cull all the pigs.*"

Although Hanshiwei put lots of effort into preventing the disease, still the pig disease has led to higher production costs. For example, the African swine fever epidemic directly disrupted the Hanshiwei production pace. Hanshiwei has made huge investments to prevent African swine fever, established high-standard biosafety procedures and prevention and control measures, and upgraded existing pig farms and new pig farms resulting in an increased production cost. The upgrade and renovation delay the production schedule. some pig farms have to be idled. The embargo measures to prevent and control the African swine fever epidemic in various provinces make it impossible for sow pigs to be transported across provinces and can only be sold as fattened pigs at lower prices. In addition, to avoid the risk of the epidemic, some of Hanshiwei's live pigs are released for slaughter in advance or later. So, the pig's body weight deviates from the normal range, which increases the average unit cost. In 2019, due to the African swine fever epidemic, Hanshiwei has a profit loss of 17.5951 million RMB. Concerning the high impact of the African swine fever epidemic, Hanshiwei has started to invest in the construction or acquisition of some own fattening farms, so that the whole production process can be more controlled. At the same time, the company continues to retain and develop pig farmers with better biosafety conditions.

7.3.3 Environmental policy uncertainty

The Environmental protection policies are getting tighter. The tightening policies force firms to upgrade technology and optimize equipment and actively carry out the combination of planting and breeding to best utilize the manure and protect the environment. Hanshiwei cooperated with professional environmental protection companies and established Anhui Hanjiale Agricultural Development Co., Ltd to develop environmental protection equipment. Based on local environmental protection requirements and land resources, Hanshiwei uses advanced manure treatment technology to fully utilize manure and water in Hanshiwei's sow and piglet weaning farms. The company consults the relevant government department to make sure the farm's location is outside of the prohibited area or a restricted area. Advanced sewage facilities are installed to collect all the manure. The manure water treated in the pre-treatment stage enters the anaerobic system for anaerobic fermentation, which greatly degrades the pollutants in the manure water. Then the manure water is used for crop fertilization after anaerobic fermentation. The manure residues produced by the solid-liquid separator are put into the composting workshop for drying treatment, and the compost is fermented to make organic fertilizers. Hanshiwei has built manure treatment and organic fertilizer production lines in all self-owned farms, with an annual output of 150,000 tons of organic fertilizers. Figure 7.4 shows Hanshiwei's pig manure treatment process. The smells of manure and residue are always a big challenge for Hanshiwei. There are always cases that local villagers make complaints about the smells. Hanshiwei tries to build good relationships with local villagers by giving out organic fertilizers for free or hiring a local respectable person to mediate the disputes. As the Managing Director of Hanshiwei Anhui Ltd Dr Wei said,

"Hanshiwei invested heavily in environmental protection. We are always concerned about environmental checks and regulation changes. We try to build good relationships with the government, so we can get early informed about the check and policy changes. We are not like individuals; we are a formal big company. So, there are lots of under-table things which we cannot do. We need to strictly follow the guidelines. We are consistently upgrading our manure treatment facility which is a huge financial pressure for us. Another big problem is the local villagers. Pig raising does produce the smells. The villagers always make complaints. The government informs us, and they do not want to fine us. Instead, they want the problem to be solved. We give local villagers our fertilizers for free. We have built pipes to connect the liquid organic fertilizers directly to local villagers' tea tree fields. And sometimes, we give them compensation. But it is still difficult. The supply of liquid organic fertilizer is not stable. If it is

too little, villagers are not happy since the fertilizer is not enough. If the supply is too much, the tea tree may die. Also, some of the villagers want to take advantage of the compensation. So, they intend to make trouble for us. To deal with it, we hire the village head as our consultant. We pay him a salary. He is respected by local villagers and has some powers. He is responsible for mediating the disputes between us and villagers and sometimes helps us to communicate with the local government."

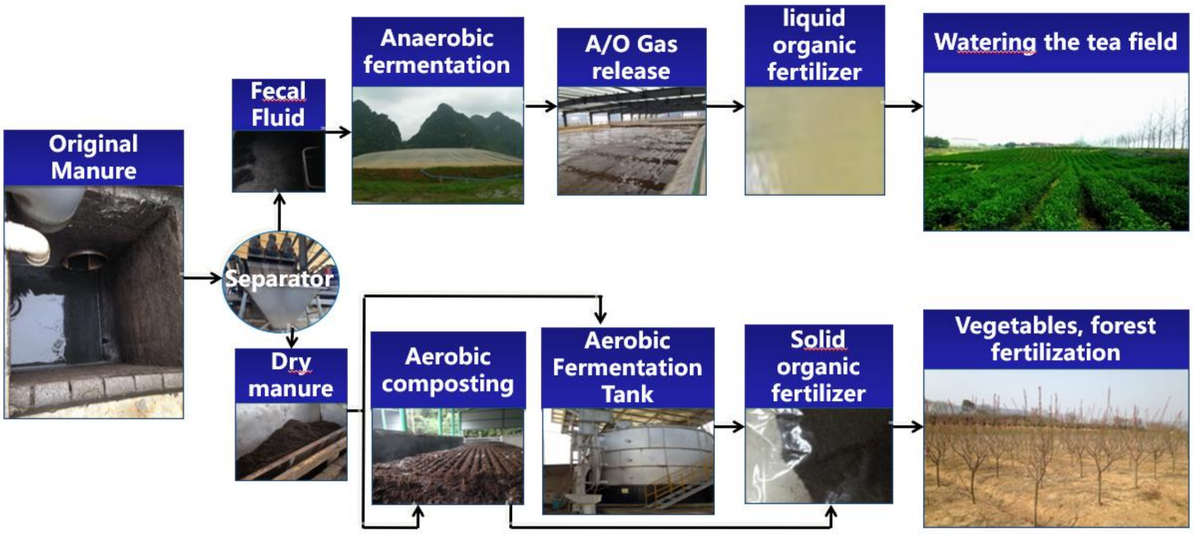

Figure 7.4 Hanshiwei's pig manure treatment process

Due to resource constraints such as land and capital, Hanshiwei works closely with pig farmers. Since the investment in environmental protection equipment is high, some of the farmers either use cheaper and low-quality equipment or try to not use it. Hanshiwei tries to standardize the production and operations to better control the process of production and avoid environmental risk and collaborates with the farmers who are willing to follow the environmental protection procedure. Firstly, Hanshiwei chooses farmers who are introduced by acquaintances or existing collaborated farmers. And for new farmers, the service department conducts background checks on the character and credit of the proposed farmers. This is to make sure the farmers are trustworthy and have fewer opportunities behaviours. Meanwhile, the service department inspects the pig farm sites including evaluating the facility and checking the local environmental protection policy (whether it is a prohibited area or a restricted area) and the existing environmental protection procedures and manure treatment methods of the pig farm. In addition, the farmers must also have the labour capacity and a certain amount of funds for future environmental protection facility investment. For farmers who meet the standards, Hanshiwei guides them to build or transform their farms according to the technical standards.

For example, the farmers' houses are required to install sewage facilities including automatic manure scrapers and dry and wet separation devices. Hanshiwei has a professional team to design farmers' pig houses and provide information on relevant environmental protection facilities and devices not only to meet the needs of farmers but also to meet the environmental standards required by the company and local government. As the Head of the Service Department, Mr Lee described,

"When building a pig farm, the technician tells the farmers how to use each equipment and the function of each facility. The technician also introduces farmers to the knowledge of environmental protection, together with the pig-raising technology. We will tell them that it is a good thing to carry out environmental protection. When Hanshiwei chooses farmers, we will only collaborate with farmers whose farm meets the environmental protection standards. When it is below the standard, we will check if the farmers are willing to carry out transformation and upgrade according to the company's requirements. Hanshiwei only continues to cooperate with them once their farms reach the local environmental standard. And if the farmer refuses to upgrade accordingly, the company will stop the collaboration."

If the farmers are not punished by relevant departments for environmental protection issues and have no environmental disputes occur during the entire pig raising, an environmental protection subsidy will be given back. The subsidy can offset farmers' environmental protection investment, which is a big incentive for farmers to invest in environmental protection. In some cases, because of the policy change, the area where farmers' pig houses will be changed to the prohibited areas. Hanshiwei communicates with local government departments to fully understand local land use and planning. Then the company helps farmers to choose a suitable new site for pig farm reconstruction. Still, due to the uncertain change of prohibited area, Hanshiwei has lost a large number of collaborated farmers. As one of the farmers said,

"At the end of 2017, due to changes in the urban development plan, my pig farm was listed as a prohibited area. The government requested that the pig house in this area had to be completely demolished within 2 months. The fattened pigs in the pen are only 80 days and cannot reach the stage for sale. To avoid subsequent loss, I agree to demolish the pig farms and accept the government's compensation. Since the fattening pigs are assets of Hanshiwei, I have no right to deal with the pigs in the pen. Hanshiwei negotiated with the government about the time of transfer, the cost of the transfer, and quarantine and epidemic prevention

procedures during the transfer process. Then Hanshiwei transferred the pig herd to another farm. And the government also paid a certain number of subsidies for the transfer to encourage relevant parties to cooperate with the implementation of the policy. With the assistance of Hanshiwei, I found a suitable construction site 30 kilometres away from the original pig farm and completed various approval procedures to build a new pig farm. At that time, When I knew that (my farm) had become a prohibited area, and I was very worried. I could only cooperate with the government to demolish the pig farm. I still wanted to carry on pig raising. But I do not want to invest a lot. If the policy changes again, wouldn't the investment become in vain? Even if the compensation was received, I still lost the profit. I just hope the newly built pig farm can maintain normal production, and I dare not invest too much in any facilities. If a similar thing happens again, I will not have any capital to build a farm and continue pig farming again."

7.4 Case Summary

In this Chapter, firstly, Hanshiwei's development has been introduced and followed by its existing resources. Then, as one of the top pig breeding enterprises, Hanshiwei as a relatively new established company has actively expanded the market by outsourcing the fattening process. Consequently, loss of control over the process technologies and quality standards makes risk mitigation difficult. Through analysing Hanshiwei's strategies to mitigate three types of major risks, how Hanshiwei improves the resilience of current supply chains has been highlighted (Shown in Table 7.2).

<table>
<tr><th>Risks</th><th colspan="2">Resource Strategies</th></tr>
<tr><td rowspan="4">Price Fluctuation</td><td>Control the quantity and speed of piglet supply to the farmers to avoid financial loss</td><td rowspan="3">Invest in facility resources and partial Vertical integration to provide flexibility and efficient control of the production process</td></tr>
<tr><td>Build sow farms to attract the farmers</td></tr>
<tr><td>Provide subsidies to farmers to carry out technological upgrading and pig house transformation to scale up production and quickly acquire extra profits to compensate for the loss during the low-price period</td></tr>
<tr><td>Control production capacity by adjusting the number of the farmers</td><td>Manage supplier resources to achieve flexibility and cost management</td></tr>
</table>

	Work with the Tianbang feed research institution, Hanshiwei optimises the feed formula and reduces the raw material procurement costs	
	Collaborate with farmers to minimize the production costs	
	Control the farmers' production costs through reward schemes	
Pig Disease	Select farmers who meet the requirements to collaborate	Collaborate with farmers and external suppliers to control and prevent the disease
	Stop or suspend working with unqualified farmers	
	Get high-quality veterinary drugs from the Chengdu Tianbang Group	
	Technicians regularly visit farmers and provide technical guidance, inspection, and supervision	
	Work with farmers to establish clear immunization programs and healthcare plans for each pig	
	Equip advanced testing equipment in sow farm to prevent the disease	Invest in knowledge building
Environmental Policy Uncertainties	Cooperate with professional environmental protection companies and established Anhui Hanjiale Agricultural Development Co., Ltd to develop environmental protection equipment	Work with external suppliers to bridge the knowledge resource to meet the policy requirements
	Consult the relevant government department for the regulations	
	Build good relationships with local villagers by giving out organic fertilizers for free or hiring a local respectable person to mediate the disputes	Build relationships (farmers and residents) resources to meet the environmental standards
	Try to standardize the production and collaborate with the farmers who are willing to follow the environmental protection procedure	
	Have a professional team to support farmers to select the locations and build pig houses which meet the environmental standards	
	Use advanced manure treatment technology to fully utilize manure and water in Hanshiwei's own sow and piglet weaning farms	Accumulate equipment resources to buffer the risk

Table 7.2 Hanshiwei's resource management strategies to deal with the risks

Hanshiwei still keeps breeding in its own production process. Through acquiring and collaborating with other companies, Hanshiwei strengthened its breeding technology and vaccine production capability. Hanshiwei controls the breeding quantity and speed to avoid loss when the price fluctuates. Hanshiwei also invests heavily in environmental protection facility building on its farms to avoid environmental policy uncertainty.

The outsourcing fattening process makes farmers the key resources for Hanshiwei to finalize pig production. Hanshiwei carefully choose the farmers to collaborate with and regulates the pig house design, controls the feeds, medicine, and vaccines, and unified the sales. Thus, on one hand, the cost of and the quality of the piglets, feeds, medicine, and vaccines can be better controlled. On the other hand, production and sales are strictly monitored from the very beginning to ensure the quality of live pigs and food safety. The environmental protection department has mandatory punishment measures towards farmers who do not comply with environmental regulations. Hanshiwei guides the farmers to renovate and upgrade the pig farms to meet the existing policies and standards.

However, this is always tension in Hanshiwei since the resources are limited especially the financial resources. Hanshiwei has to decide whether to invest in internal knowledge building or develop external resources to mitigate the risks.

Chapter 8. The Case of Nanchuanhe Cooperative

This chapter discusses the Nanchuanhe cooperative's resilience-building strategy. It begins with the introduction of the background of Nanchuanhe and the analysis of Nanchuanhe's existing tangible and intangible resources. Then, how Nanchuanhe mitigates the impact caused by price fluctuation, pig disease, and environmental policy uncertainties is presented respectively. Finally, the summary concludes the key findings from this case.

8.1 Background of Nanchuanhe Cooperative

Liuyang city, located in the northeast of Hunan, has a long history of pig production. Hunan Province is one of the provinces with the largest number of live pig production in China (The pig site, 2012). The local terrain is mainly composed of mountainous areas. Unlike the plain areas where there is a large area of land where large-scale farms can be built, the pig production in Hunan province heavily relies on backyard (less than 50 heads) and small-scale (50-99 heads) pig production (as shown in Table 8.1).

Scale	Number of farmers		Number of produced	
	2015	2016	2015	2016
Backyard (<50 heads)	13,8865	12,6829	57,7969	54,9816
Small scale (50-99 heads)	3,681	3,467	20,0225	19,0685
Medium scale (100-499 heads)	2,383	1,345	71,0385	68,3500
Large scale (≥500 heads)	273	248	44,3321	45,5199

Table 8.1 Pig farms and production volume in Liuyang in 2015 and 2016 (adapted from Livestock Bureau of Statistics of LiuYang, 2015-2017).

Established in September 2007, Nanchuanhe cooperative is the first Farmers specialized pig cooperative in Liuyang City of Hunan Province, China. Through continuous growth, now Nanchuanhe has over 1080 members and is able to not only have its own pig farming bases but also offer a fully comprehensive business package (including feeds and veterinary drugs sales, marketing, financial service, logistics, education and training, environmental protection consulting and other services) to pig farmers based on sound and effective customer service. The services of Nanchuanhe co-operative have covered the whole of Liuyang city and expanded to other cities and provinces, such as Jiangxi province, Guangdong province, Shanghai, and Shenzhen. Nanchuanhe co-operative has a leading role in the production and sales of live pigs in Hunan Province. The members of Nanchuanhe raise pigs under the management of the cooperative and accept the governance of the cooperative.

In the earlier period of establishment, Nanchuanhe had 15 members with an initial registered capital of 1 million RMB. There are clear cooperative rules and regulations and organizational structure. Decisions are not made according to the 'one member one vote' principle, but rather concentrated in Nanchuanhe's management team. Farmers have the right to withdraw from the cooperative if notification is given in advance. Nanchuanhe also has the right to suspend or stop farmers' memberships if members break the rules of the cooperative. Nanchuanhe uses collective power to source low-price feeds, veterinary drugs, and piglets for farmers. Due to the vast number of cooperative members, Nanchuanhe has bargaining power when negotiating the price with suppliers. Also, the members collectively decide on purchasing decisions such as supplier selection and quality requirements. The cooperative not only owns pig breeding bases, but also collects pigs from members and sells them at premium prices. Regular membership meetings are held, and dividends are distributed according to the members' trading volume at year-ends. Most of the cooperative's revenue came from selling the feeds to members. Figure 8.1 shows the early business model of the Nanchuanhe cooperative.

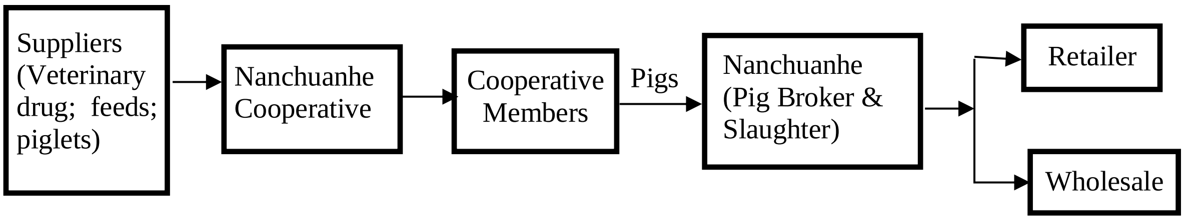

Figure 8.1 The early business model of the Nanchuanhe cooperative

In 2014, the feed market reached saturation, and price competition has become highly intense. Feeds companies could directly provide cooperative member feeds at preferential prices. The sales of feeds and veterinary drugs account for 80% of the cooperative's business. The falling price of pigs also forced a large number of small farmers out of the market. Later, the setup of restricted production areas leads to the close-down of many pig farms which failed to meet the environmental requirements. As a result, the size of the cooperative membership decreased significantly.

Following discussions at the Cooperative General Assembly, Nanchuanhe transformed into a platform model to provide value-added services to members through establishing network links with the government, upstream feed suppliers, environmental equipment suppliers, slaughters, logistics, finance providers, and research departments. As the President of Nanchuanhe Mr Gan said,

"In order to respond to the government's call on promoting the pig industry, Nanchuanhe tries to change to a model which may help members to achieve maximum shared value. The platform model increases the profit growth points. Utilizing limited capital resources and aligning with external resources, Nanchuanhe is capable to complete various projects such as upgrading members' farms at a lower cost."

By matching the external suppliers' service with member farmers' needs, Nanchuanhe provides environmental protection, financial and environmental protection services in addition to traditional operations (pig raising, marketing/sales, slaughtering, and supplying feed and vaccines) (as shown in Figure 8.2).

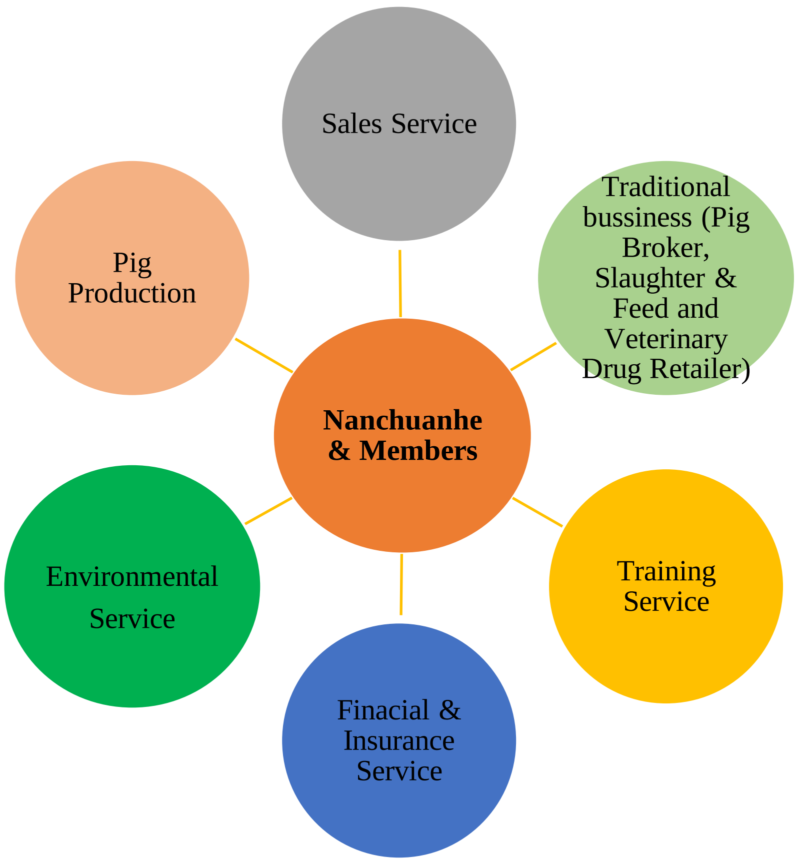

Figure 8.2 Nanchuanhe's business model since 2014

Due to the limited level of education, farmers do not know how to properly deal with manure. Collaborating with environmental equipment suppliers and research institutions, Nanchuanhe not only provides tailored environmental protection solutions but also sources the equipment for members at a lower price.

Due to environmental protection policies and the fall in pig prices, farmers (1) who want to expand production; (2) who have withdrawn due to environmental protection and pig price fluctuations; (3) who temporarily have capital turnover problems need funds to resume production. The cooperative provides financial service in three ways: (1) provide guarantees for farmers when applying for business loans from banks; (2) provide short-term, small-amount loans to farmers who experience temporary financial difficulties; (3) provide information to farmers regarding preferential insurance plans for sow pigs from insurance companies. Nanchuanhe also provides farmers with information regarding pig prices, environmental protection policies, subsidies, epidemics, and pig vaccines. In addition, working with the universities, Nanchuanhe provides management and technical training for members.

In 2017, in addition to traditional pig sales channels (selling to brokers or slaughterhouses), Nanchuanhe reached an agreement with Jiabiangou, which is the largest online and offline food retail company in Hunan province and started helping members to sell pigs directly to Jiabiangou at an agreed price. Nanchuanhe helps members to scale up and provide training to farmers regarding quality control and safe drug use so that farmers can be qualified to become certified suppliers of Jiabiangou.

To provide farmers with better and more services, Nanchuanhe establishes service modularity teams. The team are composed of specialists who collect the needs of farmers and collaborate with external partners to deliver the service to farmers. Information of around 1,080 members from 32 counties and towns in Liuyang City has been collected and grouped by villages. Each village has 1-2 team leaders responsible for communication between the cooperative and farmers and supervises members to ensure the successful delivery of the services. Figure 8.3 shows the structure of Nanchuanhe's service modularity team.

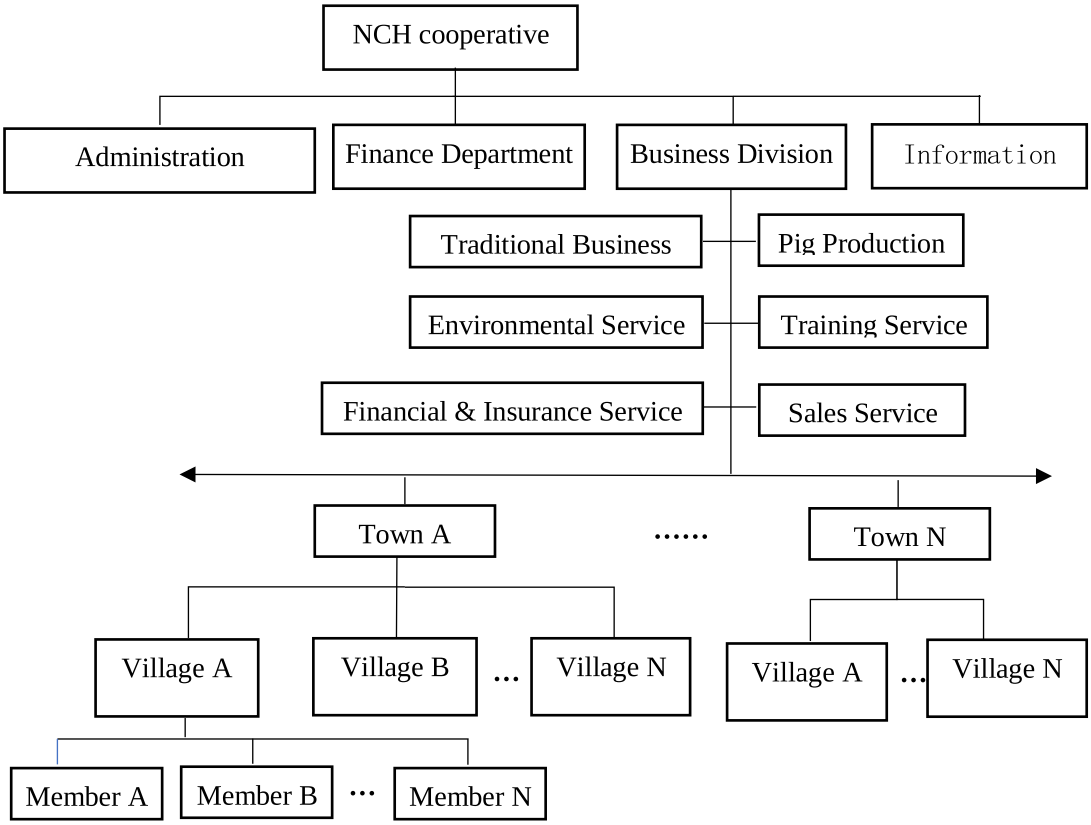

Figure 8.3 Nanchuanhe's service modularity team structure

8.2 Nanchuanhe's Organizational Resources

Since 2014, Nanchuanhe has changed to light-asset platform models and collaborated with external suppliers to provide members with pig production related services. In this section, Nanchuanhe's existing resource base is analyzed.

8.2.1 Material resources

Nanchuanhe itself does not produce any feeds or veterinary medicine. Instead, the cooperative assists its member to source all the input needed from suppliers. Nanchuanhe owns small-scale sow farms which can supply a small number of piglets. The cooperative also collects fattened pigs from members and sells them at premium prices.

Nanchuanhe collectively purchases feeds, veterinary drugs, and piglets in large quantities from supplier companies at a low cost according to the needs of farmers and sells them to farmers at a price lower than the market. Farmers can get a stable supply of high-quality feeds screened by the cooperative. And the meantime, Nanchuanhe helps to reduce the feed costs during pig production. As one cooperative member, Mr Wang said, *"Sometimes, if we purchase the feeds ourselves, the quality cannot be guaranteed. Inferior feeds will be mildewed. Plus, it is more expensive and inconvenient to be delivered. The cooperative helps us identify the quality of feeds and has established long-term cooperative relations with feed and veterinary drug companies with good reputations. When pigs are due to be vaccinated. Nanchuanhe sends us reminders on time. Also, the feeds and veterinary drugs can be delivered to the pig* houses. *Nanchuanhe* Cooperative *brings us lots of benefits".*

8.2.2 Facility resources

Nanchuanhe owns small-scale sow farms and pig farms itself which produce around 1,000 pigs per year. The cooperative also invested in some members' pig farming. Nanchuanhe relies on its member farmers to finish the pig raising. Based on the farmer's previous pig-raising experience, and the size and location of the farms, Nanchuanhe can recommend suitable pig house designs to farmers. The cooperative also helps its members source and install feeding systems and manure treatment solutions. Part of the facilities are used in self-owned pig farms, and some are sold to the members.

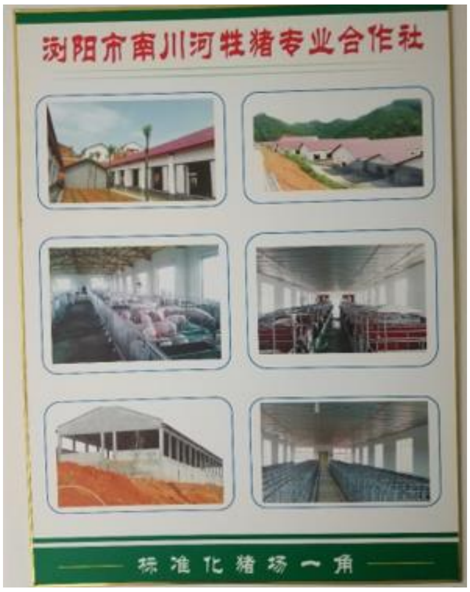

Figure 8.4 Nanchuanhe's standardized pig houses

There is a cooperative information management system which is developed in collaboration with Hunan Agricultural university. The system is used to manage member information and record their pig-raising progress, which is to increase the visibility of farmers' operations and better understand farmers' needs. Due to their low educational background, the farmers do not have the capabilities to use complicated information systems, so Nanchuanhe uses "public" platforms including WeChat and Fetion to communicate with farmers. WeChat and Fetion are the two largest standalone mobile apps in China and are widely used by Chinese people. WeChat and Fetion have many functions such as free messaging, calling, and video conferencing. Through these platforms, Nanchuanhe can also provide members and non-members information regarding price changes of live pigs, disease prevention and control solution, environmental protection policies and food safety regulations.

8.2.3 Land

As Nanchuanhe itself does not carry out large-scale pig production, the land is not a key constraint for its development. Member farmers own their farms and land. According to the People's Republic of China Livestock Law, the site of the farm needs to be located outside of the legally defined forbidden breeding area, and the pig farm needs to have good ventilation conditions. More specifically, pig houses are required to be located more than 2,000 metres away from the main traffic line, more than 500 meters away from residential areas, and more than 200 meters away from any river. Many pig farmers do not have the knowledge to choose the proper sites for pig house building. As one of the cooperative members, Mr Li said,

"The requirements for building pig farms are getting stricter and stricter. In the past, we never worried about site selection. We just raised pigs on our land, and I had never heard of environmental assessments or requirements. My land is close to the village river. If the Nanchuanhe cooperative had not told me that my land cannot be used to raise the pigs, I would have probably been fined. And there are so many procedures to follow and application forms to fill out. If it were without the help of the cooperative, with my junior school graduate background, I do not think I would be able to deal with them."

The cooperative guides its member farmers to select the site for pig houses meeting the requirements of regulations. With the support of Nanchuanhe, farmers can apply for land permission from the local village committee and the national land and resources department.

8.2.4 Financial resources

Nanchuanhe is registered with an initial capital of 1 million RMB. Members need to pay a 1,000 RMB membership fee annually. Besides the cooperative membership fees, as a leading cooperative in Liuyang city, Nanchuanhe receives subsidies and rewards from the local government each year. Cooperative makes profits through producing and selling pigs. Also, Nanchuanhe charges commission fees when providing services to farmers. Due to the light asset model, Nanchuanhe faces fewer financial risks.

8.2.5 Knowledge resources

The management team of Nanchuanhe are mostly educated at the high school level. Most of them raised pigs before but are not equipped with much advanced knowledge. The whole team, however, is very experienced in working with the government, local farmers, feed companies, and other stakeholders. Through collaborating with research initiations and universities, Nanchuanhe obtains intellectual support and meanwhile transfers knowledge to farmers. In October 2017, the Nanchuanhe cooperative became the exemplary cooperative practice base of Hunan Agricultural University and farmers' innovation and entrepreneurship base. At Nanchuanhe, training courses are provided to farmers. The university students can work in Nanchuanhe unitising their advances in agriculture science and business management to improve cooperative 's operations and farmers' pig farming knowledge. Meanwhile, students can acquire practical experience in pig raising and cooperative management.

Figure 8.5 Nanchuanhe as farmers' innovation and entrepreneurship base

8.2.6 Relationship resources

Nanchuanhe maintains good relationships with various stakeholders. Not only it collaborates with farmers to carry out pig production, but Nanchuanhe also works closely with local government and maintains long-term relationships with research institutions and feeds, piglets, and equipment suppliers as well.

Nanchuanhe has built strong relationships and mutual trust with cooperative members. Farmers are the most important group of stakeholders in Nanchuanhe's pig supply chain, as they are in charge of fattening the pigs once the piglets are sent into pig houses. Nanchuanhe facilitates cooperative members to sell the pigs, purchase feeds, veterinary drugs, machines, and equipment, and apply for government subsidies. Nanchuanhe arranges pig-raising technical training for farmers and provides them with financial assistants and suggestions for pig house building. A designated team leader is assigned to be responsible for the communication between Nanchuanhe and the farmers. The trend of the hog price, market demand, and the updated government policy and regulation information is shared with the farmers through WeChat and Fetion daily so that the farmers can be well informed of the pig raising related information. The pigs produced by farmers are sold either to Nanchuanhe or to brokers introduced by Nanchuanhe. Nanchuanhe guarantees the sales of the pigs. At the end of the year, dividends are rewarded back to its cooperative members. Nanchuanhe endeavours to provide better services to members and achieve value cocreation with its members. As cooperative member Mr Wang said,

"Nanchuanhe cooperative is the first contact point if I have any difficulties. The purpose of the cooperative is to serve our members. I do not have so much information and knowledge. But Nanchuanhe has. Nanchuanhe tells us how to make money. It is our leader, and we would like to follow it."

Also, Nanchuanhe has a good reputation and is well-recognized by local villagers. This is because Nanchuanhe advocates value cocreation and serve the members, most of whom are from local villagers. A good reputation has been spread through word of mouth. Besides, the management team of Nanchuanhe is from local Liuyang city and has a wide range of personal connections with local villagers.

To keep a stable supply of veterinary drugs and feeds at reasonable prices, Nanchuanhe work closely with various suppliers. Regular reviews of the price and quality are carried out. Those suppliers with bad records will be flagged and even eliminated from the supplier list. Due to the number of cooperative members and accreditation from the government, many suppliers such as feed companies and environmental technology companies proactively approach Nanchuanhe.

Since Nanchuanhe can guarantee a stable supply of pigs, slaughterhouses and pig brokers are willing to establish long-term relationships with Nanchuanhe. The pigs sold by Nanchuanhe can have the priority to be slaughtered which reduces the weight loss in the waiting time.

Since 2017, Nanchuanhe has cooperated with Jiabiangou Co. Ltd, which is the largest online and offline food retail company in Hunan. Jiabiangou invested in the establishment of an agricultural company with Nanchuanhe and acquired a slaughtering line. Jiabiangou purchased live pigs from Nanchuanhe and its member farmers at an agreed price and sold them directly in offline and online stores.

The management team of Nanchuanhe regularly attend the Annual Conference of China's Cooperative Economy and other pig association meeting and conference to share their experience. Research collaboration has been established with various universities. Every year, students are sent to Nanchuanhe either to carry out research or work as trainees.

Nanchuanhe also maintains very a good relationship with the government, supporting the government to implement environmental policies and poverty alleviation activities. The Cooperative President Mr Gan has regularly reported and given suggestions to different departments in local government such as the Agriculture Commission, Animal Husbandry Bureau, Bureau of Agriculture, and Environmental Protection Agency. Together with the local government, Nanchuanhe supports farmers in poverty with funds to start up and provides training in pig-raising technology. The guaranteed sales make sure that the farmers can have sustained income. As cooperative member Mr Li said,

"I'm a veteran and have a disability in the legs. After I demobilized and went home, I never thought I can do any more work. When President Gan contacted me and suggested raising pigs, I thought it was impossible. Since I had never raised pigs before. The cooperative provided me with a loan and supported me to apply for some funding from the government. They also helped me build the pig houses and step by step taught me how to raise pigs. They visited me regularly and told me when pigs should be vaccinated, and what feeds pigs at different growth stages should eat. They even help me to sell all my pigs. Over the past few years, I have changed from a poverty household which received state subsidies to a farmer who owns middle-scale farmers with more than 400,000 RMB annual income. I completely got out of poverty and was no longer a burden to the government. Three years ago, I would never have thought of what I have achieved now. I am planning to expand the production scale and raise more pigs. All my huge change was brought by Nanchuanhe."

8.3 Risk Management Process

As a cooperative, the core value of Nanchuanhe is to serve the members and achieve value co-creation. Farmers are responsible for finishing the pig fattening process and are the most important stakeholder in Nanchuanhe's pig production supply chain. However, this relationship between Nanchuanhe and its members can be a double-edged sword - both Nanchuanhe and pig farmers can either achieve mutual benefits or suffer the loss of profits together. So, in Nanchuanhe's risk management strategy, how to help farmers to mitigate the risks and continue production is a key task. As the President of Nanchuanhe Mr Gan said, *"Nanchuanhe is composed of farmer members. Without their participation, the Nanchuanhe just cannot exist. If they stop pig raising or withdraw from the cooperative, our supply chain will disrupt. We are bonded together and try to solve the problems together with the farmers."*

8.3.1 Price fluctuation

Nanchuanhe cooperative's members are different in production scales but are predominantly small backyard farmers with a production scale of fewer than 200 heads of fattened pigs per annum. Most of them do not have strong financial capability and are vulnerable towards pig price reduction. Due to the limited production scale, when pig price increase, limited extra profits can be obtained. When pig price decrease, small farmers experience cash flow interruption to buffer the financial loss.

Nanchuanhe uses facility resources such as information management systems to provide members with information on hog prices. The information team in Nanchuanhe closely monitors the pig price change on the market, exchange information with experts in the industry and estimate the tendency of price change. Although the pig price cannot be precisely predicted. Nanchuanhe tries to identify the trend as early as possible so that the best advice can be given to the member farmers. Once the price starts to decrease, Nanchuanhe gives immediate warnings to farmers and recommends them to stop purchasing piglets and start selling the sows to avoid further profit loss, when the price continues to decrease. Also, during the price reduction, Nanchuanhe contacts equipment suppliers to help farmers to update the pig houses. So, as a response, farmers can be ready to expand their production capacity and recover quickly when the pig price increases. As Cooperative member, Mr Li explains,

"Nanchuanhe regularly send us information regarding the pig price change. So, we can get early informed of the market situation. I trust Nanchuanhe. When they tell me to stop buying piglets and sell sows, I will follow. I know they want to help us. I understand if I lose less when the market price is low, I can have the opportunities and funds to resume production later and earn the money back. Mr Gan also encourages us to upgrade the pig farm and sow farm. When the pig price is low, many small farmers cannot hold and withdraw from the market. Nobody wants to raise the pigs. The price of pig-raising equipment is cheaper as well. We can buy the equipment now which means a saver for the future. Not many cooperatives have this vision."

Nanchuanhe uses members' collective power to source feeds at a lower price which saves the costs of farming inputs for its member farmers. Nanchuanhe regularly visits the feed companies and gives feedback to farmers regarding the feed's quality. Nanchuanhe chooses well-formulated feeds and negotiates for cheaper prices than the equivalent in the market. Member farmers are allowed to purchase feeds from Nanchuanhe without paying cash immediately rather than on credit. When their pigs are fattened and sold to Nanchuanhe, the cost of the feeds can be directly deducted from the payment for pig selling. In addition, Nanchuanhe purchases fattened pigs at a price 1 per cent higher than the market price. If Nanchuanhe does not purchase farmers' pigs, the farmers do not have to pay back the feed costs. This also helps farmers to buffer the cash flow problem when the market situation is poor.

Nanchuanhe has also developed close relationships and collaborations with pig brokers, slaughterhouses, and wholesalers to solve the pig-selling problem for farmers. Nanchuanhe negotiates contract prices with Jiabiangou on behalf of its members to get a minimum guaranteed price. So, when the market price is low, the agreed contract price can still guarantee farmers' profits or at least not lose profits. For Jiabiangou, sustained pig supply can be secured at well. As the President of Nanchuanhe Mr Gan said,

"Nanchuanhe serves as a bridge between external stakeholders and member farmers. We use our resources to help farmers to sell pigs at a higher price. This is especially helpful for farmers when the pig price is low. When farmers' pigs are purchased through Nanchuanhe, either Nanchuanhe or Jiabiangou pays higher than the market price. It is a triple win for farmers, Nanchuanhe and Jiabiangou. Farmers may avoid significant profit loss and do not need to worry about hold-up problems when the market price is low. Nanchuanhe may avoid losing the farmers due to their bankruptcy. Jiabiangou may reduce the purchasing transaction costs and secure the supply. We are trying to build long term relationships between Jiabiangou and farmers."

By coordinating pigs together and saving transportation costs for brokers to get the pigs from member farmers' houses, Nanchuanhe can negotiate a better price for farmers as well. Since the pig farmers are highly fragmented and distributed in the different mountain areas. Transportation is difficult to organize and expensive. Nanchuanhe has intensive communications with brokers and logistics companies in Hunan and nearby provinces, and regularly share updates on member farmers' production schedules. So, the brokers can get updated information regarding where the pigs are located, how the pigs are fattened, and what type of pigs they are. Nanchuanhe arranges vehicles to collect the pigs and several brokers can share one vehicle to save costs. Through coordinating with brokers and slaughterhouses, the farmers can get better prices indirectly. Pig broker Mr Zhu gives an example, *"The reason why I am willing to give Nanchuanhe a premium price is that they help me to get cheaper transportation and sell the pigs at a higher price. I just share part of the profits with the farmers. Like this one, this vehicle came here to drop the live pigs at a slaughterhouse nearby. Nanchuanhe knows the owner of the lorry. They arrange this lorry for me to collect the pigs from their members. The transportation cost is very low since this lorry originally would go back in empty. Now, at least, the driver can earn some. Also, Mr Gan has contacted a slaughterhouse in Zhejiang Province where I am going to sell the pigs this time. This is because the live pig price in Zhejiang Province is much higher than in Hunan Province recently. In addition, Mr Gan has a personal relationship with the owner of that slaughterhouse. When my pigs are transported there, the pigs will be slaughtered first. The slaughterhouse measures the pigs' weights before the pigs are slaughtered and pay us according to the weight. The shortened waiting time may reduce the pigs' weight loss. Thus, I can get more profits."*

There are still farmers who cannot sustain themselves during the pig price reduction. Nanchuanhe believes it is the natural process to die out small-scale farms. But with Nanchuanhe's reputation and capabilities, these withdrawn farmers are quickly replaced by other farmers. More farmers are interested in joining Nanchuanhe.

8.3.2 Pig disease

In rural areas, pig diseases are difficult to control. Most of the small farmers in Hunan province are located in rural mountain areas. Farmers do not have proper education and professional pig-raising knowledge. And there is a lack of vets or medical technicians in these areas. When pig disease spreads, efficient treatment may not be available immediately, which results in the further rapid spread of the virus. In some cases, to avoid the loss, farmers deliberately still sell the sick pigs to the market, which leads to food security problems. In addition, the poor hygiene condition of pig houses contributes to the spread of disease. For example, in some farmer's houses, young generations go to the big cities for work, while the elderly are left at home, which means a lack of labour. The pig pens which have not been cleaned in time can become full of mosquitoes flying around and spreading the disease.

Nanchuanhe gathers information including symptoms of common pig diseases and how to cure and sends it to farmers through information management facilities such as WeChat and Fetion. So, farmers can be better equipped with knowledge of disease diagnosis. Ear tags with chips to record pig production information has been recommended and/or taught to farmers. If highly infectious diseases are found, Nanchuanhe would require farmers to cull all the pigs. For high-valued sows, Nanchuanhe recommends farmers buy the insurance and would help farmers to apply for insurance from its insurance supplier.

Figure 8.6 The pig raising information system app

Working closely with the governmental Epidemic Prevention Department, Nanchuanhe provides technical assistance to farmers to install the pig-raising information system which is developed by Hunan Animal Husbandry Bureau. This system is a mobile app which can be used to record detailed information on pig farmer's owner, pig farm scale, pig growth, and vaccination status. All the information is kept in Nanchuanhe's information system as well. The local government requires all pig farmers to install and use this app so that the pig growth can be inspected instantly. However, Farmers have difficulties in installing and operating this app due to their low level of education. Nanchuanhe arranges training sessions for each member and supervises the farmers to input the information required. When pigs are due for vaccinations, the app will automatically send notifications. Manager of Animal husbandry station (the local government department which is in charge of livestock Epidemic Prevention) Mr Xi said,

"We would like to work with Nanchuanhe. As a government department, we do not have the labour to teach farmers to install and use the system one by one. Nanchuanhe did the job for us, and the farmers trust them. This system is extremely important for disease prevention and

control. It has vaccination information for each pig. Also, if the pig is dead. It tracks where it goes. The dead pig needs to be sent to the harmless treatment centre and be recorded dead. So, the dead or ill pigs will not go to market."

Nanchuanhe has established a long relationship with veterinary drug companies. Veterinary drug companies provide free professional veterinary consulting services to member farmers. And Nanchuanhe's veterinary drug supplier offers cheaper vaccination for member farmers. This is to avoid some of the farmers using cheaper but bad quality veterinary drugs. As an information channel between farmers and veterinary drug companies, through Nanchuanhe, farmers' problems and requests can be effectively passed to veterinary drug companies. Nanchuanhe has a team leader in each village. These leaders are normally pig farmers with outstanding performance. They are locally prestigious, rich in breeding experience, sensitive to changes in policy information and have strong abilities to perceive risks. These leaders regularly visit members' pig farms to check the condition of the pig and monitor the pigs' growth progress. Once pig disease is identified, it will be reported to Nanchuanhe's pig production team immediately. Then, veterinary services will be arranged for the infected pig farms. With the support of these leaders, Nanchuanhe also either organizes local villagers to clean pig pens for pig farmers who lack labours in their households or employs labours to work for them (The salary will be deducted from the income of final pig selling). For some of the large-scale pig farms, Nanchuanhe works with the equipment suppliers to install CCTVs for farmers so that sick pigs can be identified immediately.

8.3.3 Environmental policy uncertainty

In 2014, China's agricultural and rural environmental administrative regulations, "Regulations for the Prevention of Livestock and Poultry Farming" came into effect. The national environmental protection agencies have imposed strict supervision on key areas of hog production. Many members worried that their farms would be closed. Because their pig farms failed to meet the national environmental requirements. As one member Mr Wang recalled:

"I have been raising pigs for several decades and relied on them to make a living. If the environmental protection department closes my pig farm, I don't know what I can do instead."

Nanchuanhe arranges multiple meetings with the local animal husbandry department, environmental protection department, and land department to consult relevant policies and regulations on breeding land and pig farm site selection. Nanchuanhe also reports back and gives recommendations to the local government regarding the inconsistent understanding of environmental protection provisions. As the Manager of the Animal husbandry station, Mr Xi said,

"We are deeply impressed by the staff of Nanchuanhe cooperative. They came many times to consult us on how to choose the site and what the specific environmental protection requirement for small-scale pig farms are. Now Nanchuanhe might be more familiar with the regulations than we are."

For members whose pig farm is located in forbidden farming areas which have been introduced in the Law of Environmental Protection of the People's Republic of China in 2015 (The pig site, 2017), it is required that the pig house needs to be demolished within two months. To avoid the impact on subsequent pig production, Nanchuanhe negotiates compensation for the demolition of the pig house with the government on behalf of their farmers. And the farmers receive guidance from Nanchuanhe to choose a new qualified site to build pig houses.

Due to the complication and changes in environmental protection policies and the limitation of farmers' education level, farmers do not know how to deal with manure. Nanchuanhe collaborates with environmental facility suppliers to provide customized manure treatment plans for cooperative members. According to the breeding scale of each pig farm and the conditions of the pig house, the corresponding environmental protection solution is provided. The related environmental protection equipment is sold to members at a cheaper price. Once the facilities are installed, Nanchuanhe will monitor the manure treatment performance.

With support from Hunan agricultural university, Nanchuanhe organizes training sessions to increase farmers' environmental protection awareness and cooperate with the government to promote environmental protection policies. Study groups among members are organized by Nanchuanhe to communicate and exchange pig farming experiences. Nanchuanhe gives rewards to farmers who have better environmental protection performance. These farmers are recognized as role models and share their experiences with other cooperative members.

Nanchuanhe has leveraged the resources to upgrade farmers' environmental facilities in accordance with the requirements of environmental protection which helps farmers to avoid heavy fines. In addition, farmers whose farms were shut down due to environmental problems can search for new production sites and acquire funding with the support and guidance from Nanchuanhe. Through the development of environmental protection projects, farmers' resilience toward environmental policy uncertainties has been improved. Recognizing for its effort, Nanchuanhe was awarded the Liuyang excellent Demonstration Cooperative by the Liuyang Municipal Commission of Agriculture. The Cooperative President Mr Gan said,

"Because of the environmental policy, a large number of farmers cannot meet the current requirement and quit the market. Many cooperatives face a decrease in members. Due to the success of our environmental protection project, more farmers have joined the cooperative. We lead them to upgrade their farms, I am confident that even if the environmental policy becomes even stricter, our members can still comply with the standards."

8.4 Case Summary

In this Chapter, firstly, the development of business models of the Nanchuanhe cooperative has been introduced and followed by its existing resources. Table 8.1 summarizes the development of business models of the Nanchuanhe cooperative.

Period	Business Model	Main operations
2007—2013	Cooperative establishment, traditional business model	Sale of feed, veterinary drugs, acquisition of live pigs, slaughter, pig broker, transportation.
2014 afterwards	Platform model	Establish a cooperative platform service centre. Establish a network of relationships with the government, upstream feed suppliers, environmental protection companies, slaughter companies, logistics companies, finance, and scientific research departments. Provide value-added services to members.

Table 8.2 Business model evolution of Nanchuanhe cooperative

Nanchuanhe adopts a light-asset model and does not possess many tangible resources including lands, materials, facilities, and financial resources. However, Nanchuanhe established close relationships with various stakeholders. Taking advantage of these relationship resources, Nanchuanhe achieves better value cocreation with its member farmers and bridges the resources to mitigate the risks for farmers.

Through analysing Nanchuanhe's strategies in dealing with three types of major risks, how Nanchuanhe builds its SCR by bridging the resources to farmers has been shown (Shown in Table 8.3).

Risks	Resource Strategies	
Price Fluctuation	Use information management systems to provide members with information on hog prices to control the time of pig selling	

	Closely work with experts in the industry to monitor the pig price change on the market, exchange information and estimate the tendency of price change	Closely work with farmers and suppliers to reduce the cost and sustain the farmers
	Use members' collective power to source feeds at a lower price which saves the costs of farming inputs for its member farmers	
	Allow farmers to purchase feeds from Nanchuanhe on credit.	
	Purchase fattened pigs from farmers at a price 1 per cent higher than the market price	
	Develop close relationships and collaborations with pig brokers and retailers to guarantee the pig sales	
	Coordinate pig transportation together to save the costs	
	Regularly visit the feeds companies and gives feedback to farmers regarding the feed's quality	
Pig Disease	Work closely with the governmental Epidemic Prevention Department, Nanchuanhe provides technical assistance to farmers	Collaborate with farmers and external suppliers to control and prevent the disease
	Use pig raising information system developed by Hunan Animal Husbandry Bureau to record detailed farmer and pig-raising information	
	Work with the Animal husbandry station to vaccinate the pigs in farmers' pig house	
	Work with farmers to establish clear immunization programs and healthcare plans for each pig	
	Establish long relationships with veterinary drug companies to provide free professional veterinary consulting services and quality drugs to member farmers	
	Build teams to regularly visit the farmers, provide technical guidance, inspection, and supervision to farmers	Knowledge dissemination to farmers
	Gather information including symptoms of common pig diseases and how to cure and send it to farmers through information management facilities	
Environmental Policy Uncertainties	Consult the local animal husbandry department, environmental protection department, and land department for the policies and regulations on breeding land and pig farm site selection	Work with external suppliers to bridge the knowledge and facility resources to meet the policy requirements

	Collaborate with environmental facility suppliers to provide customized manure treatment plans for cooperative members	

Table 8.3 Nanchuanhe's resource management strategies to deal with the risks

To deal with price fluctuations, Nanchuanhe works with its suppliers to lower the production costs for member farmers. When price decrease, Nanchuanhe sends out early warnings to farmers to reduce production so that further loss may be avoided. Meanwhile, recommendations to upgrade the pig houses will be given to farmers to get ready for expanding production when the pig price increases. If some member farmers cannot sustain themselves and withdraw from the market, Nanchuanhe regards them as natural elimination and will quickly find other farmers to collaborate with.

Nanchuanhe fully collaborates with the government, equipment suppliers, and veterinary drug companies to prevent and control pig diseases. Nanchuanhe provides training to farmers to get them familiar with the symptoms of common pig diseases and information on how to cure the disease.

Nanchuanhe provides technical assistance to farmers to install the pig-raising information system so that the government can get updated pig vaccination and production information. Timely reminders are sent to farmers once the vaccination is due. Nanchuanhe acts as an information channel between farmers and veterinary drug companies. Farmers' problems and requests can be effectively passed to veterinary drug companies through Nanchuanhe. The setting of the village leader facilitates Nanchuanhe to better manage and supervise farmers' disease prevention.

Nanchuanhe leverages the support of an environmental company to customize and upgrade farmers' pig manure fermentation facilities in accordance with the requirements of environmental protection. Also, relevant training is organized to increase farmers' environmental protection awareness.

Overall, Nanchuanhe establishes network links with stakeholders including the government, upstream feed suppliers, environmental protection, slaughter, logistics, finance, and research departments. Through bridging the resources, Nanchuanhe provides value-added services not only to nurture the member farmers but also to help them to manage risks.

Chapter 9. Cross Case Analysis

In within case analysis, I carried out data coding on the raw data based on each case (Within case analysis) and develop a comprehensive compendium based on raw data. A myriad of informant terms, codes, and categories emerged early in the research within each case. I identified significant features of each organization's resource management practices in dealing with various risks. Then I further derived themes that I saw emerging from the analysis of the resource management practices. When I have the full set of themes (theoretical saturation), the basis of the data structure was built. This process allows the unique patterns of each case to emerge before I generalize patterns across cases. The within-site analyses of Chapters 5,6,7,8 provide materials for comparison of cross-site analyses as they enable to compare of the main research variables of this study. I selected categories or dimensions that emerged from the within case analysis, and then looked for within-group similarities coupled with intergroup differences. For example, both Muyuan and Lihua invested in internal knowledge building and worked more on vertical integration, while Hanshiwei and Nanchuanhe invested less, but they focus more on managing the relationships with farmers. This chapter presents the cross-case analysis developed on findings from the single case analysis. Comparison among four case companies is made to explore the similarity and differences between the four case companies and find the relationship between constructs, which could lead to the propositions. The risks embedded in pig supply chains and stress are presented in Section 9.1, the existing resource caravan is presented in Section 9.2, different resource bundles are presented in Section 9.3, different resource management capabilities are presented in Section 9.4, and finally four organizations' resilience statuses are presented in Section 9.5.

9.1 Risks Embedded in Pig Supply Chain and Stress

9.1.1 Risks embedded in pig supply chain

Agricultural supply chains are exposed to ubiquitous and varied risks and uncertainties. These risks may come from different sources, and supply chain members may experience multiple risks at the same time. The four cases clearly show that these organizations' pig production operations are highly affected by three types of risks, namely: livestock diseases, public policy risks (uncertain environmental policy), and market-related risks (pig price fluctuation).

There are five types of risks mentioned in four cases which are natural disasters, operational risks, biological risks, public policy risks and market-related risks. Natural disasters such as floods and high temperatures can affect the quality of pigs and sometimes disrupt the flow of supply and services. However, it occasionally happened and did not cause serious consequences in all four case companies. For high temperatures, both Muyuan and Lihua have air conditioners in the pig houses. Hanshiwei and Nanchuanhe require farmers to install cooling and ventilation equipment in their pig houses. The operational risks mainly include equipment failure or staff /cash shortage. Muyuan and Lihua have backup electricity generators and spare equipment to deal with emergency breakups or storage. They consistently recruit employees from the universities as backup staff to avoid staff shortages. Both Muyuan and Lihua stand in strong financial positions. When pigs are sold, the money needs to arrive at the companies' account from buyers first, then the buyer will be allowed to pick up the pigs from the pig houses. In such ways, companies' cash flow can be guaranteed. Both Hanshiwei and Nanchuanhe outsource the production to farmers, so they do not directly face direct operational risks. Thus, natural disasters and operational risks happen but do not impose significant impacts on our case companies.

It is identified that biological risks, public policy risks and market-related risks are the main concerns of the case organizations. All four cases highlight these three risks due to their severe impact. Livestock disease is a major biological risk in pig production. It may cause direct death yield and quality reductions and can also lead to disruption of the production flow. Since pig diseases are normally highly contagious, the loss of the pigs will have significant financial implications. Changing or uncertain regulatory and legal policies are the main public policy risk, which affects the whole industry. The change in environmental regulations and how these rules will be enforced result in more investment in the equipment and may even lead to disruptions to production. In addition, pig price fluctuation is a typical market-related risk which is the most volatile. Price uncertainty is very high and has a direct impact on companies' profits. The pig-raising cycle is six months. After six months, the company may face the situation that either the pigs are sold without profits or keep the pigs until the prices increase. However, it occurs extra costs to maintain these unsold pigs. Table 9.1 portrays different types of risks that may be encountered by pig production companies and the likelihood of the risks.

Type of Risks	Examples	Muyuan	Lihua	Hanshiwei	Nanchuanhe
Natural disasters	Flood; excess temperature storms	Low	Low	Middle	Middle
Operational risks	Equipment breakdown; inability to adapt to changes in cash and labour flows	Low	Low	Low	Low
Biological risks	Livestock diseases	High	High	High	High
Public policy risks	Changing or uncertain regulatory and legal policies	High	High	High	High
Market-related risks	Changes in prices of inputs or outputs	High	High	High	High

Table 9.1 Categories of major risks facing pig supply chain

As the above discussion indicates that among the five mentioned risks, *livestock diseases*, *uncertain or changing environmental policy* and *pig price fluctuation* are the major risks identified in our cases. In addition, we highlight where particular risks do not happen frequently, but once occur they can have significant implications on the continuity, costs, and efficiency of production activities.

9.1.2 Organizational stress

Conservation of resources theory implies stress may occur under the following three situations: 1. When existing resources are threatened; 2. there is actual resource loss; 3. There is a lack of resource gain following significant resource investment (Hobfoll, 2001).

Following this, Table 9.2 summarizes the organizational stresses case companies experienced due to the three major risk events identified in the previous discussion. The analysis suggests that all the case companies suffered from the stress of financial loss facing pig disease. For Muyuan and Lihua, the financial loss comes from direct or threaten of pig death, the increasing cost of disease treatment, potential damage to the companies' image and the slow recovery and capital return due to the long pig production cycle. While Hanshiwei and Nanchuanhe, differently, both organizations suffer from financial loss not only because of the pig death but also loss of the resource of collaborated farmers who fatten the pigs for them. The loss of farmers' relationships causes not only current direct but also future production interruptions.

In the case of price fluctuation, all case organizations face the situation that when the price increases, companies cannot immediately increase the production capacities to earn more profits due to the long production period. While, when the pig price is low, companies are unable to adjust quickly which leads to financial loss. Especially, for Hanshiwei and Nanchuanhe, both invest significantly to establish relationships with farmers. However, when the pig price is high, farmers may stop collaborating with companies and turn to raise the pigs themselves.

In the case of uncertain change in environmental policy, all the case companies have the pressure of government fines and suspension of production either directly in the companies (Muyuan and Lihua or in the collaborative farmers’ pig houses (Hanshiwei and Nanchuanhe). Facing such stress, Muyuan and Lihua tend to overinvest in manure treatment equipment which significantly increases the operating costs.

Indeed, companies may face the pressure of multiple risks. Many of such expected losses resulting from the risks facing the agricultural supply chain are related to uncertain events for which the probabilities are unknown. When the actual risks happen, companies may suffer from resource loss. The stress which comes from the direct interruption of production and financial loss is significant. Sometimes, even large number of resources are invested, companies may still fail to go back original production level.

Risk sources	**Stress: （Economy consequence）**			
	Muyuan	Lihua	Hanshiwei	Nanchuanhe
Pig Disease	Due to the large-scale intensive breeding mode, the contagious diseases may spread quickly and affect more livestock in Muyuan than in any other pig breeding companies. Pigs may be culled as part of efforts to contain and eradicate disease; Pig death; Increased cost on the treatment of pig disease (Veterinary drug, cost for external labour, specially formulated feeds), cost to dispose of the dead pig, plummeted stock price; Potential Consumer food safety concerns toward Muyuan's pig; Long pig fattening cycle slows down the recovery and capital return; The quality of the pig can be reduced.	The cost increase in disease recovery; Slow in capital return; Pig death; Material loss due to farm workers' cheating behaviour (Kill the infected pigs rather than curing); Decrease in sales because of the restrictions on hog products (pig and pork variety meats) transportation between provinces (due to the outbreak of Africa Swine fever); Reduce the pig quality; Potential Consumer food safety concerns toward the company's pigs.	Difficult to control the disease due to outsourcing the fattening process to pig farmers; Financial loss due to pig death; Technician shortage due to the high technical demand from pig farmers; Significant cost increase because farmers overuse veterinary drugs; The Farmers kill the infected pigs rather than curing them; Reduce the pig quality; Reputation damage.	No financial gain because of the pig death at the pig farmers' houses; No potential future gain as farmers withdraw from the market due to the loss of pigs; Farmers may lose confidence in Nanchuanhe's service and break up the relationships.
Price Fluctuation	Difficult to estimate the future sold price of the pigs; When the price increases, as the only integrated pig breeding	When pig price is low, the more pigs are produced, the more financial loss is;	Profit loss due to the pig price decrease; Some of the farmers withdraw from the industry	When pig price is low, Nanchuanhe's supply base shrinks which leads to the reduction of its profits;

	company in China with breeding bases, due to the long production period, Muyuan is unable to respond quickly. So, the potential opportunities to increase sales may be missed; When the price decreases, expected profits cannot be reached; The unstable of financial performance and cash flow restricts the speed of expansion.	Financial difficulty if low price lasts longer; It is difficult to raise funds when the pig price is low, the company misses the extra profit gain in the future high price period; Difficult to find experienced farmers during the high pig price period.	due to insufficient profits, which cause Hanshiwei to lose its supply base; When pig price is high, farmers choose to raise the pig themselves to obtain more profits, which threatens Hanshiwei's supply base; Farmers sell Hanshiwei's feeds and replace them with cheap feeds during the high pig price period; Fluctuated financial performance affects credits in financial institutions; Significant changes in pig supply numbers lead to difficulty to coordinate the feeds and piglets.	When pig price is high, there is high market demand. Farmers may sell pigs to other buyers which leads to financial loss for Nanchuanhe; If significant cooperatives members were withdrawn, the cooperative would not have sufficient profit to maintain its operation.

Environmental Policy	Some of the land acquired cannot be used to raise pigs due to their location near the water and residential areas; Production may be temporarily suspended until the manure treatment facilities reach government standards; Penalty; Overinvestment in manure treatment equipment may increase operational costs; Reputation damage;	Government fine; Local villagers protest; Government's restriction on future land acquisition; Delay in use of the pig pen until the manure treatment facility meets the government's environmental requirements; Previous manure treatment facilities cannot meet the new regulations; The government directly asked Lihua to transfer 20,000 sows within three months because the manure treatment in the production plant was not in place. Lihua had to sell all the pigs directly.	Pig production can be interrupted as some of the pig farmers whose lands are located in the restricted areas cannot raise pigs for Hanshiwei anymore; Pig production can be delayed until the pig farmers upgrade their manure and water treatment equipment to reach the government's standards; Have negative impacts on the relationship with local government;	Government stops providing funding to support the Cooperative due to member's environmental pollution behaviour; Damage the relationship with the government; Cooperative members may withdraw from the market due to their limited abilities to comply with environmental regulations, cooperative loss its members.

Table 9.2 Risks and stress

9.2 Existing Resource caravan

Conservation of resources (COR) theory pointed out that companies strive to shepherd their resources to obtain, retain and protect their resource reservoirs (Hobfoll, 1988, 1989, 1998, 2001). Different resource characteristics within organizations form a firm's unique resource caravan. Resources' inherent properties and how resources are characterized have important implications for understanding their influence on firms 'risk mitigation strategy. In our case companies, it is found that in the situation of stress, organizational resource caravans have been highly characterized in terms of their availability, valence, and complementarity.

Following this, descriptions of each company's resource caravan are found in Table 9.3 and Table 9.4.

When dealing with stress brought by the risks, firms' resources may be readily available or unavailable. According to COR theory, sufficient resources may buffer against the risk directly which in turn reduces companies' stress from resource loss. Such abundant resources may be used as investments to recover from losses and generate more resource gain for companies. So, companies' resource availability plays an important role in risk mitigation. Based on the six types of key resources tangible resources (machine, capital, plants, or materials) and intangible resources (relationship or knowledge), the resource availability of four case companies is examined (as seen in Table 9.3 and Table 9.4). Through comparing four case companies' resource availability. It is shown that Muyuan and Lihua possess sufficient land, finances, facilities, materials and knowledge directly linked to pig production. Both Muyuan and Lihua own the land for pig production and invest in piglet production factories. Muyuan even owns the sow production factory and tries to control all the pig production processes. Both developed and produced their feeds for pig raising. The difference is Muyuan employs technicians to raisie the pigs and piglets, while Lihua let out the pig houses to farmers and takes advantage of farmers' knowledge to raise pigs. Also, Muyuan has more tangible resources stock than Lihua.

Through the cross-case analysis, it is found that the other two case organizations, Hanshiwei and Nanchuanhe have different available resource bundles in their resource caravan, they possess abundant relationship resources. They obtained the essential resources for production and finish the pig production by collaborating with different partners. Farmer suppliers are the key stakeholder for Hanshiwei and Nanchuanhe to finish the pig production. Both outsource the fattening process to farmers. Hanshiwei manages and develop farmer suppliers through its production service department who provide comprehensive service to farmers throughout the whole pig fattening process, including suggestion on pig house building, application of water and manure treatment facility, nutrition formula, disease prevention and treatment and financial assistance. Hanshiwei still owns the feed production factory while as a cooperative, Nanchuanhe helps its member farmers to source the feeds, and equipment from collaborative suppliers. Both organizations have established long term relationships with veterinary drug and vaccine suppliers and have a vendor list and purchasing system, regularly monitoring the quality of the vaccine, and updating the vendor list. They also have good relationships with the pig brokers to guarantee the sales and the government to be well informed about the policy change. Nanchuanhe as a cooperative barely owns any tangible resources for production but occupies more relationships to acquire the resources.

Two other resource characteristics, resource valence and resource complementarity have been highlighted when case companies' management teams discuss resource orchestration during the risks. Table 9.5 suggests that the companies may have different levels of resources base, the management teams in case companies all have clear expectations and objectives on what resources to obtain to achieve the organization's goals. It is shown that the senior managers in all four organizations show a clear understanding of why certain resources are required. Muyuan's and Lihua's strategy is more focused on cost minimization. We reveal that when firms experience resource losses, they tend to use their resources more strategically for risk mitigation.

Furthermore, according to COR theory, companies need to invest resources to get the resource gain. It is identified in the cases that companies continue evaluating the resource caravan and make the decision on what extent resource investments are needed (Table 9.6). The resources investments come with costs. All case companies are quite cautious about resource investment. In all the case organizations, the invested resources are gone through the evaluation process (formal or informal) to assess if it would be appropriate (inappropriate) for mitigating the risks (Table 9.6). Although adopting different resource management strategies, Muyuan, Lihua, Hanshiwei and Nanchuanhe all make aggressive investments to build resource repertories to protect themselves from resource loss. Similarly, facing the pressure from the consequence of potential and existing risks, all companies strategically manage the investment of resources to mitigate and offset the effects of disruptions. A matching level of investment is carefully reviewed and made on developing resource surpluses and SCR capability building. Muyuan's decision-making is more centralized. Nanchuanhe involves its members in jointly making strategic decisions. All of them evaluate the current status of operations, the cost efficiency of the investment, and also the possibility of the implementation of risk recovery plans. Many factors are considered such as IT system compatibility, staff availability, and operation process change. It can be seen that all four organizations make effort to resource investment due to the stress or concern of the consequences of the risks.

Overall, before and during the company’s resource management, a systematic approach has been taken to analyse various kinds of resource characteristics (inherent as well as situational), resources in various combinations and to what extent resources should be invested.

Resource Type	Muyuan	Lihua
Land	Prepare the largest land for the integrated pig production factory in advance; Acquired large land through lease contract with local government; (A typically integrated factory including pig reproduction area, feeding factory, fattening factory, manure treatment plant and living area for employees covers an area of around 4,000 acres and a construction area of 400,000 square meters, which can produce 1 million head of hogs annually). In 2001, the company has already had 2.3 million hectares of land in stock. "Although some of the land we get cannot be used for pig production due to the environmental regulation, we are still aiming to stock as more as possible". The criteria for Muyuan to announce the establishment of subsidiary companies is the obtainment of various certificates such as land and environmental assessment, and then the pig farm will be opened within 1-2 months at the latest. The company was founded in 1992. After 24 years of development, it now has 88 wholly-owned subsidiaries located in Henan, Hubei, Shandong, Shaanxi, Shanxi, Hebei, Inner Mongolia, Jilin and Jiangsu province, which means that the land stock in Muyuan is very rich.	Lease with local government to rent large land for pig fattening and feeding factories. Since 2011, Lihua acquired land in Suqian city, Lianyungang city, in Jiangsu province and Taizhou city in Zhejiang Province. Because most of the ingredients of the feeds are centrally sourced and some feeds are produced in the feeds factory in the headquarter located in Changzhou city, Jiangsu Province. All the land Lihua acquired is not far from its feeding company. Also, since the pig production company does not need to pay taxes to the local government and pig raising may cause environmental problems. Getting land becomes quite difficult for Lihua.
Financial	Very Strong. Listed on the Shenzhen Stock Exchange in 2014; Raise a total of 36 billion Renminbi (RMB) until 2017; The market value reached 57.6 billion RMB in 2018; Stable cash flow due to the cash-on-delivery model; High profit and high credits attract various investments (10 million US dollars from International Finance Corporation); Annual profits reach 2.366 billion RMB in 2018;	The total amount of registered capital is 362.6 million RMB. In Feb 2019, Lihua's stock is listed on Shenzhen Stock Exchange. In 2018, Lihua's total sales revenue reached 7.21 billion RMB (including chicken sales), an increase of 21.6% compared with sales in 2016; Lihua does not allow customers to overdraft. Payment needs to be done at the same time as the sales. Some of the pig agents pay cash directly. The cash flow is good.

Facility (Farms/ plants; Machine; equipment)	Each pig factory is highly integrated including sow farms, pig fattening farms, feed production factories, pig manure and wastewater treatment factories and staff living areas. The production management system (established in 2011) and the ERP (established in 2013) platform supported the rapid development of the company. At present, there are at least 80 pig house engineering in Muyuan. Muyuan's pig house is the most advanced in China, which considers the temperature, ventilation, and humidity of each breeding stage and the production costs. A large number of advanced and high-efficiency automation equipment (Temperature monitor and control system, automatic feeding equipment and manure cleaning system) are used to reduce production costs and increase productivity.	The company adopts the cooperative breeding mode of "company + base + farmer", which is, the company uniformly carries out feed production, pig house construction, etc. Farmers then rent the pig pens in the company's self-built farms to raise the pigs. Lihua's pig farms are all self-constructed and are integrated with nursery houses, mating houses, breeding houses, pregnancy homes, delivery rooms, and boar stations. The boars are originally bought from Piesi (Zhangjiagang) breeding pig improvement Ltd. Automatic feeding, and auto manure treatment facilities are used to improve feeding efficiency.
Material (Feeds; Veterinary medicine; Piglets)	The subsidiaries are mostly located in the main grain producing areas. So, the original main ingredients of the feed can be purchased nearby, and the smooth use of the tanker completely solves the intermediate packaging cost. It also reduces the risk of contamination of feed. The produced feeds are only fed to Muyuan's pigs and are not sold to external pig companies. The company can make good use of alternative feed materials such as wheat to control the feed costs. For example, based on the "corn + soybean meal" formula technology, combined with the characteristics of the main wheat producing areas in Nanyang City, the company developed the "wheat + soybean meal" feed formula technology according to local conditions. Wheat and corn have certain mutual substitutions, and the protein content of wheat is higher than that of corn. The use of wheat to some extent saves the use of protein materials such as soybean meal. The company can adjust the main materials in the feed formula according to the overall cost of raw materials and effectively reduce the feed cost.	Generally, corn, soybean meal, and wheat which are the main raw ingredients of the feeds account for respectively 36.09%, 38.42%, 42.27%, and 35.62% of the total cost of pig production. Lihua adopts the "headquarter centralized procurement" model to have cost advantages and well control the quality of the raw material of the feeds, drugs, and vaccines. Lihua has a vendor list and sources directly from the farmers and domestic drug and vaccine suppliers. The procurement of raw materials mainly considers existing stocks, consumption, and market conditions to keep proper inventory and meanwhile control the procurement costs. The company has already built a pig feed factory, which has a total production capacity of 270,000 tons. The ownership of the pigs and piglets belongs to Lihua. Lihua develops its own EAS information system. The EAS information system enables real-time data monitoring, analysis and feedback on production and sales.

	Muyuan has a veterinary drug supplier list, and the suppliers are selected and reviewed through its bidding system every year. Muyuan also invested 100 million RMB to build its own veterinary drug laboratory and factory to produce more reliable and low-cost veterinary drugs. In 2005, Muyuan imported 470 original breeding pigs from Canada. Muyuan is the first national pig breeding farm. In 2014, two national pig breeding farms were built, and there are more than 8,000 sows in stock. The company has also invested in 4 independent boar stations and 5 on-site boar stations. So, there is no shortage of piglets. The ownership of the pigs and piglets belongs to Muyuan.	At the same time, the company has set up internal environment monitoring systems in all the pig houses, collecting environmental data such as humidity and wind. It can achieve also self-adjustment of the environment.
Knowledge	429 national patents have been obtained; Muyuan is recognized as "the national key leading enterprise of agricultural industrialization", "National Livestock Reserve Base", "National Pig Industry Technology System Inner Town Comprehensive Test Station", the first batch of "National Pig Core Breeding Farm", "Henan Province Livestock and Poultry Health Breed Academician Workstation". Chairman Mr Qin and the senior management team frequently travel around the world to learn advance advanced pig raising technology and pig company management knowledge. Experts are invited to provide training and some of them directly participate in technology improvement. And the total cost savings will be shared with experts. High salary and Equity allocation scheme to attract university graduate students and experienced pig-raising technicians. In 2017, the proportion of college graduates or above reached 30.9%.	11 people have PhD degrees, 88 people have master's degrees and 1087 people have college above degrees which accounts for 30% of the total employees. Until 2018, 64 people in the technical department are responsible for R &D related to production and disease prevention and control. The KPI of the research department is related to the number of patents applied and the effect of knowledge transfer. Lihua collaborates with Yangzhou University, Nanjing Agricultural University, Jiangsu Academy of Agricultural Sciences, China Agricultural University, and other research institutes and establish, the Institute of Jiangsu Enterprise Postgraduate Workstation, Jiangsu Enterprise Academician Workstation, and Jiangsu Postdoctoral Innovation Practice Base.

	There are over 100 research teams which are located in each production process, such as feed production, breeding, veterinary drug monitoring, and fattening. The total R&D expenditure in 2017 was RMB 73,975,400, an increase of 494.57% compared to 2016.	
Relationship	It was very difficult to cooperate with universities in the early years. Many research projects were funded by the government. So， the firm was not allowed to use the research outcome. In the early years, it was not allowed to pay the researchers for using their research results, which will be treated as corruption. Now, it is permitted. Since pig production company does not need to pay tax, the government provide very limited support. For example, there is a national experimental station for the pig industry system in Muyuan set by the Ministry of Agriculture. However, there is no financial support from the government. Still, maintain a good relationship with the government. Not highly dependent on suppliers. Muyuan produces main feeds and Veterinary drugs itself.	There are no government subsidies. Still partially reply on suppliers for piglets and Veterinary drugs. Sometimes have problems with the local community due to water pollution and the smells from the pig raising.

Table 9.3 The resource availability of Muyuan and Lihua

Resource Types	Hanshiwei	Nanchuanhe
Land	Have relatively small land for boar stations and sow farms. Mainly adopts the “company + family farm” model, collaborating with farmers to fatten the pigs. Hanshiwei does not need a large amount of land, since farmers own the land and raise the pigs for the company. Through working with farmers, Hanshiwei rapidly expand to more than 10 provinces in China including Jiangsu, Anhui, Guangxi, Jiangxi, Hunan, Hubei, Hebei, Shanxi, Shandong, Fujian and Heilongjiang, and has become one of the top ten breeding enterprises in China. Has to compete with other chief livestock companies for land.	Except for offices, do not need large land for pig production. Get access to the land by fully cooperating with cooperative members to fatten the pigs in Liuyang, Hunan province.
Financial	Hanshiwei is a wholly owned subsidiary of Tianbang Group, the parent company Tianbang Group was listed on the Shenzhen Stock Exchange in 2007. Has less financial pressure, since the cost of the pig house building is covered by farmers.	With an initial registered capital of 1 million RMB. Each year, the local government provides subsidies to promote the development of cooperatives. Collecting cooperative membership fee. Commission fee for service provided to its member. Due to the light asset model, there is very little financial pressure.
Facility (Farms/ plants; Machine; equipment)	Hanshiwei build a small number of boar stations and sow farms to produce weaned piglets. Since the fattening stage has been outsourced to farmers. No pig houses or production machines are needed. Hanshiwei provides the farmers with the design of the pig house and recommends them the feeding system and manure treatment equipment.	Nanchuanhe owns very small pig farms which can raise 1000 pigs per year and small-scale sow farms. Nanchuanhe helps its members to build pig houses and recommend feeding systems and manure treatment solutions. but not as advanced as what big companies are using.

Material (Feeds; Veterinary medicine; Piglets)	Hanshiwei's parent company Tianbang Group originally specialized in feed production. So Hanshiwei feeds are all supplied by Tianbang feed factories at a lower price compared to the market price. Except for producing feeds, Tianbang Group also use the OEM model to produce the feeds. Tianbang has veterinary drug factories to produce certain types of veterinary drugs and supply them to Hanshiwei. Hanshiwei has established long-term cooperative relationships with some vaccination manufacturers. Most of the vaccination is still centrally purchased from its vendor lists. At the beginning of its establishment in 2013, Hanshiwei acquired the world-famous breeding company CG and several national-level laboratories for the cultivation of breeding pig genes were built, which ensure the quality of the breeding pigs. However, Hanshiwei does not have enough sow farms to produce piglets due to the limited land acquired and the unstable number of farmers' suppliers. So Hanshiwei still needs to purchase piglets from other piglet suppliers.	As the first Farmers specialized cooperative in the Liuyang City of Hunan Province, Nanchuanhe itself does not produce any feeds or veterinary medicine. Instead, the cooperative helps its members to source all the inputs needed for products from third-party suppliers. The small-scale sow farms may produce few piglets. The Cooperative also collects fattened pigs from members and sells them at a premium.
Knowledge	Hanshiwei carries out joint breeding with the world's leading pig breeding company, Choice Genetics (CG), using big data Genetic evaluation, genome selection, CT scanning and automatic feeder measurement technology to improve the quality of breeding pigs. Adopt e-procurement platforms to increase the transparency and traceability of the procurement. Use the mobile App WeChat to instantly connect to pig farmers. Developed Family Farm patrol systems through which can monitor whether the technicians visit and provide service to the pig farmers regularly. The technician department is the core team in Hanshiwei who is responsible for supporting farmers to raise pigs and developing new farmer suppliers. However, it is difficult to recruit and keep experienced technicians (competitor companies poach the talent by paying higher salaries)	The management team of Nanchuanhe are mostly educated at the high school level. And they have less knowledge in pig raising using advanced technology. But they have plenty of experience in working with the government, local farmers, feed companies and other stakeholders.

Relationship	Farmer suppliers are the key stakeholder for Hanshiwei to finish the pig production. Hanshiwei manages and develop farmer suppliers through its production service department who provide comprehensive service to farmers throughout the whole pig fattening process, including suggestion on pig house building, application of water and manure treatment facility, nutrition formula, disease prevention and treatment and financial assistance. Established long term relationships with veterinary drug and vaccine suppliers. Have a vendor list and purchasing system, regularly monitor the quality of the vaccine and update the vendor list. Also have good relationships with competitor companies, since Hanshiwei purchases piglets from them. The sales team maintains good relationships with the pig brokers using personal relationships. But often there is corrupt behaviour between salespersons and brokers. Work closely with research institutions (employ university professors as senior consultants to provide technical support) Carefully maintain good relationships with the local government, since the government can help Hanshiwei to promote the company and attract more farmers to work with Hanshiwei. In some cases, Hanshiwei signs exclusive contracts with the local government to prohibit its competitors to enter this area. But it always happens that Hanshiwei needs to re-establish the relationship with the local government due to the change of the leaders in certain government departments. Employ powerful local people to establish and manage the relationship with the local community especially when a dispute happens.	Maintains very good relationships with the government, supporting the government to implement environmental policies and Poverty alleviation activities. Have mutual trust with cooperative members. Help cooperative members to sell the pigs, purchase feeds, veterinary drugs, machines, and equipment, and to apply for government subsidies. Provide pig raising technical training and suggestion for pig house building and financial assistance. Due to the great number of cooperative members and accreditation from the government. Many environmental technology companies and feeds and veterinary medicine companies, slaughterhouses and pig brokers want to establish relationships with Nanchuanhe. Since the management team of Nanchuanhe is from Liuyang city. Nanchuanhe has a good reputation and is well recognized by local villagers. Regularly review the price and quality of veterinary, feeds and work closely with suppliers.

Table 9.4 The resource availability of Muyuan and Lihua

	Resource availability					
	Land	**Financial**	**Facility (Farms/plants; Machine; equipment)**	**Material (Feeds; Veterinary medicine; Piglets)**	**Knowledge**	**Relationship**
Muyuan	Strong	Very Strong	Very Strong	Very Strong	Very Strong	Weak
Lihua	Middle	Strong	Strong	Strong	Strong	Middle
Hanshiwei	Middle	Strong	Weak	Middle	Middle	Strong
Nanchuanhe	Weak	Middle	Weak	Weak	Weak	Very Strong

Table 9.5 The comparison of resource availability in four case organizations

(Strong implies there are sufficient and abundant resources available. Weak means the level of available resources is low)

Resource Characteristics	Resource Valence (Individual's expectation on resources to help to achieve the goal)	Resource Complementarity (New resource complementarity to existing resources)
Muyuan	"We believe the application of multiple feeds formula could significantly reduce the overall production cost and even when the pig price decrease, we can still keep our cost under the sales prices." "We have clear objectives and have done the cost calculation. Once we want to acquire land, we target to get the return within two years."	"The decision-making in Muyuan is still highly centralized in the headquarter. Take the recent African swine disease as an example, we had a series of roundtable meetings with all the directors from different departments sitting together to analyse the situation. We discussed the available approaches and evaluated how effective these approaches can form the epidemic prevention solution in Muyuan. Of course, every department needs to check what resources we have to support the implementation of the strategy. Do we have enough staff to carry out extra inspections and if they are fully equipped with swine disease knowledge? Do we have enough cash flow to either develop or purchase vaccines? Does our current Epidemic prevention procedure strict and comprehensive enough to stop the spreading of disease? If we make any changes to the procedures, how each department will need to adjust its operation (e.g., more regular inspection for feeds and vaccine tests) to coordinate with each other? If we decide to purchase the vaccines from suppliers, are they suitable for Muyuan's pig breed? Will they have side effects on the quality of the pigs? We will consider all these factors to find the best suitable disease prevention solution for Muyuan."
Lihua	"I would expect to improve our technology to well raising the pigs and I believe if the pigs are well looked after, naturally they will have stronger immune systems to defend against the animal diseases)." "The reason for us to invest in the procurement system is that we would like to increase the transparency of the purchasing activity so that we can get more control of the whole process. We think it is an appropriate strategy for Lihua"	"Cash flow is always a big problem for Lihua, so we cannot invest in every resource. We would make sure the investment would build on our existing resources. For example, we can source ERP systems from third-party suppliers, but instead, we decide to develop our own. Since the current ERP system on the market is for manufacturing systems not compatible with agricultural production. For each investment, the senior managers from the related departments will be gathered to evaluate if the investment is workable and reasonable. How each department will be affected? And how each department

		can support the initiatives? We have clear procedures to evaluate the impact of the investment and make sure the strategy will complement and strengthen the existing resources.”
Hanshiwei	“It is undoubtedly agreed in the company that the relationship with farmers is key for our development. If those farmers work harder and carefully look after our pigs, the production cost and the rate of dead pigs can be reduced, and the overall quality of the pigs can be improved. That is why the production service team who provides comprehensive services to those farmers is the biggest in Hanshiwei. We would expect them to not only well manage the farmers but also explore new farmers for us.”	“Hanshiwei will not have very high requirements for farmers in their pig houses building and use of advanced equipment. Since the cost to build such pig houses and the adoption of advanced technology is too high. Our farmers cannot afford it. Although the design can significantly reduce the production cost, it is not compatible with the current situation of our farmers.” “When we want to develop new farmers in a new area, our technical team will carefully evaluate if the farmers will cause conflict with the local community or other farmers. Do we have enough technicians to provide technical support? Do we have enough sow farms to provide piglets and feeds factory close by or do we need to invest in building local facilities and teams?”
Nanchuanhe	“As a cooperative, Nanchuanhe was supervised by the Chinese government. The development of Nanchuanhe highly relies on the local government. So, we make lots of effort on developing a good relationship with the local government which introduces us to the funding source, informs us of the policy changes earlier and help to promote our cooperative.	“We will only cooperate with someone who supports the development of our members.” “We carefully choose the wastewater treatment equipment suppliers for our members. Some of the equipment is too advanced and expensive, our members cannot afford them and do not have enough knowledge to use them.” “We normally will consult our members for their opinions to see if they think the investment would have value and if they are able to carry out the initiatives.”

Table 9.6 The resource valence and complementarity of four case organizations

Resource Characteristics	Extent of investment
Muyuan	"The reason why we made such big investments is that before we were seriously concerned about the devastating consequence of pig price decrease. It is not like the interruption of the power supply or equipment failure, small investments in spare equipment may solve the problems. It is a continuous long-term investment in cost control of the whole production system. It is a never-ending process, but the more we do, the more improvement we can get. And the result would be less economic losses. The initial investment decision was hard, and the investment was huge, but now once the system and procedure have been built, less investment is needed. And now our production cost is the lowest in the whole industry, we have less sensitive to price fluctuation than other companies." "Of course, we have great pressure from the tightening of the environmental policy. We were informed to stop production until the pig manure and wastewater problem were solved. We made huge investments in building environmentally harmless treatment factories, which enable us to deal with the dead pigs and the environmental problems brought by pig raising. The investment in technology research and factory building is huge. We try to earn extra profits by treating dead pigs for other local pig farmers and sales of organic fertilizers. However, until now, the payback of our investment has not been achieved. The reason why we made a huge one-time investment is first that we want to make sure we comply with the government environmental regulation which is a huge pressure for us. Secondly, Although the investment is high, our investment in equipment meets higher environmental standards. So, in the future, if there is any change in the regulation, we will not be affected.
Lihua	"For Lihua, the pig price decrease is fatal. The more we produced, the more financial loss we made. In such a situation, we cannot sustain ourselves long. It was a critical period and everyone in the different departments are in great tension. We monitored the price every day and strictly control all expenditures. We have a WeChat group composed of all senior managers from different departments. You can see that so many messages and discussions have been carried out during the price reduction period. All kinds of information regarding price prediction and examples of best practices have been spread in the group every day. Because Lihua suffered hugely because of the price fluctuation. It is about live or die. So, no matter how much we need to invest, we have to do it. We are investing in optimizing our system and once we can keep our production cost under the lowest pig sale price. and we will not suffer from the pig price, no more big investment would be needed. Muyuan is the only one in this industry to achieve this, so the price decrease has less impact on them"
Hanshiwei	"When the company decides the amount of the investment. We consider it case by case. We have internal evaluation processes. If the impact of the risks is huge and critical, definitely huge funding would be needed and approved by the headquarter. The division of restricted farming areas made us totally lose the production capacity in certain areas. It is a big pressure for all the pig raising companies like Hanshiwei. Some of the areas were not affected, but we still

	need to help them to update farmers' pig manure treatment equipment. Although we do not invest directly, small investments in the extra technical persons are needed. In some areas, the policy has huge impacts. Investment is imperative. We need to rebuild the whole supply chain. We invest in building new sow farms and feed factories. We collaborate with the government to help farmers to find other lands to raise the pigs for us and make sure their new pig farmers comply with the local environmental policies. We also need to invest in exploring new farmers to work with us. So, different levels of and types of investments are needed depending on the impact of the policy and existing available resources."
Nanchuanhe	As a small cooperative, we have limited funding, not as much as those big production companies. So, when we invested, we are very cautious. We prioritize dealing with the risks which have significant impacts on our members. For example, the recent African swine flu is highly contagious and may directly cause a massive number of pig deaths. But our member farmers do not have the knowledge or proper facility to control the spread of the disease. It has become that once we heard the name "African Swine", everybody has become so nervous. The president of the coops all faces the same pressure. We meet regularly to discuss the development of the epidemic and possible solutions. We need to report the epidemic situation to our members every day. Collaborating with the Liuyang city government and Hunan agricultural university, we have invested hugely in training our members and step by step teaching them how to carry out epidemic prevention. It is a big expenditure for Nanchuanhe, but we think it is worth it. The African swine flu seriously affects the development of the coop. Our members are key to the cooperative's existence. It is the cooperative's responsibility to make sure that our coop members have enough resources and capabilities to pass through difficult periods.

Table 9.7 Management team's decision on extent of resources investment

9.3 Different Resource Bundles

As Hobfoll (1988;1989; 2001) asserts that firms may mobilize and invest resources to protect against resource loss, recover from losses and gain resources when facing stressful events. Following this, Table 9.8 summarizes the resources investment strategy when case organizations experience major risks. Correspondingly, in this research, it is revealed that six types of critical resources in four case organisations have been proactively used to cope with resource loss and gain future resources and form different resource investment strategies. The table suggests that the focal companies may have different resource investment strategies for mitigating the consequence of risks.

9.3.1 Knowledge-based resource management

Both Muyuan and Lihua invest mostly in land, facility, material, capital, and knowledge building. Muyuan and Lihua both own their feed production, piglet, sow, and pig fattening factory which require a large number of land (as shown in Table 9.8). Land acquisition is a challenge for pig production companies since pig raising may cause significant environmental problems for the local community. The government is very cautious when giving land permission. Both companies make lots of effort on acquiring as much land as possible. This is not only because the company's scale-up requires land. But also, due to the environmental policy change, some of the previously owned lands may become forbidden areas and unsuitable for carrying out production anymore. Thus, the backup land may enable the company to efficiently resume production. Muyuan and Lihua also invest significantly in facilities, materials, and knowledge resources. Advanced pig houses, pig feeding, house cleaning and manure treatment equipment and ventilating system are adopted in these two case companies. The application of the modern facility keeps pigs well monitored and looked after which reduces the possibility of pig disease and death. Both companies develop their enterprise resource planning (ERP) systems to efficiently manage and integrate information regarding financials, operations, and human resource activities. When facing risks, the ERP system may bring more visibility, help with quick action taking and proactively respond to operational disruption or market change. Both case companies develop their feed formula not only to reduce the feed cost but also to guarantee better pig growth. Employees with advanced knowledge are recruited in pig raising and both companies emphasise technology innovation and staff training. And both companies encourage information sharing and knowledge building. Optimization of operation procedures and cost reduction is the focus of production. Financial resource is the key to a company's survival. Muyuan and Lihua are both Listed on the Stock Exchange to acquire more financial resources from the capital market. They also invest in futures of feed raw materials such as corn and soy to reduce production costs. Due to the larger production scale and stronger financial position, Muyuan can invest more heavily than Lihua in all types of resources.

9.3.2 Relationship-based resource management

Different from Muyuan and Lihua, Hanshiwei and Nanchuanhe invest heavily in relationship resources to mitigate the resources (as shown in Table 9.8). Since these two organizations outsource the fattening process to farmers, land, facility, and knowledge for pig raising can be acquired through farmers. When collaborating with farmers, Hanshiwei and Nanchuanhe choose farmers who have the land and financial capability to invest in pig houses. The pig house building, manure treatment equipment and ventilating system installation need to reach certain standards. Hanshiwei works with pig house experts to provide construction plans to farmers. Nanchuanhe also collaborates with consultants to provide suggestions to its members to upgrade the pig houses. Hanshiwei still provides its own produced feeds to farmers to save overall costs. While Nanchuanhe works with various feeds and veterinary companies and environmental equipment suppliers and closely manages the relationships with them to source low-cost supplies for farmers. Very little innovation is carried out in these two organizations. Hanshiwei and Nanchuanhe both work closely with the government to get well informed about policy changes. If the farmers are unable to carry out pig production due to the financial burden of pig price decrease or pig disease, these two organizations tend to search for new collaborative farmers. Especially, during the pig price decrease, Hanshiwei and Nanchuanhe may work with downstream pig brokers to sell the pigs earlier to reduce the potential profits loss. Overall, Hanshiwei and Nanchuanhe work more on managing and obtaining relationships either replacing the loss of the resources or acquiring resources they are not able to produce.

	Resource management strategy	Resources Investment					
		Land	Facility	Material	Financial	Knowledge	Relationship
Muyuan	Knowledge-based resource management	Largely acquire lands and store backup lands	Adopt the most advanced pig houses, pig feeding; house cleaning and manure treatment equipment; ventilating system; self-developed ERP software.	Invest heavily in genetics technology of pig breeding and self-made feed formula.	Listed on the Stock Exchange in 2014; attract International Finance Corporation investment. Invest in futures of feed raw material.	Recruit University graduated employees and world leading research teams; Heavily invested in technology innovation, staff training and culture building; optimize operation procedures.	Maintain essence relationship with stakeholders.
Lihua		Acquire lands and store backup lands	Adopt advanced pig house design, pig feeding; house cleaning and manure treatment equipment; ventilating system; ERP system.	Apply advanced genetics technology of pig breeding; Introduce self-made feeds formula.	Listed on the Stock Exchange in 2019. Invest in futures of feed raw material.	Recruit employees with professional knowledge; invested in technology innovation and staff training.	Maintain essence relationship with stakeholders.
Hanshiwei	Relationship-based resource management	Only acquire lands for feeds and	Adopt a self-developed ERP system.	Apply advanced genetics technology of	Affiliated to Tianbang group who provides capital to	Recruit employees with professional knowledge; regular staff training.	Established extensive relationships with local farmers, various governmental

		sow plants		pig breeding; use better quality feeds formula.	Hanshiwei; Invest in futures of feeds raw material.		departments, local village committees, banks, and research institutions.
Nanchuanhe		Do not acquire lands	Use WeChat and Feixin to communicate with partners.	Do not invest	No investment	Recruit professional staff and occasional staff training.	Heavily invest in establishing strong relationships with local farmers, feed suppliers, veterinary suppliers, feeding suppliers, piglet suppliers, environmental equipment suppliers, banks, all levels of governmental departments, industry associations, and research institutions.

Table 9.8 Resource management strategies

9.4 Different Resource Management Capabilities

The analysis of organizations' resource management capability is discussed under vertical integration in Section 9.4.1, knowledge management capability in Section 9.4.2 and Supplier integration capability in Section 9.4.3.

9.4.1 Vertical integration

Evidence suggests that firms' risks may be reduced through vertical integration (Helfat and Teece, 1987). It is claimed that uncertainties may complicate a company's decision-making processes and make comprehensive contingent planning on how to deploy resources impossible. By adopting vertical integration, information flows become internal, which minimizes the cost of identifying and disclosing information. Also, the flow between separable stages can be smoother and more efficient since there are no proprietary boundaries encountered. Vertical integration can reduce a firm's exposure to uncertainties.

It is shown that during the risks event, four case organizations tend to engage in different levels of vertical integration (as shown in Table 9.9). In the table below, a tick means that the organization integrates the relevant production processes into its operations.

	Vertical integration					
	Sow farm	Piglet farm	Pig fattening plant	Feeds plant	Environmental equipment supply	Veterinary plant
Muyuan	√	√	√	√	√	√
Li Hua	√	√	√	√	×	×
Hanshiwei	√	√	×	√	×	×
Nanchuanhe	×	×	×	×	×	×

Table 9.9 Vertical integration

Muyuan takes control over all the stages of pig production. Muyuan builds its own sow and piglet farms and feeds plants. Such a strategy may be essential to assure a supply of critical materials such as piglets and feeds. Apart from the impact on materials cost saving, shortages or low quality of feeds and piglets in industries are extremely damaging because they lead to low usage of expensive facilities and even the disruption of production. Even when supplies of materials are plenty in the market, Muyuan's fully vertical integration strategy may greatly reduce the purchasing and handling costs incurred when sourcing from suppliers. And it can also permit cost reductions and the increase of efficiency through improved coordination of production and inventory scheduling among stages. It is revealed that Muyuan is best equipped to innovate with the vertical integration structure. The integration enables the company to participate in most of the production operation activities in which change can occur. In addition, vertical integration improves the coordination of technical functions in each operation stage. In both Muyuan and Lihua's cases, feeds are specially formulated in their own feed plants to suit pigs in the different growing stages and will be adjusted according to the cost of raw materials. In this way, the cost is strictly controlled to deal with the pig price reduction. Similarly, self-owned veterinary plants equip Muyuan to quickly develop and produce veterinary drugs to deal with fast-spreading pig diseases. Especially, when the disease is large-scale, the self-owned veterinary plants may guarantee a stable supply of the drugs. Muyuan innovates its environmental equipment to meet environmental requirements. The technicians from the environmental equipment supply team may closely monitor and quickly identify the problems in the production processes, innovate suitable approaches and coordinate with pig raising technicians to solve the manure leak. However, when a firm integrates its operation processes, high investment intensity is required. Therefore, Lihua who possesses less capital is less vertical integration compared to Muyuan. Compared to Lihua which invests in sow and piglet farms, pig fattening plants, and feed plants, Hanshiwei integrated fewer production stages. Both Hanshiwei and Nanchuanhe outsource the pig fattening processes to farmers. Nanchuanhe barely carries out any production and becomes a resource integrator.

9.4.2 Knowledge management capability

Nerf (2005) suggests that the key to a proactive risk management process lies in the organization's ability to mobilize the knowledge and corporate intellectual resources so that accurate and timely information about risks can be get quickly and accurately. To do this, various operations within firms as well as external environmental issues need to be monitored so that potentially explosive issues can be quickly identified or resolved. Knowledge management capability refers to an organization's ability to acquire knowledge and information, also continuously create new knowledge through leveraging existing knowledge to achieve high operation efficiency (Bose, 2003; Liu et al. 2004). Through developing knowledge management capability, knowledge inherent to individual employees can be developed into organizational knowledge through knowledge management processes such as knowledge acquisition, retention, and distribution (Patterson and Ambrosini, 2015; Martín-de-

Castro, 2015; Lee et al., 2016). Gold et al. (2001) pointed out that KM capability consists of organizational capabilities of knowledge acquisition, conversion, application, and protection.

Based on the within case analyse, evidence shows that with four case organizations, Muyuan and Lihua exhibit strong knowledge management capability during the risk recovery processes (as shown in Table 9.10). Both develop abilities to gain and accumulate knowledge from inside the companies to generate risk mitigation plans. The organizational internal risk management routines are well established, practised rigorously, and therefore reinforce over time. Both firms with strong knowledge capabilities can best utilize and benefit from existing resources. Knowledge management capability can play a critical role in leveraging portfolio resources and support to generate breakthrough innovation in risk mitigation. Communication channels within companies are open to enable efficient potential hazard identification and reporting. Employees are encouraged to be involved in collaborative problem-solving processes. In this way, staff's intellectual resources can be fully utilized to generate risk recovery solutions. Routines are developed to organize and integrate the knowledge which enhances the usefulness of existing knowledge toward risk prevention and mitigation. Muyuan and Lihua learn from their previous risk management experiences. Leading practices toward risk management are captured. These lessons can all be applied in a formal process that will help a company to sense and respond to potential risks. Then, decision support systems are developed to help the organizations to develop preventive risk management policies and avoid costly repetition of errors. Both case companies continue modifying and optimizing the pig disease prevention procedure based on previous experiences. Advanced IT system has been applied to store and use the knowledge which enables the knowledge can be accessed and employed across the organization. Enterprise resource planning systems provide various performance data which can be used to predict trends and provide early warning towards risks. For example. Companies monitor the price fluctuation historical data and trends using accurate market analysis tools to understand potential market price risks. Finally, both firms are equipped ability to prevent knowledge within an organization from being inappropriately or illegally used or stolen by other organizations. Muyuan applied for patents for its pig house designs and feed formula which is the key to its cost reduction.

Overall, knowledge management capability enables Muyuan and Lihua to capture and distribute relevant and time-sensitive information, generate, and identify risk mitigation solutions and capture lessons learned, and complete business research and analysis so that companies can deal with the risks in a timely way.

	Knowledge management	Supply Chain Practice
Muyuan	Knowledge acquisition	Proactively absorb knowledge from employees and turn it into codified knowledge; Generate new knowledge from existing knowledge; Periodically review and use feedback on projects to improve subsequent projects; Exchange knowledge within different branches of the company; Provide acknowledgement and award for the creative processes; Employee recruiting.
	Knowledge conversion	Work with employees from different departments to integrate different sources and types of knowledge; Organize and Filter knowledge; Replace outdated knowledge; Distribute knowledge throughout the organization; Knowledge sharing. Transfer organizational knowledge to individuals through training; Integration of the transferred knowledge resources with the existing knowledge bases; Make sure expertise and work processes are compatible;
	Knowledge application	Use advanced IT tools to facilitate and increase processes of storage and distribution of knowledge; Work with employees to quickly apply knowledge to deal with the risks; Take advantage of new knowledge; Apply knowledge learned from mistakes and experiences; Use knowledge to improve efficiency;
	Knowledge protection	Apply for patents to protect knowledge from inappropriate use outside the organizations; Establish effective protective policies and procedures to prevent knowledge theft; Emphasize the importance of protecting knowledge; Restrict access to some sources of knowledge.
Lihua	Knowledge acquisition	Encourage employees to innovate; Regularly review and summarize the experience on projects; Exchange knowledge within different branches of the company;
	Knowledge conversion	Regular meetings to distribute knowledge throughout the organization Integration of the experience and knowledge of chick raising into pig raising.
	Knowledge application	Use ERP system to facilitate and increase processes of storage and distribution of knowledge; Work with employees to quickly apply knowledge to deal with the risks; Apply knowledge learned from previous experiences to treat the pig disease and predict price fluctuation;

Knowledge protection	Have established policies and procedures to prevent knowledge inappropriate use; Establish a culture of protecting knowledge; Restrict access to some sources of information.

Table 9.10 Knowledge management

9.4.3 Supplier integration capability

According to Sheffi and Rice (2005), firms' resilience can be accomplished through either creating redundancy or increased flexibility. Increased flexibility can be deployed through engaging in supplier integration. Supplier integration involves core competencies related to coordinating, collaborating, and interacting with supply network partners and involving them in production operations (Flynn et al., 2010). Risk management is a resources intensive process. Supplier integration provides routes for external resource acquisition.

Based on the single and cross cases analysis, it is shown that Hanshiwei and Nanchuanhe develop their supplier integration capability to achieve effective supply chain risk management (as shown in Table 9.11). Different from vertical integration, supplier integration allows Hanshiwei and Nanchuanhe lower fixed costs and thus increased flexibility. Both organizations engaged in information sharing, joint problem solving and system coupling which indicate high levels of supplier integration. Both organizations collaborate with farmers to carry out pig fattening. The high level of supplier integration capability enables them to work with a large number of farmers, which can lead to economies of scale. Activities such as communication over specific requirements toward manure treatment facilities, shared understanding of specifications of the pig raising, regular meetings and feedback, and training have been carried out to reduce the probability of occurrence of risks and also reduce the potential impact or damage caused by the event without requiring huge resource commitment.

	Supplier integration **Supply Chain Practice**
Hanshiwei	Regular communications with contracted farmers; Collaborating with suppliers and co-suppliers (e.g. raw material producers); Provide technical support and general information about pig raising; Joint problem-solving with farmers (environmental and disease); Build mutual trust with farmers; Top management commitment to supplier relationship development; Provide financial assistance to farmers; Provide training to farmers (such as pig house building); Formal supplier evaluation procedures; Establish a database for farmers who raise pigs; Granting supplier performance awards and rewards;

Nanchuanhe	Intensive communications with all the suppliers (farmers, feeds, veterinary drugs and equipment, piglet suppliers, pig brokers, government, research association); Collaborate through both formal and informal relationships with farmers; Regular meetings with all the suppliers; Collaborating with suppliers and co-suppliers (e.g. raw material producers); Intensive visit to the farmers for information sharing (pig price, policy); Regular report to government; (achievement and farmers' improvement) Provide information about pig raising to farmers; Joint problem-solving with farmers and government; Deep mutual trust with cooperative members; Commitment to supplier relationship development; Joint investments with farmers; Technological assistance to the suppliers; Risk sharing with Farmers; Financial assistance to farmers; Provide Training to farmers; Direct communications between production schedulers at pig brokers and farmers; Concern for supplier earning fair profit; Granting supplier performance awards and rewards through the Cooperative;

Table 9.11 Supplier integration

Supplier integration allows both organizations and their suppliers to communicate efficiently. Information on disease spreading, environmental policy change, and pig price fluctuation can be collected in time and reliably, thus the change and unexpected events can be informed to all supply chain members at earlier times which leaves more time for organizations to take necessary action toward the risks. For example, when pig disease happens, how quickly organizations can take action to stop the disease from spreading is crucial. Through regular visiting and frequent communication with farmers and local villagers, farmers' production capacity and progress can be well collected accurately by Hanshiwei and Nanchuanhe. Thus, organizations with such information may improve risk preparedness, detection, prevention, and reaction capabilities. The effectiveness and efficiency of risk information gathering and processing can also be ensured. In the extreme case, if the farmers withdraw from production, organizations may take advantage of the local information, quickly develop, and align with other local farmers to continue production. The adequate, timely and reliable information results in a high level of operational flexibility in both case organizations. Also, regular information sharing with veterinary drug suppliers guarantees a suitable and enough supply of veterinary drugs to deal with the disease. A high level of information sharing improves supply chain visibility and the speed of response and reduces the negative impact of the disruption. which is regarded as one key enabler for effective risk management (Ritchie and Brindley, 2007).

Through developing supplier integration capability, the focal organizations and their farmers collaborate through risk and revenue sharing mechanisms. It implies that suppliers can share positive outcomes if they put efforts into risk mitigation (Fan et al., 2017). Both organizations grant farmers rewards if the death rate of the pig is low. Especially, for Nanchuanhe extra recognition will be given to farmers to show its pioneer in environmental sustainability activity. For Hanshiwei, risk sharing is directly linked to review sharing. After the pigs are sold, the pig death rate will be calculated into the payment to farmers. Also, when the pig price decrease, Hanshiwei guarantees farmers minimum payment.

Furthermore, two case organizations make decisions jointly. Farmers are the persons who carry out pig production on a daily base. Farmers' expertise and knowledge affect an organization's ability to learn and adapt. change Joint decision-making mechanisms improve the firm's information processing capabilities and support the firm to make the most appropriate risk recovery plan. As a cooperative, Nanchuanhe consistently consult its members for various decision such as collectively sourcing manure treatment equipment to improve the environmental sustainability level of the farms, leveraging fund from banks, and arranging logistics together to reduce costs. Similar joint decision-making can be shown in Hanshiwei. Hanshiwei provides technical support to farmers on individual cases. Based on the farmer's financial status and requirements, Hanshiwei recommends different pig houses and environmental protection solutions. When pig disease is spreading, farmers and technicians decide to either cull all the infected pigs to stop further spreading or wait to cure the pigs.

Overall, Hanshiwei and Nanchuanhe develop strong supplier integration capability and mobilize supplier resources to develop risk contingency so that smooth operations and effective information and product flow can be achieved.

9.5 Resilience

Aligning with the social ecological perspective, SCR is defined as the capacity of a supply chain to persist, adapt, or transform in the face of uncertainty and risks (Wieland and Durach, 2021). According to COR theory, organizations employ key resources to conduct the regular production and their operation of social relationships. It is suggested that striving and self-preservation is the central value of organizations even if the core resources repertoire differs individually (Hobfoll, 1991). Resilience is operationalized as the status of the resources an organization possesses to persist, adapt, or transform in response to stresses and strains caused by risks and disturbances. The four case organizations in this study possess different resource repertoires in types and quantities. All these core resources become challenged or lost when risks happen and affect organizations' ability to carry out their production operation normally and fully. Thus, it acknowledges that an organization may evolve with its supply chain over time to maintain smooth production, information, and financial flow, which requires managers to strive for adaptability and transformability, thereby foreseeing and timely dealing with the embedded uncertainties in the environment.

Resilience represents multiple statuses of a firm's resource repertoires after the firm experiences the disturbance. These statuses enable organizations to not only conserve a state which may maintain the continuity of essential production operations, but also generate possibilities for organizations to continue renewing, adapting, and transforming towards a desirable trajectory to deal with future uncertainties and discontinuities. Resilience is not a static phenomenon, it can be built or diminished over time. The extent, speed, and success of rebuilding will nevertheless depend on the degree to which resource caravans remain intact following the disaster. It is shown that all four case organizations exhibit a certain level of resilience through either buffering or absorbing the three major risks.

Based on the single case analysis, Muyuan can resist a high degree of the devastation of resources caused by the disaster and continue its operation production during the risk event. It is shown in the previous analysis that Muyuan invest in tangible and knowledge resources to build up its resilience during the three major risks. When pig prices fluctuated, Muyuan undergo maximum cost control. Therefore, no matter how low the market price is, Muyuan's production capability enables it to control the overall production cost below or equal to the market price. The established disease prevention and control procedure and system enables Muyuan to reduce the possibility of disease happening and even when disease happens, Muyuan can quickly stop the spreading of the disease or continue normal production. When environmental policy changes, heavy investment in advanced manure treatment facility enable Muyuan to equip with the exceeded capability to deal with pollution and reach higher environmental standard than the government requires. Muyuan's resilience building is shaped by the stress process in both subtle and substantive ways that do not necessarily signal a firm's growth. However, the built resources repertoires equip Muyuan to achieve a high internal locus of control to absorb the risks and efficiently prevent business discontinuity and even thrive in the future.

Not all organizations recover at the same speed and to the same degree. Compared to Muyuan, Lihua shows less resilience (as shown in Table 9.12). Lihua who is tenuous in tangible and knowledge resources have limited reserve capacity to manage stress and increased vulnerabilities. Having fewer resources available results in fewer resources to invest when coping with the risks and at the same time are linked to greater stressful experiences and consequently, are less likely to have the resources necessary post-disaster to rebuild their operations. Lihua cannot guarantee that its production cost is lower than the market price, which means profits may lose during certain periods. Also, Lihua's knowledge-building toward disease control is less effective than Muyuan's. The slower disease identification and curing will lead to pig death and the disruption of production. The less investment and innovation in environmental protection facility can only support Lihua to passively cope with the environmental policy and regulations which is constantly changing and getting even stricter. So, Lihua represents certain levels of resilience through buffering the loss of resources. However, it tends to be more reactive coping and less efficient.

Resilience is different when firms possess different resources base and allows firms to access extra key resources to provide safety and protection against resource loss and promote resource growth. Hanshiwei and Nanchuanhe show different temporal processes of resilience. Nanchuanhe and Hanshiwei utilize, mobilize, and create relationship resources to bridge the resources to effectively recover from the production discontinuity on the farmers' side. Nanchuanhe establishes closer relationships with farmers, the government, and other suppliers, which increases its ability to access resources. Farmers are the key resources for both case organizations to guarantee production flow. So, maintaining farmers' resources is the critical aim. Pig production in developing countries is dominated by informal governance, especially when working with farmers. Nanchuanhe established close informal and personal relationships with pig brokers, farmers, local villagers, and government officers. The relationship with pig brokers enables Nanchuanhe to help farmers sell the pigs earlier during pig price decreases. Pigs need six months to be fully fattened. In normal circumstances, the earlier sale of pigs may cause profit loss since the pigs will not reach the ideal weights for sale. However, during the price reduction. the earlier the sale, the fewer profits loss may cause. These pigs cannot be accepted and slaughtered in the regular slaughterhouse since they have not reached the standard. So, the pigs will be slaughtered in small scale or informal slaughterhouses. Nanchuanhe also utilizes the relationship with government officers to get informed of the policy change in advance so that the farmers can update the equipment and get prepared earlier. Nanchuanhe's resilience lies in its alliance portfolios which enable it to acquire external resources and combine a wide variety of resources and capabilities in an ongoing manner. This is because Nanchuanhe's internal resources are insufficient to buffer the risk, Collaborations with partners with rich resources provide Nanchuanhe with access to valuable resources which can be combined to create resilience in pursuit of risk mitigation. The relationship portfolios equip Nanchuanhe with strong resilience to manage risks and uncertainties and enable Nanchuanhe to uniquely benefit from the specific resource contributions of partners.

Compared to Nanchuanhe, Hanshiwei also collaborates with various partners to effectively persist in the continuity of essential production operations. Its resilience is also composed mainly various of relationship resources. However, it is challenging to gain farmer loyalty due to incentive misalignment. Hanshiwei has spent much effort to overcome the challenges concerning farmer selection and training, and the liaison with the government and other partners in the hope of building and securing long-lasting relationships and becoming financially viable over the long term. Still, the identity clashes, distrust and transcending behaviours of agents create unique agency problems and barriers for Hanshiwei to manage the relationship resources. So, still occupies resilience through bridging the resources. However, compared to Nanchuanhe, Hanshiwei is less resilient.

Overall, all case companies present certain levels of resilience (as shown in Table 9.12). They continuously seek improvement, invest resources in risk mitigation and reach multiple statuses of the firm's resources repertoires. These multiple statuses represent firms' resilience which makes organizations capable of maintaining desired functionality and recovering quickly under unexpected hazards. It is shown in the analysis that Muyuan and Nanchuanhe presented a high degree of resilience. While Lihua and Hanshiwei presented a low level of resilience to resist and respond to the three major risks.

	Resilience
Muyuan	Facing the pressure of pig price fluctuation, environmental policy uncertainty and pig disease, Muyuan proactively utilizes, mobilizes, and invests available knowledge and tangible resources to reduce its production costs and advance its technology to efficiently recover from the business discontinuity. In addition, the renewed resource repertoires may equip Muyuan to achieve the best possible performance when facing the same types of risks in the future. **(High)**

Lihua	Lihua utilizes and mobilizes available knowledge and tangible resources to buffer and mitigate the consequence of three types of risks. The renewed resource repertoires enable to persist or recover back the continuity of essential production operations. However, the minimum coping fails to enable Lihua to continue building resource repertoires to buffer against future risks. **(Low)**
Hanshiwei	Hanshiwei collaborates with farmers to effectively persist in the continuity of essential production operations on the farmers' side. Also, the immediately renewed resource repertoires may enable Hanshiwei to cope with current risks. However, the insufficient relationship resources investment may not ensure Hanshiwei enough collaborative farmers to carry out production facing future change. **(Low)**
Nanchuanhe	Nanchuanhe proactively utilizes, mobilizes, and creates relationship resources to bridge the resources to effectively recover from the production discontinuity on the farmers' side. In addition, during the risk recovery process, the renewed relationship resources repertoires may equip Nanchuanhe to help farmers to better cope with the possible risks in the future. **(High)**

Table 9.12 Resilience of four case organizations

9.6 Chapter Summary

This chapter presents the cross-case analysis of four case companies and identifies the similarities and differences among them. The discussion focuses on risk constructs including risks embedded in the pig supply chain and stress, existing resource caravan, different resource bundles, different resource management capabilities and resilience. It has been identified that livestock diseases, environmental risks, and pig price fluctuation are the major risks in Chinese pig supply chains in which the case organizations are involved. Resource availability, valence, and complementarity are highlighted as important constructs to analyse the organizations' resource caravan. Based on different resource caravans, the four case organizations show two different types of resource investment strategies to mitigate the risks, investing in relationship resources or bundles of tangible resources and knowledge resources. In turn, the four cases show different levels of vertical integration and develop two types of dynamic capabilities to mobilize the resources, knowledge management capability and supplier integration capability. The case organizations build different levels of resilience through these resource management processes.

Based on the themes identified in the cross-case analysis, the next chapter reveals the relationship between these constructs and leads to the propositions and resilience-building framework.

Chapter 10. Discussions of The Findings

10.1 Revisit and Extend The Conservation of Resources and Ambidexterity Theories

The organization is where resources are gathered and can be regarded as a resource caravan. The organization needs to utilize and mobilize available resources to ensure the business to run smoothly and to achieve the best possible performance. Thus, resources can be an important single unit to study organizational behaviour. When risks occur, the company may experience serious resource loss. The constraint on the availability of resources may cause organizations to struggle to survive. Companies with optimal resource management strategies could not only recover quickly but also gain competitive advantages through the events.

However, resources can be difficult to manage since the value of resources can be varied for each organization according to its individual circumstance. For example, the high-tech pig pen design is regarded as a valuable resource to increase production efficiency and recover from production disruption in Muyuan while it is not valued by Hanshiwei who chooses to outsource its pig fattening process to individual pig farmers and does not own any pig pens. Instead, relationship development with farmers is highly valued in Hanshiwei. And the relationship may even be affected by forcing farmers to adopt advanced technological pens because farmers have limited capabilities to afford and maintain such high-specification pens. Organizations adopt different resource management strategies to mitigate the impact of risks.

Adopting the social-ecological view (Holling, 1996; 2001), this research takes a more adaptive and integrated approach to reinterpret a firm's supply chain as an organic system composed of various resources (Nilsson and Gammelgaard, 2012). Through tracking the dynamic change of resources when external conditions change, this research may reveal the evolutionary processes which allow firms to not only adapt to new circumstances but also transform to a more desirable and radically different trajectory in a turbulent and uncertain environment (Davoudi et al., 2013; Evans, 2011; Gunderson, 2002). That is why understanding the principles of resource management strategy is so essential to help organizations successfully overcome sudden supply chain disruption. More importantly, it may overcome traditional supply chain static and reductionist assumptions and provide a dynamic view to analyse how firms change their supply chain structures and processes as a result of both internal dynamics and external interactions in the complex world over time (Wieland, 2021).

In this chapter, adopting the conservation of resources perspective, the constructs derived from the within and cross-case analysis chapters (supply chain risks, resource caravan, vertical integration, knowledge management, supplier integration and resilience) are discussed in more detail to identify the relationships among them. In this way, the various dynamic rules, and processes that a firm's resources are expected to follow in the risk events are scrutinized. Before doing so, we will briefly summarize the key principles and corollaries of the conservation of resources (COR) and ambidexterity theory.

The role that resources play in an individual's reactions to external change is highlighted in the Conservation of Resources theory (Hobfoll, 1988; 1989; 2001). It has two main principles. Principle 1 Primacy of Resource Loss states that resource loss happens disproportionately more salient than resource gain. The Resource Loss rules imply that for the same amount of resource loss and resource gain, resource loss has more profound impacts than resource gain not only in magnitude but also in speed and duration (Hobfoll, 1988, 1989). In such an ever-changing, unpredictable business environment, organizations and their supply chain are inevitably exposed to multifaceted challenges and under the threat of resource loss. The powerful negative impact of the resource loss will cause significant stress, in turn, individuals may tend to engage in behaviours to create and maintain the resources. This leads to Principle 2 Resource Investment which reveals what resources strategies individuals may take facing the resources change. The resource investment principle asserts that individual needs to invest resources to protect against resource loss and to gain resources.

Extended from these two principles, Hobfoll (2001) proposes four major corollaries, which can be applied to build complex strategies to cope with major stressful conditions at the organizational level. Corollaries 1 and 2 emphasise the importance of the organization's existing resources. Corollary 1 asserts that individuals equipped with greater resource bases are less vulnerable to resource loss and more capable of achieving resource gain through resource orchestration. Conversely, those who lack resources are more vulnerable to resource loss and less capable of resource gain

(Hobfoll, 2001). Corollaries 2 and 3 reveal the continuous effect of resource loss and gain. Corollary 2 states initial resource loss leads to future resource losses (Hobfoll, 2001). Because the resources recovery is restricted due to the lower availability of resources to invest. Corollary 3 mirrors corollary 2 stating that as individuals gain resources, they are in a better position to invest and achieve additional resource gain (Hobfoll, 2001). Corollary 4 asserts that apart from investing resources to acquire resources, organizations will also take protective strategies to safeguard the remaining resources when experiencing resource loss (Hobfoll, 2001). Finally, COR recognizes the interlink among resources and proposes the idea of resource caravans. Although individual resources are crucial, resources are always bundled together. (Hobfoll, 1998). It asserts that the association of linked resources may be created and sustained as a resource pool within the organization which is the result of resource loss and gains (Hobfoll, 1988; 1998).

In summary, the Conservation of resources theory (Hobfoll, 1988; 1989; 2001) is a motivational theory to provide an understanding of how organizations are motivated to acquire and conserve resources for survival when confronted with situations that are perceived as being stressful. COR theory points out two critical roles which resources play in coping with stressful events. First, resources can be a stream of tangible and intangible necessary for mobilizing and organizing to form various coping strategies when organizations face stressful events (Hobfoll, 2001). Correspondingly, in this research six types of resources (Knowledge, financial, facility, material, land, and relationships) are identified as critical resources embedded in the agricultural supply chain to deal with the crisis. Second, triggered by the threat of uncertainties, organizations may be put into various dysfunctional states in the absence of sufficient resources. That is where stress occurs.

Resources can be used in a proactive form to cope with such stress as individuals invest them in various activities to safeguard the existing resource, protect against resource loss, recover from past losses, or gain future resources (Freedy et al., 1992; Hobfoll, 2001). Correspondingly, six types of critical resources identified previously are recombined and bundled as resource management strategies forming two types of organizational dynamic capabilities, either knowledge management or supplier integration, which reflect two types of orientations in organizations: exploitation and exploration and can be explained through ambidexterity perspective. These two capabilities construct organizational systems to deploy existing resources and develop new resources effectively in risk events. They are identified as a set of identifiable and purposefully developed routines or processes that may facilitate the deployment of other resources possessed by the firm (Eisenhardt and Martin, 2000; Winter, 2003). Through these processes and routines, firms are able to transfer resources into new configurations of resources to deal with the hyper-volatile environment (Weigelt, 2013; Wang et al., 2015). Knowledge management capability and supplier integration capability enable firms to continually build, integrate and reconfigure internal and external resources (Teece et al., 1997). Here, instead of relying on stability, resilience building in this study is recognized as a continually evolving and transformative resource mobilization process. Every time, a company overcomes one risk event and achieves a resilience status, the company's resource base will change. Consequently, various resilience statuses can be achieved through either direct offsetting the resource loss or indirect replenishment by acquiring external resources. Neither of the two resource management strategies is inherently "better" or "worse". Both may effectively protect firms against resource loss, depending on the specific context.

By explicitly embedding the COR theory and combined with the ambidexterity perspective, the principal objective of this research was to bring clarity to the role and effect of firms' resources, in the process of SCR building, and thereby to introduce and elaborate the SCR framework from the resource management perspective. Eight propositions were derived theoretically and grounded empirically from the case studies.

Thereby, the discussion of the findings is divided into the following three sections. Section 10.2 discusses the relationship between supply chain risks/ uncertainties and organizational stress. Section 10.3 discusses the relationship between stress, existing resource caravan and different resource bundle investments. Section 10.4 discusses the role and effect of building different resources bundle. Section 10.5 discusses the relationships between resource bundles and supply chain strategy (vertical integration and supply chain collaboration. And finally, In Section 10.6, how supply chain strategies formed by resource bundles lead to SCR is presented.

The discussion of the research findings provides important insights into how resource-based research, supply chain management and risk management can be integrated and extended.

10.2 The Relationship Between Supply Chain Risks/ Uncertainties and Stress

Firms need to coordinate their material, financial and information flow to accomplish their business performance in a dynamic environment. The nature of supply chain management is to maintain and improve the resources that flow through the supply chain. Grant (1991) classifies resources into two types, tangible resources (such as machines, capital, plants, or materials) and intangible resources (such as relationships or knowledge). Tangible resources refer to essential fixed physical assets in which organizational activities take place and require (Reed, 2005). Tangible resources in this research are identified as land, feeds, financial capitals, pigs, and facilities such as pig plants, air conditioning systems, auto feeding and clean systems, which have a tangible embodiment. While intangible resources refer to those immaterial resources. In this research, intangible resources refer to the knowledge of pig raising, process management and relationship with stakeholders.

It is understandable that firms tend to strive for a continuous, orderly, and reliable pattern of resource flows and try to achieve resource efficiency (Katz and Kahn, 1978; Weick, 1969). However, in a highly turbulent environment, firms are exposed to various risks which may cause potential or actual loss of resources and interruption of the resource flows. When the consequence of risks exceeds the firm's coping capacity and affects the operation flow, firms may be confronted with the stress of resource uncertainty. Consistent with COR theory, within organizations, stress may occur because of (1) the threat of net loss of resources, (2) actual resource loss or (3) a lack of resource gain following the investment of resources (Hobfoll, 1988;1989). Accordingly, in all four case companies, the top managers expressed their worries about the actual and future economic losses due to loss pig disease, profit loss due to the pig price decrease, and suspended production due to increased government environmental standards. Since the pig growth period is six months, the production cannot be immediately recovered. All the senior managers express their concerns regarding continuous profit loss and future profit gain. The prolonged and severe supply chain risks or uncertainties may cause the direct breakdown of the production system or threaten firms' normal operation. A resource equilibrium can be broken between a firm's decreased resource reservoir and the resources required to accomplish the goals (coping with the risks). This means organizations are facing resource loss on the one hand and need extra resources to cope with the risks on the other hand. In line with

Corollary 2 of COR theory, the perceived or actual initial resource loss can have profound and powerful impacts on the organization, not only threatening the firm's normal resources flow but also making future resources recovery difficult. The concerns of the consequence of failure to cope (risks) can be regarded as sufficient for producing stress for organizations.

In this research, the stress is operationalized as the consequence which organizations may face due to the actual or potential risk events. Within the agricultural supply chain, risks are inherent and varied. The nature of these shocks is often unpredictable and unmeasurable. The conventional risk management paradigms that attempt to quantify the probability and outcomes of disturbances have the limitation to address this type of unexpected risk. Therefore, with the ubiquitous inborn high risks in the agricultural supply chain, firms may have a high possibility to expose to the severity of resource loss. The uncertainties and devasted disastrous events can not only lead to the disruption of production but also intensify competitive pressures by creating opportunities for new entrants, leading companies to become more aggressive in defending their strategic positions through resource accumulation (Schumpeter, 1934). Consequently, organizations are under consistent pressure for resource loss and in turn motivated and directed economically, socially, and culturally to orchestrate their resources to obtain, retain and protect their existing resource. It is shown in our research that four case companies all have experienced production disruption or great financial loss caused by three types of major risks in the pig supply chain: pig disease, price fluctuation and environmental risk.

The firm's operation strives to acquire sufficient quantity and quality of resources. However, resources can be depleted and reduced due to various risks, which may in turn disrupt the normal operation of the supply chain. An organization's tangible resources within the company can be naturally depleted, such as machines and plants depreciating their value over time due to technology development or wear and tear during use. Besides, tangible resources are often threatened and depleted directly by disruptive risks such as pig death, insufficient pig manure treatment equipment, and financial or land losses. Typically, animal diseases can adversely affect yield by either reducing the growth rate of the livestock or increasing morbidity. In Muyuan and Lihua, for highly contagious diseases such as African Swine fever, once found, livestock must be culled as part of efforts to contain and eradicate disease, which leads to the disruption of the production flow. The loss of material resources then leads to firms' financial loss. Similarly, the change in environmental policy may cause Muyuan's Manure treatment equipment fails to comply with the new standard. As a result, pig production can also be suspended.

In other cases, as risks are naturally embedded in the supply chain network, the consequences of the risks on one agent may be partly or entirely transferred to other agents within the supply chain which indirectly leads to focal firms' resource loss. Rather than having direct influences on tangible resources for production, three major risks (environmental policy change, pig disease, price fluctuation) identified in the case all have negative impacts on the supplier relationship resources in Hanshiwei and Nanchuanhe who collaborate with farmers to fatten the pigs. As farmers hold the critical resources, land and production facilities for pig production and they are the critical points to connect the material flow. Such supplier relationship resource loss leads to the disruption or loss of land, material, and facility resources (see cross-case risks and stress table for Hanshiwei and Nanchuanhe). Notably, In the case of pig disease which affects farmers' production capacities, such missing capacities or inventory at the disrupted suppliers' facility may cause the reduction or interruption of the production in the focal company at the next stages in the supply chain. If the pigs are infected and die, Hanshiwei will not be able to get enough fattened pigs to generate profits. If the supply chain is disrupted longer than some critical period of time (Simchi-Levi et al., 2015), the key production performance indicators such as production rate may be affected. So, the original resource loss in suppliers may cause disruption propagation in the supply chain and negatively affect firms' operation performance. This ripple effect has been extensively documented in the literature (Ivanov et al., 2014; Dolgui et al., 2018; Schmitt and Singh, 2012).

Together, these arguments suggest that the risks may lead to the possibility of supply chain disruption which comes from the loss of endowment resources either located inside of the firms or embedded in the firms' supply networks.

All the senior management team expressed deep concerns about the potential consequence and actual loss before and during the risk event. Even after overcoming the risks, the management team still worries about how they can deal with the next risk and if the same strategy may protect them from the risks again. To reduce such stress, organizations are motivated to compensate for the real or anticipated resource imbalance by simultaneously retaining, protecting, and/or increasing their valued resources (Halbesleben et al., 2014). The management team's perceptions about the risks that can be characterized as concern for risk consequences will foster the adoption of organizational risk management practices.

Based on the discussion above, the following propositions are derived:

Proposition 1a: The unexpected risks or uncertainties (pig price fluctuation; disease and policy) may lead organizations to face the stress of direct or anticipated resource degradation and loss caused by direct loss of material and facility resources.

Proposition 1b: The unexpected risks or uncertainties may lead organizations to face the stress of direct or anticipated resource degradation and loss caused by indirect loss of land, material, and facility due to the supply relationship disruption which adversely affects the inward flow of any type of resources for production.

10.3 The Relationships Among Stress, Existing Resource caravan and Different Resources Bundling Investment

From a resource perspective, stress occurs when an organization perceives that an expected or experienced difficulty overloads or exceeds its existing resource reservoir and potentially threatens its survival (Lazarus and Folkman, 1984; Hobfoll, 2002). Literature also suggests that the firm`s existing resource availability plays an essential role in the process of resource recovery (Cohen and Levinthal, 1990; Isobe et al., 2008). Resource availability refers to the extent to which the resources are obtainable (accessible) for use when needed (Törnblom and Kazemi, 2012). When an organization experiences a disturbance, the resources may be readily available (abundant) or unavailable (scarce) to be assembled to cope with the risks. From COR's perspective, firms with high Resource availability of the existing resource caravan are less stressful and vulnerable to resource loss and more capable of orchestrating resource gain; conversely, organizations that lack resources perceive more stress and are more vulnerable to resource loss and less capable of obtaining resource gain (Hobfoll, 1988;1989). Those who have excess valuable resources can use their resource reserves during "problematic" situations to buffer against the negative effects inherent in resource loss, and meanwhile, these resources richer firms may be capable of investing resources to protect against resource loss. For example, Muyuan and Lihua have similar supply chain settings, while Muyuan owns more tangible assets and is more advanced in its supply chain management and production technology than Lihua. As cross-case analysis shows, the management team's decisions on resources investments indicate that for the same types of risks like price decrease, Lihua's managerial team expresses more concerns than Muyuan. Since Muyuan uses its highly efficient way to manage the pig supply chain which keeps pig production cost as lowest in the industry. Even experiencing the same level of pig price decrease, for Muyuan, it means less profit gain. However, for Lihua, it means financial loss due to its higher production costs. Meantime, Muyuan could take advantage of its strong financial resources to better buffer the impact of long-term price decreases. Hence, the existing resource base will not only affect the level of the firm's stress when facing the loss of resources, but also firms that occupy richer resources are more likely to build and exploit the potential value of their resource base to defeat the risks.

Thus, it can essentially say that the amount of the firm's current resources is the primary prerequisite to buffer the resource loss and enhance resource productivity (Isobe et al., 2008). These abundant valuable resources can assure firms have less pressure when facing turbulence in turn becoming more resilient. Based on the discussion this research proposes that:

Proposition 2: The Resource availability of existing resource caravan negatively influences the level of a firm's stress.

The model of conservation of resources goes beyond stating where organizations are abundantly equipped with resources, they are likely to form a coping capacity and feel less stress toward the turbulence (Rappaport, 1981). It can be also introduced as a framework for understanding the consequences and coping strategies for major stress caused by supply chain risks. Specifically, it inherently states that when confronted with stress (caused by the significant consequence of direct resource loss), the organization strives to minimize the net loss of resources. When not currently confronted with stressors but facing the stress of anticipated resource loss or unsatisfied resource gain, the organization strives to reduce the stress by developing resource surpluses in order to offset the possibility of future loss or accelerate future gain. As the Managing Director of Muyuan said:

Muyuan's success rests on the overcome of various severe challenges. The financial crisis in 2008 caused the break of capital flow in many pig production companies. In the last ten years, the frequently occurring Epidemic diseases such as blue-ear disease and Streptococcus suis disease and the fluctuations in live pig prices have caused major economic losses among many pig producers. Many producers have been forced to withdraw from the market due to the limited availability of capabilities to hedge against the risk. And now, the environmental protection policy comes. I reckon many production companies will have to be washed out from the market this time due to their limited capability to comply with government policy. Muyuan is still alive. We are consistently and long termly under various serious risks of attack; thus, we must improve ourselves and get ready for these events. We do not fear competition from other big production companies. In the pig industry, there is a famous sentence: to live is to win. What we do is compete with ourselves and improve ourselves to best raise our pigs.

Similar opinions are echoed by the Managing Director of Hanshiwei:

I have seen so many pig production companies appearing and disappearing quickly in these ten years. Generally, they are not capable of coping with those events (risk events). They were knocked out of the market which is natural selection. Pig raising is a high-risk industry. The risks consistently shuffled the market players. For example, the central government set a general guideline for the environmental policy toward water treatment. The regulations set by the local government could be very different. Some require that any area away from the water source or river for 500 meters becomes restricted areas for pig raising. Any farmers within this area are forbidden to raise pigs. And anyone who is having pigs in the pig house in the forbidden areas needs to either kill or sell all the pigs within three months. For Hanshiwei, we have other pig farmers who raise pigs for us outside the forbidden areas but still within this district. Otherwise, production in this district will be disrupted. Some of the other pig production companies whose farmers are concentrated in the restricted zone were not lucky enough to survive. Every year, the risks are so devasting. When others are down, we are still alive. We can say that we are the final winners. Of course, we are under huge pressure. It is the question of 'live or die'. Thus, building up yourself and preparing for the future is most critical in the pig raising industry.

So, all case companies experienced significant stress due to the dramatic consequence of risks embedded in the pig industry. Such intensive stress calls for the continuous adaptation behaviour of pig companies which is a natural response to protect the firm from risk challenges to its normal resource flow. The more significant consequence the risks may cause, the more actively and aggressively the organizations would defensively engage in investing resources to prevent the loss of resources and survive. Pettit et al. (2010) prove that to mitigate and offset the effects of disruptions, a matching level of investment needs to be made in developing resource surpluses and SCR capability building. The major risks we identified in the pig supply chain are all severe enough to lead to the disruption of the company's normal production, which generates significant stress for our case companies. In our study, we reveal that all the case firms tend to invest in behaviours that are more strategic in their use of resources due to the stress from the risks. Correspondingly, although adopting different resource management strategies, Muyuan, Lihua, Hanshiwei and Nanchuanhe all make aggressive investments to build capabilities to protect themselves from resource loss. Such investment is positively related to the stress organization are facing. For the same severity of the risks, the stress will disappear only if the capabilities building can be enough to overcome the disturbance. In such a case, no extra investment will be required. Due to strict environmental regulations, Muyuan and Lihua both invested heavily in pig manure and wastewater treatment facilities building and technology development. While Hanshiwei and Nanchuanhe adopt different approaches, investing in educating their farmer suppliers to update their pig pens. Although different technologies and approaches are adopted, such investments equipped case companies with the capabilities to handle pig manure and wastewater to comply with government regulations. So, the companies' environmental protection stress will be reduced. Once companies or farmers meet the swine manure and water treatment standards required by the government environmental regulation, except for the general maintenance cost, no extra investment would be needed until the standards are updated to another level.

Based on the discussion this research proposes that:

Proposition 3: The level of organizational stress is positively related to the extent of firms' effort on resources investment.

10.4 The Resource Management Strategies

Based on the resource-based view (RBV), it is asserted that the resources underlying competitive advantages need to be valuable (Barney, 1991). The value of resources stems from their meeting with the organization's desired objective and from their being instrumental in the acquisition or maintenance of desired resources. We recognized that RBV and COR theory share one common assumption which is that resources must be heterogeneous. It means resources that organizations possess differ from one company to another. From the COR perspective, if organizations would have the same amount and mix of resources, facing the same levels and types of uncertainties, they could generate the same levels of stress, in turn, employ the same resilience-building strategies to protect against resource loss. Yet, in the real market, it is impossible to find companies which possess the exact same resources. Therefore, in our study, we reveal that when firms experience resource losses, they tend to invest in behaviours that are more strategic in their use of resources. Our findings also show that companies achieve their own resilience by investing in different bundles of resources. The difference lies in COR theory and RBV is that COR does not focus on aspiring firms to acquire unique resources over others to create competitive advantages. RBV follows the logic that firms actively seek resources to increase the chance of success, but one that has been relatively ignored is how firms avoid the loss of required resources to survive. In a highly vulnerable environment, organizations seek to maintain the necessary resources reservoir to enable the normal flow of the operation (survive) rather than thrive. The model of conservation of resources rests on this later situation. It is suggesting that organizations will engage in different resource management behaviours that avoid resource losses since loss can have such a profound negative impact on the organization itself.

Behaviour to resources conservation can be done through investing resources to either accumulate existing resources, such as investing financial resources to update the machinery (Muyuan and Lihua) or acquire new resources, such as establishing new supplier relationships to increase the redundancy (Hanshiwei and Nanchuanhe), in which case, if there is a supply disruption in the future, the backup farmer resources are increased to offset the loss of existing farmers to continue the pig raising production. Facing uncertainties, pig production firms must make decisions on which resource management strategy may be the best choice to reduce the pressure of current resource loss, and even yield a competitive advantage. In general, investment of resources generates costs and exacts a price that must be considered. If such investments do not stem the tide of resource loss or contribute to other resource gains, then the investment gradually drains firms' resource reservoirs. Resource selection and accumulation are endogenous outcomes of managerial decisions and perception of the value of invested resources. Halbesleben et al. (2014) integrate the COR literature with insights from the strategic management literature and conclude that an individual's willingness to invest in resources can be judged by the following three contextual resource characteristics -- (1) the individual's expectation on resources to help to achieve the goal (the perception of resource Valence), (2) the resources individual already has (the availability of the resources), and (3) the new resource complementarity to existing resources (the complementarity of resources). Here, resource availability refers to the readily available resources to cope with the risks. Resource Valence refers to the appropriateness (favourableness) of the resources for offsetting loss as the consequence of the risks (Törnblom and Kazemi, 2012). Resource valence is positive (negative) when the resource is considered to be appropriate (inappropriate) for risk mitigation. While resource complementarity refers to the extent to which invested resource fits with a firm's current resource portfolio, thus increasing the value of whole resource bundles. (Wernerfelt, 2011). Firms invest valuable resources that can potentially complement the resources the firm already possesses (Schmidt & Keil, 2013). Within the four case companies, managerial choices are all influenced by the evaluation of resources investment strategy by assessing the existing resource availability, resource valence to cope with the risks, and resource complementarity.

As described by Mr Tian who is one of the senior team cofounded Muyuan,

The decision-making in Muyuan is still highly centralized in the headquarter. Take the recent African swine disease as an example, we had a series of roundtable meetings with all the directors from different departments sitting together to analyse the situation. We discussed the available approaches and evaluated how effective these approaches can form epidemic prevention solutions in Muyuan. Of course, every department needs to check what resources we have to support the implementation of the strategy. Do we have enough staff to carry out extra inspections and if they are fully equipped with swine disease knowledge? Do we have enough cash flow to either develop or purchase vaccines? Does our current Epidemic prevention procedure strict and comprehensive enough to stop the spreading of disease? If we make any change to the procedure, how each department will need to adjust its operation (e.g., more regular inspection for *feeds and vaccine tests) to coordinate with each other? If we decide to purchase the vaccines from suppliers, are they suitable for Muyuan's pig breed? Will they have side effects on the quality of the pigs? We will take all these factors into consideration to find the best suitable disease prevention solution for Muyuan.*

In Muyuan's case, to deal with the pig disease, Muyuan analyses its existing resources base and considers if there are enough quantities of resources such as human resources, and cash flow to invest in and implement the risk mitigation strategy. Also, Muyuan evaluates if such an investment in resources can stop the disease from spreading or reduce the chance of the disease happening. In addition, Muyuan considers how to better incorporate invested resources into existing production processes.

A similar consideration process happened when Lihua makes its decision on the application of Enterprise resource planning software (ERP). As Muyuan grows, there is a requirement for increasing the visibility of production operations and ultimately optimising the performance of business processes. Originally, Lihua chose the software provided by a third party. However, such software is designed for standard manufacturing companies and is not completely compatible with managing the production process of livestock breeding companies. So, after considering the investment budget and evaluating the existing research development team's capabilities, Lihua decided to develop its own ERP system. For example, developed by Lihua's Purchasing Department and Information Technology Department, the "e-purchasing platform" is an online bidding management system consisting of functions such as procurement notice release, bid release, invitation bidding, bid management, evaluation/calibration management, etc. The system enables automatic management of the procurement process and traceability management of procurement data, which reduces the probability of supplier collusion during the bid and minimizes procurement costs.

Although having different supply chain settings and resource reservoirs, the other two case companies also evaluate similar contextual resource characteristics when they decide on resource investment strategies.

Based on the discussion, this research proposes that:

Proposition 4: The perception of resource Valence (appropriateness) of senior management to mitigate the risks, the Resource availability of existing resource caravan and the complementarity of future invested resources toward the existing resources jointly leads to the investment in different resource bundling strategies.

In line with the resource investment principle of COR theory (Principle 2), resource investment is necessary in order to protect against resource loss, recover from losses and gain resources (Hobfoll, 1988;1989). As firms strive to retain and build the existing resources for themselves, they assemble the bundle of resources and create necessarily supportive supply chain structures to achieve this aim. During this process, the resources investment strategy is formed (Lippman & Rumelt, 2003; Rumelt, 1984). Two approaches are commonly employed for coping with the stress brought by the uncertainties embedded in the supply chain. One is resource accumulation, and the other is resource acquisition. Makadok (2001) uses a mathematical model to prove that both strategies (acquiring new resources or the deployment of resources a firm already possesses) can generate rents. These two resource management strategies represent the ambidexterity strategy undertaken by firms – the simultaneous pursuit of exploration and exploitation. The exploitation strategy represents the resource conservation strategy which refers to the use and refinement of existing resources (March, 1991). It has been related to creating efficiency, standardization, centralization, and tight cultures (Benner and Tushman, 2003). While exploration strategy is corresponding to the resource acquisition approach which refers to the pursuit of new resources (March, 1991) and has been associated with flexibility, decentralization, and loose cultures (Benner and Tushman, 2003). Competing in an increasingly volatile and unpredictable marketplace (Christopher and Holweg, 2011; Dubey et al., 2018), ambidextrous organizations simultaneously decide the resources allocation and consider balancing or trade-off between exploiting existing competencies and exploring new opportunities (Ancona et al., 2001; Floyd and Lane, 2000; Levinthal and March, 1993).

Correspondingly, two types of resource management approaches have been identified in this research which firms used to mitigate the risks: knowledge-based resource management and relationship-based resource management (as shown in Figure 10.1).

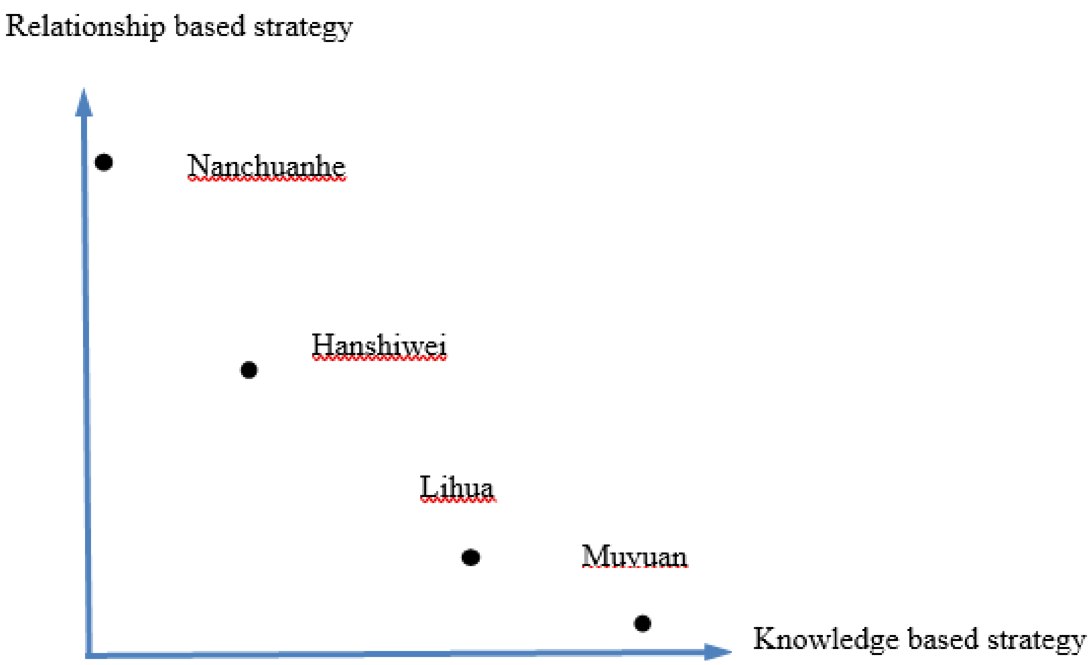

Figure 10.1 The resource management strategies of case organizations

Knowledge-based resource management strategy indicates that firms consistently bundle internal knowledge and tangible resources (physical resources and financial resources) in order to efficiently accumulate, maintain and reconfigure the resources during resource loss. Knowledge-based resource management underlines the resource accumulation process and reflects the exploitative oriented strategy. Two of our case companies, Muyuan and Lihua adopt this resource management strategy. Under risks situation, to minimize the stress from resources shortage, Muyuan and Lihua both invest in tangible resource accumulation, knowledge building, encouraging internal innovation and aim at stocking and extending firms' resources in order to buffer the resource loss and enable efficient resources recovery to situational demands during the risks. Muyuan owns all its land for pig production, production facility, advanced production system and is in a stronger financial position than Lihua. Lihua also owns the land and production facility. But, instead of having employees to raise the pigs, Lihua rent the pig house out to the farmers to fatten the pigs. Muyuan also invests more in knowledge building.

Another resource management strategy has been identified in this case, named relationship-based resource management strategy which emphasises the resources acquisition process and reflects the exploitative oriented strategy. Relationship based resources bundle indicates that the firms focus on managing a portfolio of relationships with various stakeholders (e.g., government, customers, and suppliers) and aligns its supply chain processes in order to effectively acquire external resources to compensate for the resource loss (Horvath, 2001). Relationship-based resources may equip firms with a full spectrum of relationship resources. These relationship resources may enable firms to have close information exchange with the partners and link firms with any new resources which can replenish the resource net loss caused by various risks. Among four of the case companies, Hanshiwei and Nanchuanhe invest in relationship-based resources and continuously integrate suppliers' resources when needed. Both organizations collaborate with farmers to raise the pigs and work closely with other stakeholders such as the government. Hanshiwei still has its own feed production company while Nanchuanhe as a cooperative heavily relies on its members to carry out production. Nanchuanhe mobilizes various relationships to finalize the pig production process.

The knowledge-based resource management and relationship-based resource management strategies fundamentally reveal how tangible and intangible resources are bundled and mobilized to shape exploitative and explorative coping strategies and protect firms against uncertainties by achieving either efficiency or flexibility.

Thus, together, the below proposition is proposed:

Proposition 5: Knowledge-based resource management strategy, relationship-based resource management strategy or hybrid strategy are adopted by firms to shepherd firms' resources in order to obtain, retain and protect existing resource reservoirs and offset net loss of resources.

Within the knowledge resources bundle, tangible assets provide higher utility towards a firm's operation. Tangible resources are mainly composed of two groups of resources physical and financial resources (Barney, 1997). In this research, physical resources include three types of tangible assets: (1) land for production; (2) infrastructure assets such as buildings, machinery, and equipment which are needed to carry out the manufacturing operation; and (3) material resources including pigs, feeds, Veterinary drug, energy, and other important inputs (Faulkner and Bowman, 1992; Barney, 1997; Ma, 1999). Greco et al. (2013) highlighted that facility and material resources alone are insufficient to maximize profits. Firms need to secure sufficient financial resources together with facility and material resources to be able to implement internal improvement strategies.

The knowledge resources in this study consist of technical knowledge (e.g., pig rearing) and organization process knowledge. Technical knowledge refers to employee skills and know-how and intellectual property of the organization such as patents and licenses. Muyuan has obtained 436 national patents in pig production. Notably, Muyuan has developed 12 generations of pig houses to achieve better insulation and ventilation. Lihua also heavily invested in research in diagnostic management, animal population management and biosecurity which has greatly elevated firms' ability to control pig diseases and reduce the possible pig death in the future. Both case companies develop their own advanced feeding system which can automatically clean the remaining feeds in the trough to prevent mildewing. At the same time, the design of the separation of dry feed and wet feed avoids feed waste so as to reduce total feed cost. Another type of knowledge, organization process knowledge refers to the organization's operation processes such as methods of production, organizational dynamics, and knowledge management support systems (Costa, 2012; Costa and Evangelista, 2008). The process knowledge allows companies to have better visibility toward the whole operation activities and adapt or modify the flow of each business process to make quick responses to the risk attack with minimal lost resources. Both Lihua and Muyuan use ERP systems which allow data to be efficiently shared across the company and each process can be optimized to achieve low-cost production. For example, the feeding department can be informed instantly of the purchasing price and quantity change of the feed material sent by purchasing department and then develop suitable feed formula in a cost-efficient manner.

When risks happen, firms experience financial loss and sometimes material interruption and facility shortage. Knowledge resources allow firms to assess more accurately the nature and the impact of uncertainties in the environment and the appropriateness of resource management strategies to cope with resource loss (Cohen and Levinthal, 1990). Knowledge itself does not ensure profits. When it is bundled with tangible resources, this specific bundle may help the company to achieve operational efficiencies through outright cost reductions or process refinements (Demarest, 1997; Glazer, 1991). With knowledge resources, organizations can strive to develop tangible resource surpluses in order to offset the current and possibility of future loss. Evidence given by the research findings shows that knowledge resources can be used to manoeuvre tangible resources in order to buffer against the loss of resources and to generate the above normal rate of resources which can offset the loss and decrease of resources when disturbance happens. Inmyxai and Takahashi (2010) emphasize that the firm's physical resources boosted with sophisticated technology can be expected to increase production operations. The knowledge resources may facilitate firms to produce the product with fewer inputs of tangible resources and form an advanced production system to cope with the risks. Through developing knowledge-based resources, organizations' specific routines and processes are generated which yield enhanced operational and governance efficiency (Demsetz, 1988; Kogut and Zander, 1992, 1996; Monteverde, 1995; Moran and Ghoshal, 1996). Such firm-specific routines and processes are most compatible with the organization's existing resources. Both Muyuan and Lihua adopt knowledge-based resource management strategies which incorporate investing in controlling more stages in the supply chain from the sources of raw material (piglets, pig houses and feeds) to final products (pig) and focusing on internal knowledge building to efficiently manage the business operation. These two case companies are both centrally controlled, and all have clear rules and formal procedures within their companies, which comprises the interactions among each operation process and department. The knowledge about efficient production and potential risks embedded in the production are encouraged and gathered in the headquarter through regular cross-functional roundtable meetings. The knowledge will be analysed and evaluated to develop a common understanding and plan for efficient resource coordination within the whole company.

In addition, in a highly vulnerable market, as an idiosyncratic resource, a knowledge-based resource bundle can ensure resources to be readily available (abundant) and most appropriate to meet a firm's specific requirements and help to achieve efficient resource configuration, but also enhance the discovery and exploitation of opportunities. Muyuan takes advantage of its advanced production system to strictly control its production costs. More segmented feed formula, high technology equipment and management method to control the consumption of water and electricity and advanced pig house design, procurement system and internal process control system all contributes to minimizing production costs. Muyuan can always carefully control its production cost under the average pig sold price even when the pig price decreases significantly. When other companies suffer from a financial loss due to the price decrease, it is only a profit reduction for Muyuan.

The knowledge resources enable organizations to foster continuous learning and persistently adapt to the transforming environment. Related arguments are put forward in organisational learning theory. It is recognized that knowledge diversity positively fosters learning and innovation, as it provides a robust basis for assimilating new and related knowledge based on existing knowledge, and encourages internal resources refinement and adaptation, with the hope of reducing future disruption (Cohen and Levinthal, 1990). Many studies have proved that the success of firms in increasingly turbulent environments depends directly on the competitive quality of their knowledge-based assets and the successful application of these assets in operational activities to fulfil firms' objectives (Bohn, 1994; Grant, 1996; Spender, 1994; Teece, 1998; Teece et al., 1997; Wiig, 1997). Both Muyuan and Lihua have developed sophisticated record-keeping programs which are used to monitor sow productivity. Muyuan use ab advanced electronic tracking and recorder system. While, due to the financial resource constraint, Lihua still relies on the farmers in the plant to manually input the data. But still, this record-keeping system keeps information on the individual pig's growth, and it is also used to develop standardized production criteria that allow comparisons within the herds. With the vast amount of production data available, large databases could be developed for benchmarking purposes and to help the company identify opportunities for improvement (Koketsu et al., 1996). As a result, key drivers of profitability may be identified, and the adoption of new technology could be monitored and evaluated (Baas, 1996). Today, production data is now coupled with financial analysis and profit projections to help control costs, manage risk, and increase revenue.

Organizations with rich knowledge and tangible resources tend to engage in resource "exploitation" (use and extend current tangible resources and develop internal knowledge based on existing base), because the returns from exploiting existing resources are generally more certain and controllable than those from exploration (i.e., the pursuit of new relationships, adopt new operation process) (Levinthal and March 1993). Both Muyuan and Lihua were equipped with advanced knowledge in pig production when they were founded. Muyuan's founder, Mr Qin graduated from Henan Agricultural University major in livestock management. Muyuan's initial team have intensive experience and knowledge of livestock breeding and plant management. While, before Lihua entered the pig breeding industry, it has already been the largest yellow-feathered chicken breeding company that has extensive experience in livestock breeding and plant management. The continuous investments in tangible resources and knowledge together may rapidly refine the production operation and make sure that the replenished resources are more valuable and sustainable toward future disturbances. Thus, the very possession of valuable knowledge-based resource bundles paradoxically leads organizations to focus an increasing amount of attention on applying and improving existing knowledge and tangible resources rather than exploring and developing new types of resources.

Based on the discussion, this research proposes that:

Proposition 5a: Knowledge-based resource management strategy indicates that firms consistently bundle internal knowledge and tangible resources (physical resources and financial resources) in order to efficiently accumulate, maintain and reconfigure the resources during the resource loss; Knowledge resources, coexist, leverage and bundle with the tangible resources to form an advanced production system.

Another resource management strategy to cope with the stress brought by the risks is a relationship-based resource management strategy. In the pig supply chain, the relationships organizations need to coordinate include the relationships with pig farmers, feeding providers and veterinary drug suppliers, government, financial institutions, research institutions, local community, banks, pig agents and slaughterhouses. Because these relationships facilitate the management of the flow and are highly related to the quantity and quality of other tangible assets such as land, pig farms and capital, the benefits should accrue directly to the firm's operational performance. The relationship network influences information and material flow along the supply chain (Skilton and Robinson, 2009). Firms establish strategic relationships and interact with other stakeholders in order to gain access to superior resources. Through working with partners, firms may not only acquire valuable resources which are essential to carry the production operation, but also may get access to rare resources which have the potential to improve existing resources or resources which firms cannot produce on their own. The relationships bundle facilitates the optimization of resource allocation among the collaborating partners and generates new high-valued resource combinations.

Except for feeds, some of the piglets, Hanshiwei relies on collaborating veterinary suppliers, piglet suppliers and pig farmers to provide essential lands, pig houses and pig breeding knowledge to finalize the pig production. Due to farmers' key role in the company to get access to the land, production facility and finishing the pig raising, the production service department which is mainly responsible for managing the relationship with pig farmers becomes the most important department within the company. The production service department is not only in charge of exploring new pig farmers to collaborate, but also providing pig farmers production service support. They provide suggestions on pig house renovation, manure treatment, and feed formula to help farmers raise pigs of better quality. They are also in alliance with the government and banks to provide financial support to the farmers. They work closely with farmers to monitor the growth of the pigs. Since most of the pig farmers are not well educated, they highly rely on Hanshiwei's service support.

While, in another case Nanchuanhe, as a cooperative, Nanchuanhe itself owns very limited land and pigs. So Nanchuanhe needs to fully collaborate with farmers to finish the pig production. Thus, Nanchuanhe outsources most of its operations to its suppliers and becomes an integrator to acquire, combine and coordinate the resources. Nanchuanhe works with several leading feeds, veterinary drug and piglet suppliers and sources products for its cooperative members. By organizing the purchasing activities together, Cooperative not only helps farmers to identify good quality products such as feeds and equipment, but also saves their purchasing costs. Meanwhile, Nanchuanhe helps the government to promote environmental protection policies and collaborate with external environmental equipment providers to update farmers' manure treatment facilities. Nanchuanhe also helps farmers to sell fattened pigs. Through managing various supply relationships, Nanchuanhe helps farmers to finish the pig production and meanwhile gain extra commission through provided service. Both case companies co-develop their supply chain and complete the product production with suppliers and co-suppliers. During this process, the two case companies must obtain and integrate knowledge, material or physical resources from their external environments and become supply network integrators both highly active in maintaining and developing relationships with key stakeholders.

The relationship bundle could work as a bridge for organizations to compensate for the decreased resources reservoir by acquiring appropriate external resources, thus reducing companies' concerns about specific resource loss. Firms adapt to environmental uncertainties by building and applying resources residing in the supply chain relationships. When these relationships with stakeholders are bonded as a bundle, different combinations of relationship resources have different synthesis effects toward dealing with various disturbances through either replacing the existing resources or acquiring new ones. The relationship bundle may also offer high flexibility which enables firms to choose the right collaborating suppliers to quickly change process structures or adapt the information-sharing process for modifying the production process (Gosain et al., 2004). Through the relationship bundle, concurrent processes of resource sharing, and co-development take place. Supply chain partnerships support the development of flexibility, and responsiveness toward change, and achieve effective production (Goldhar and Lei, 1991). The fundamental premise of a relationship-based resource management strategy is that firm combines the focal organization's resources with the resource endowments of supply chain partners and resources can be deployed and coordinated in a flexible way. When farmers gradually withdraw from the market due to the fluctuating pig prices, financial loss caused by pig disease and restriction from the environmental policy, both Hanshiwei and Nanchuanhe experience the stress of supplier loss. The two case companies do not have their own tangible resources and capabilities to buffer the impact brought by the risks. Instead, they take a relational perspective and believe that integrating and deploying resources from suppliers increases their capabilities to deal with uncertainties. The financial institution may help farmers with financial support, environmental technology companies may provide knowledge on how to properly deal with the pig manure, and the government may inform the company about the policy change earlier so that the farmer suppliers can get themselves ready for the change in advance. These supply relationships bring the case companies the knowledge of production and financial and institutional support, enabling them to develop a risk mitigation plan in a flexible and innovative way.

Firms develop different relationship bundles through complex social and supply chain integration processes (Winter, 2003). The unique bundle composed of different relationship resources are idiosyncratic and path-dependent, meaning they yield heterogeneity in stocks of firm resources (Barney, 1991). The embeddedness of the supply chain partnering firms' relational assets and the causal ambiguity makes such a relationship bundle most compatible with the firm's existing resource bases (Jap, 2001). Through better managing its unique relationship combination, firms may develop their unique core activities or develop customized production processes, which increases the firm's specific skills and realizes economies of scale, thereby improving their capabilities to cope with the risks (Park et al., 2004). For example, both case companies have developed deep mutual trust with farmers. In Hanshiwei, a reserved fund has been developed to support farmers with good track records to recover from financial loss due to pig price reduction or pig death. Such activity not only helps to encourage farmers' effort to raise pigs, but also strengthens Hanshiwei's brand. Through word of mouth, more farmers have been attracted to work with Hanshiwei.

Despite this, managing relationships bundle as a coordinated portfolio may generate value beyond what can be gained from an individual partnership. One single relationship resource has limited value in safeguarding or increasing an organization's current resource reservoir. Conversely, the failure of network agents may extend to the firms and consequently cause the disruption of operation. In the severe risk events which affect firms' suppliers, firms may experience disruption due to the ripple effect. In this case, firms can either acquire external resources by exploring new relationships to quickly recover from the resource loss. Or firms may seek a new complementary set of resources through existing relationship networks and reconfigure these resources in an innovative way to create additive value synergies. For example, if there is a farmer loss due to the environmental policy change, both Hanshiwei and Nanchuanhe will either look for government support to seek opportunities to retain the pig farmers, or directly find new pig farmers and continue operation.

We recognize that a relationship-based resource management strategy represents an explorative organizational behaviour under the threat of resource loss or constraint. Whereas exploration entails the search for new external resources through relationship bundles instead of leveraging currently available tangible resources to address the resource loss (March, 1991; Lavie and Rosenkopf, 2006; Smith and Tushman, 2005).

Based on the discussion, this research proposes that:

Proposition 5b: Relationship-based resource management strategy indicates firms focus on managing a portfolio of relationships with various stakeholders (e.g., government, customers, and suppliers) in order to effectively acquire external resources to compensate for the resource loss.

10.5 The Relationships Between Resource Bundle Strategies and Supply Chain Capabilities (Vertical Integration, Knowledge Management Capability and Supplier Integration)

Firms develop specific resource management strategies to accumulate and acquire resources to reduce the stress caused by various risks. Two strategies have been identified which are knowledge-based resource management strategy and relationship-based resource management strategy. Respectively, these two resource management strategies enable organizations to replenish the loss of resources by either efficiently generating above normal resources return internally or flexibly acquiring resources from external sources. During the resource accumulation and acquisition process, firms also build up the capabilities to construct organizational systems in order to deploy, configure and coordinate resources effectively. Following Helfat and Peteraf (2003: 999), organizational capability can be defined as “the ability of an organization to perform a coordinated set of tasks, utilizing organizational resources, for the purpose of achieving a particular end result.” The capabilities serve as forces which signal and direct tangible and intangible resources and enable firms to have access to and control over those resources flowing through their network. Those dynamic capabilities allow firms to reconfigure the mix of resources, that they are the means through which firms modify their resource base over time, allowing them to overcome risks and exploit opportunities in their environment.

Since firms perceive valuable resource endowments residing either within the firms or in the supply network. There are two ways for firms to activate the potentialities: 1) transform and generate the resources via merger or acquisition of the firms that own the resources; 2) gain access to the valuable resources by means of establishing strong relationships with firms that control the resources. As a result, two types of supply chain capabilities are respectively required to manage these two resource management strategies.

It is recognized that emphasis on investment in knowledge-based resources will enable firms to engage in different level of vertical integration and leads to the development of knowledge management capability. Here, vertical integration refers to integrating two or more stages of production or distribution that are normally operated by separate firms under one single ownership to control all the processes of production (Buzzell, 1983).

High investment in acquisitions of bundles of tangible assets including facility resources and material resources enable firms to reap the benefits of their economic scale, securing stable input of resources and centralizing the power to enable highly efficient management of the material flow. Contractual power over a firm's asset specificities enables firms to mobilize, allocate and leverage resources in order to achieve transaction efficiency. Various research from a transactional cost perspective has investigated how a firm's contractual control over its asset specificities would lead to different transactional efficiencies. In a highly vulnerable environment, to survive, organizations have the tendency to have privileged access and effective control of resources, including control of the supply of inputs, in order to provide the security to justify investments in large production facilities (Lazonick, 1990). Also, the higher quantities of tangible resources the organizations possess and invest, the more firms need to coordinate and make sure all the activities work toward a common purpose. Thus, firms would wish to establish standardized operation procedures, routines, and management rules to better manage and coordinate the resources such as facilitating information, material, and capital flows. One of this consequence of such a resource management strategy is that firms will achieve different levels of vertical integration. In our research, two of the case companies, Muyuan and Lihua have both adopted a knowledge-based resource management approach. It can be seen from Table 9.8, Muyuan invested more in both knowledge creation and production facilities. In order to stabilize the operation and achieve production proficiency, Muyuan acquires all the pig production operations under its control. Muyuan's pig production supply chain incorporates all the stages from feed production and pig reproduction to pig fattening. Muyuan and Lihua try to incorporate all production processes into their own companies and minimize outsourcing. Due to different levels of investment in knowledge and production asset, Muyuan has a higher vertical integration level than Lihua.

Vertical integration may transfer most of the key relevant tangible resources in-house and can be an effective way to make all critical resources under one management and control them. The vertical integration helps Muyuan and Lihua increase efficiency by streamlining the process of obtaining supplies for its product, closely monitoring the production cost, and eliminating the possibility of a supply disruption, such as pig farmers' opportunism behaviour. Furthermore, vertical integration has the potential to exploit innovations and enrich a firm's internal resources development because it provides the opportunity to integrate tacit knowledge with complementary assets across different supply chain activities (Teece, 1986). The synergies of knowledge resources and tangible resources could help to coordinate vertical activities skilfully. It can also build entry barriers, facilitate investments in specialized assets, protect product quality, and improve scheduling and coordination (Williamson, 1975; Chandler, 1977; Harrigan, 1984). For example, since the feeds occupy 80% of production cost, as a leading sow production company, Muyuan has built its own feed companies to source the ingredients and produce the feeds with specifically designed formulas. Meanwhile, Muyuan invested heavily in feed nutrition research to increase feed efficiency. Such integration will not only enable Muyuan to reduce pig production costs by controlling the cost of feeds, but also ensure the availability and quality of the feeds. Lihua adopts a similar approach to try to integrate more production processes when designing its pig production supply chain. When building the pig plants, Lihua will build sow plants, pig fattening plants and feeds plants together. So, knowledge development on any processes will bring benefits to Lihua's whole supply chain.

When a firm efficiently utilizes knowledge resources to manage its tangible resources in order to buffer the risks, the firm is naturally developing its knowledge management capabilities. It is found in Muyuan and Lihua's case, by investing in a knowledge-based resource management strategy, both companies have developed knowledge management capabilities. Knowledge management capability is defined as "the ability to organize, shift, configure, and arrange knowledge resources to achieve the goals of and gain business values from the organization (Kearns and Lederer, 2003). Through leveraging existing knowledge resources and continuously developing new knowledge, knowledge management capability facilitates efficient knowledge reusing, information exchange and innovation so that firms may quickly adapt and respond to the changing environment. Through investing in knowledge resources which lead to learning generation, firms are continuously improving the efficiency of organizational processes to buffer the impact of various risks. During each risk recovery, organizations carry out innovation, routine modification and improvement, and innovation in turn create their unique risk mitigation knowledge, routines, and culture. Through these routines, firms develop their own dynamic capability of redeploying existing resources and creating new resources.

Both Muyuan and Lihua develop knowledge scanning, experimentation, knowledge transfer and knowledge integration capabilities. For example, to reduce the possibility of pig disease, Muyuan and Lihua have established their own sterilizing and detecting procedures. There are clear instructions on how to deal with pig disease cases once identified. All pig-raising staff takes regular training. Both Muyuan and Lihua have developed strong risk management cultures. To deal with the price fluctuation, both companies have developed their market intelligent software to closely observe and estimate the change in pig price. They also invest in developing their own cost monitoring system to consistently evaluate the cost of each production stage. Internal technology innovations are highly encouraged. In one specific case in Muyuan, one technician was highly appraised and rewarded for innovating low-budget ventilation equipment. The senior management from different departments within these two companies has the routine of weekly round table meetings to share information and discuss important management decisions. Both companies invest and develop internal communication software for employees to carry out immediate communication. In this way, the flow of knowledge has been speeded up which improves the efficiency of production and enables organizations to respond quickly to the changing environment. Managing disasters and disruption events require managers to learn quickly and adapt to the situation. Due to the severe consequences of resource loss, such investment in risk mitigation strategy is under high time pressure. Under such circumstances, the ability of a firm to effectively extract knowledge within the company and convert it into optimal resource management solutions is paramount to efficient ways to stop resource loss. Knowledge management capability enables firms to quickly gain knowledge, convert existing processes, apply new processes, and protect from resource loss.

Based on the discussion, this research proposes that:

Proposition 6: Knowledge-based resource management strategy positively leads to a high level of vertical integration and strong knowledge management capabilities which enable organizations to accumulate resources and have full control of the production and distribution processes. Meantime, the efficient deployment and utilization of resources can be achieved.

It is recognized that an emphasis on investment in relationship-based resources will encourage firms to outsource the production process and build strong supplier integration capabilities through sharing, integrating, and obtaining resources among supply chain members. From a transaction cost perspective, investment in relationship resources among supply chain partners provides outsourcing and external acquisition possibilities which may enable firms to get access to the resources firms do not process such as land. Firms do not need to own all the production facilities and control every production stage. This is reflected in the case of Hanshiwei and Nanchuanhe. Both of them outsource the pig fattening stage to farmers. Hanshiwei still owns its own feed production unit while Nanchuanhe merely owns any physical assets.

As the managing director of Hanshiwei described,

Hanshiwei does not own pig houses. Due to stricter environmental regulations, it is getting more and more difficult to get large pieces of land from the government to build the pig plant. The current situation in China is that most of the pig raising is through small farmers who have the land. We work closely with them. We provide feeds and piglets. And they provide land and pig houses. We adopt a light assets model. We focus more on maintaining and developing relationships with farmers.

Relationship-based resource management strategy may also help to reduce the heavy cost of managing and maintaining a firm's physical and tangible resources such as pig plant, and machinery.

As the president of Nanchuanhe described,

As a cooperative, we work with various suppliers to provide service for members of cooperatives. We do not produce feeds. Instead, we source the feeds with the lowest price for farmers.

By obtaining the resources from supplier relationships, firms may reduce the internal operation complexity and allow themselves to focus on developing their key supplier integration capability. While many studies have proved that organizational relationships may bring benefits to the company, they can also be problematic in terms of time and cost (Barratt 2004; Ellram and Cooper 2014). So, organizations need to be strategic and skilful with regard to the required level of relationship integration. Firms need to develop capabilities to evaluate the relationship portfolios in order to determine the optimal ways to manage the resource flows and allocate rare management resources. Such capability would enable companies to better coordinate resource flows in the supply chain and may lead to more effective supply chain process flexibility as well as survival during the risks (Van and Van, 2008; Childhouse and Towill, 2003). In this research, it is found that both Hanshiwei and Nanchuanhe who adopted a relationship-based resource management strategy have developed supplier integration capabilities. Supplier integration capability can be defined as a dynamic capability that allows firms to develop partnerships with their suppliers in order to effectively and efficiently exchange and manage resources and resource flows, as well as apply these resources to environmental change (Carr and Pearson, 1999; Swink et al., 2007).

Lavie (2006) proves that not only strategic resources but also resource accessibility, and the right to employ resources may enable firms to create value. Specific supplier integration capability is developed when firms share, combine and exchange resources with collaborative partners through relation-specific investments, inter-firm knowledge-sharing routines, complementary resource endowments, and effective governance mechanisms. Through investment in supplier relationships, firms collaborate with their suppliers to synchronize and manage their operations in order to achieve smooth production processes (Das et al., 2006; Zhao et al., 2008). And it supports dynamic purposes, such as introducing a new distribution channel or sourcing from different regions to mitigate supply risks.

The case evidence suggests that Hanshiwei and Nanchuanhe both form close, long-term partnerships with various suppliers including farmers, feed producers, government. These supply chain members work together and share information, resources, and risk to accomplish mutual objectives. Nanchuanhe as a cooperative has higher supplier integration capability than Hanshiwei. Both case organizations engage in high levels of information sharing with farmers and build mutual trust with the suppliers. The top management all commit to relationship development. In Hanshiwei, a technical service department has been established to provide service solutions to collaborated farmers. Each farmer has been assigned a specific technician. These technicians regularly visit the farmers to provide pig-raising technical assistance, provide necessary training. These technicians also record the pig growth information including the number of pigs, pig death, feeds and veterinary drug usage and send it back to Hanshiwei. There is an efficient flow of information sharing which enables the supply chain partners to get updated information such as inventory level, production planning and scheduling. The high level of information sharing can help Hanshiwei to be more responsive to market changes and mitigate the bullwhip effect (Dejonckheere et al., 2004). The performance of the farmers has been accounted into this technician's performance as well.

The information sharing in Nanchuanhe is slightly different. It has gone through a more informal way. Since all the farmers are local villagers and live very close to the managing team of Nanchuanhe. Farmers have very high frequencies of chatting with cooperative staff and other farmers. This casual conversation happens anytime in the day. If farmer members have problems in pig production, the cooperative will facilitate problem-solving. For example, when farmers need to upgrade the manure treatment facility due to stricter environmental policy, farmers face a shortage of knowledge and information on how to update and where to purchase the equipment. The cooperative will source suppliers to help farmers to purchase and install the equipment at reasonable prices and then collaborate with the government to make sure the updated manure treatment meets the standard. Both case organizations also carry out joint planning with farmers including inventory replenishment, order placement, and order delivery and coordination of the flows of physical resources. Regular meetings have been arranged between organizations and suppliers.

Furthermore, both Hanshiwei and Nanchuanhe have used formal supplier evaluation and feedback procedures. Quality auditing programmes and supplier certification programmes are developed, which provide more certainty for organizations to manage their resources. If farmers achieve better performance, awards and rewards will be granted.

In addition, supplier integration involves resources and risk sharing. Farmers own the lands, build pig houses, and invest in pig production facilities to carry out pig production. The case company leverage its supplier relations to provide service and information to farmers and help them to sell the pigs. In addition, risks are shared between the case organizations and farmers. If there are decreases in pig prices, Hanshiwei will guarantee the minimum profits for farmers and Nanchuanhe will provide financial support. Supplier integration enables case organizations to access and leverage each other's resources and enjoy their associated benefits.

Based on the discussion, this research proposes that:

Proposition 7: Relationship-based resource management strategy positively leads to a low level of vertical integration but strong supplier integration capabilities so that not only do firms may obtain resources from individual suppliers, but also potential effective resource sharing and combining can be achieved.

10.6 Supply Chain Resilience Strategies

In line with resilience from social-ecological perspective, we recognize that a firm's resilience-building process is a continuous resource sustain, acquisition, accumulation and loss process across an organization's lifespan. The resilience-building process is composed of resource loss and gain spirals. During this building process, the level of resources reduces due to the natural depletion, resource loss caused by risks and resource investment in order to protect existing resources and assure resource gain. Meanwhile, resource gain occurs because initial resource gain continuously begets future gain. These two spirals form a double helix which reflects the dynamics of resources. The resource loss and gain spirals happen simultaneously throughout the organization's life cycle. According to COR theory, during this process, resources tend to aggregate in resource caravans and form resource bundles which are groups of resources linked with each other (Hobfoll, 1988;1989).

We extend the resource caravan concept into an organizational resource caravan. As shown in Figure 10.2, in our study, each organizational resource caravan represents one of the static resource states on the resource spirals. It accommodates the resource bundles in the organization with different quantities and types and is the overall outcome of the resource loss and gain. Each resource caravan represents an organization status in which different resource bundles are gathered.

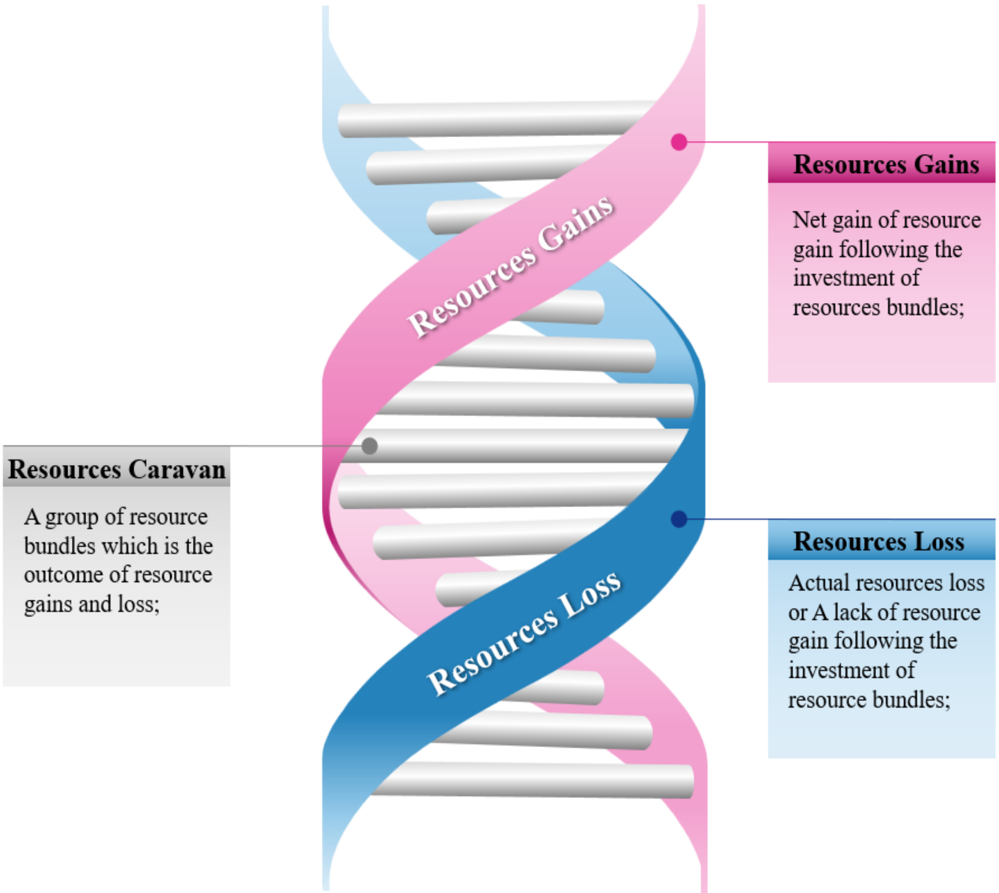

Figure 10.2 Resource caravan, resource gain and resource loss spirals

As resource loss is the primary concern for organizations, organizations strive to create and maintain resource caravans that contain necessary resource bundles for survival. The resilient resource caravans represent multiple stable resources status where firms build and maintain essential blocks of organizational resources and they are the results of resource loss and gain. The outcome of these resilient resource caravans is to allow firms to buffer the resource loss or acquire the resources in a timely and cost-effective manner while undergoing changes. Meanwhile, organizations may still retain essential continuity of operations at the desired level of connectedness and control over structure and function (Walker et al., 2004).

Because of the multiple stable statuses, when considering the extent to which organizations can be changed, recovery time does not measure all the ways in which firms may recover to essential functions. As firms may be at different resource caravan statuses before the risks happen and will reach another resilient resource caravan to recover. Furthermore, in this research, the lead time for pig production is six months which cannot be shortened. This means the recovery speed is relatively fixed in the pig supply chain. Thus, in this study, recovery speed cannot be considered as a measurement of resilience.

According to COR theory, the factors which may build resilience are the resource configuration strategies of the organizations. These resource configuration strategies enable resource recovery to situational demands (Hobfoll, 1988;1989). Two supply chain strategies, vertical integration combined with knowledge management and supplier integration which represents two types of resource management approach have been found in our research to effectively lead to a firm’s resilience building. These two supply chain strategies also reflect the organizational ambidextrous approach which is to either exploit existing resources or explore new opportunities. Exploration results from experimentation, flexibility, and divergent thinking, which reflects the orientation of supplier integration strategy. Exploitation is associated with efficiency, refinement, and focus which reflects the orientation of vertical integration combined with a knowledge management strategy (March, 1991).

Some research argues that balancing exploration and exploitation not only helps organizations to overcome structural inertia that results from focusing on exploitation, but also avoids accelerating exploration with no benefits gain (Levinthal and March, 1993). Although both types of activities are important for organizational survival, they create paradoxical challenges. Because of the resource constraints, the trade-offs between exploration and exploitation are seen as unavoidable, and organizational ambidexterity largely involves the management of these trade-offs in limited resources situations.

Different from the previous studies which address that a close balance of exploration and exploitation will enhance firm performance. It is proved in our research that firms that are resource-constrained due to high risks and uncertainties benefit the most from focusing on two ends of exploration or exploitation. We found that the commitment to either a knowledge-based or relationship-based resource management strategy will enhance firm resilience performance through building resilient resource caravans to mitigate the risks. In other words, firms focusing on either vertical integration combined with knowledge management or supplier integration will lead to high resilience performance. Both strategies will proactively create a resilient resource caravan for organizations to reduce organizational stress in the turbulent environment and develop resilience.

Exogenous risks call for immediate organizational responses (Meyer et al., 1990; Murmann and Tushman, 1997). Nevertheless, under such conditions, firms need to protect and retain essential resources to stabilize the material, financial and information flow. Some organizations like Muyuan and Lihua choose to facilitate their exploitation efforts in an attempt to generate an abundant resilient resource caravan to retain their past direct investments in knowledge and tangible resources and buffer the resource loss. Such resilient resource caravans accommodate sufficient knowledge and tangible resources to offset the resource loss during the risks, which sustains normal business operations.

Comparing Muyuan and Lihua, in Muyuan's resilient resource caravan, the level of the knowledge-based resources bundle is higher in its density, scarcity and complexity, so Muyuan is more vertically integrated than Lihua. Vertical integration reflects an exploitative approach to build resilience. The exploitation strategy refers to firms striving to refine and accumulate and extend their existing internal tangible resources together with knowledge resources to build their buffer capacity toward the risks. How firms retain their resources is strongly linked not only to the resources the firm could deplete externally, but also to the resources the firm could produce internally (Barney, 1991; Prahalad and Hamel, 1990). The firm's efficiency depends on the coherence between knowledge and physical assets, and the use to which managers are able to mobilize them. The accumulation of tangible resources created a base for Muyuan and Lihua to undertake knowledge-building. Conversely, the knowledge capability may improve the productivity of the overall knowledge-based resources bundle. The knowledge acquisition, sharing, application, creation, and knowledge transfer abilities enable Muyuan and Lihua to efficiently mobile the accumulated resources to buffer against the risks. The building of knowledge and tangible resources allowed firms to increase their rate of resource accumulation. With the accumulation of tangible and knowledge resources, vertically integrated organizations efficiently facilitate resources and information flows between separable production stages since there are no proprietary boundaries encountered. The accumulated resources created a resilient resource caravan which could be an effective buffer capacity to cope with the resource loss. Muyuan invests more than Lihua in production capability development, product quality improvement, production cost reduction, production process integration and internal knowledge building which enable Muyuan to have more internal control of its resources through building standardized production processes and highly efficient advanced production systems. Such vertical integration equips Muyuan with more resource capacity to efficiently buffer the resource loss at a lower cost. Thus, because of the benefits brought by its highly vertical integrated supply chain, Muyuan is better in resilient performance than Lihua.

Whereas, in our study, other companies like Hanshiwei and Nanchuanhe may enhance their exploration efforts to build new resource bases through incremental supplier integration. The exploration strategy means organizations engage in continuous exploration of new opportunities through collaboration with suppliers to link themselves to external resources. Although adopting different resource gain approaches from an exploitation orientation, this type of firm also creates resilient resource caravans and may achieve resilience by investing in relationship bundles. These relationships enable firms to acquire essential tangible and knowledge resources to replace the existing lost ones. Through building bridges with external suppliers, firms benefit from flexible coordination and higher possibilities of acquirement of core resources like materials, facilities, and knowledge for production. Such supplier integration offers the potential for firms to overcome turbulence and disruption in the supply chain (Christopher and Peck, 2002; Sheffi and Rice, 2005). The relationship bundle works as a bridge for firms to flexibly control and mobile the resources in order to effectively recover from the risks in a cost-efficient way.

Typically, Hanshiwei and Nanchuanhe in our case encourage collaborations from the perspective of supplier development, outsourcing, contract formation of collaboration, and product development, where the members contribute towards differential resources and know-how for agreed complementary risk reduction objectives (see Table 9.6). Outsourcing may lead to negative effects when used as the main strategy to improve performance but is more likely to cause positive effects if concurrent initiatives are taken to develop manufacturing and operational capabilities under huge uncertainties (Dabhilkar et al., 2009). Supplier integration through outsourcing can allow an organization to develop a range of capabilities to adapt to various uncertainty through flexibly leveraging and coordinating supplier resources in a range of business areas (Holcomb and Hitt, 2007) The exploration resilience approach focused more on acquiring or replacing resources through the relationship bundle. Indeed, comparing Hanshiwei and Nanchuanhe, in Nanchuanhe's resource caravan, the relationship bundle is stronger in its density, scarcity, and comprehensiveness than Hanshiwei. A complex of suppliers is involved in Nanchuanhe's relationship bundle, these stakeholders may hold differing, incompatible, and changing business objectives. Nanchuanhe have less ownership of its supply chain than Hanshiwei, however, it has a higher level of supplier integration which provides the rules and clearly classifies the resources individuals may provide. These rules and resources will be effectively applied to foster involvement, coordination and innovation which are closely correlated with organizational performance. A higher level of supplier integration may involve reducing the hidden information such as farmers' production capacity, preventing hidden action such as farmers' opportunism behaviour, ensuring adaptation such as upgrading farmers' production facility to comply with government environmental regulations, encouraging resilience specific investments such as lock-in farmers with their initial deposits for piglets. The increasing inputs on supplier integration enable Nanchuanhe to have the full flexibility to effectively replenish resources and are also seen as increasing the quality of risk-recovering decisions and their implementation. Nanchuanhe may not be the most profitable, but it has a more stable rate of growth over time, especially in a turbulent environment. Thus, The higher degree of supplier integration, the higher effectiveness of resource replacement and acquirement. The newly added resources substitute the loss of original resources and create a new resilient resource caravan which acts or serves in place of original resources to enable the operation continuity, which finally leads to the resilience of the supply chain.

According to COR theory, initial resource gain makes greater resources available for re-invest which generates future resource gain. Recognizing this resource gain cycle and facing the resources constraint, the companies will invest in initial great resources which enable the resource gain. In other words, firms will invest in the same resource management strategy to reduce the stress of future resource loss, meanwhile, guaranteeing promising future gain. Indeed, thriving and resilience are fostered by circumstances where organizations are able to consistently apply, grow, and sustain their tangible and intangible resources in a direct or indirect way. However, for firms that have access to sufficient internal and/or external resources, the simultaneous pursuit of an appropriately balanced ambidexterity is both possible and desirable. In such cases, the optimal growth of the firm involves a fine balance between the exploitation of existing resources and the development of new resources and capabilities (Penrose, 1959; Wernerfelt and Montgomery, 1988).

Based on the discussion above, it is proposed that

Proposition 8a: The focus on vertical integration and knowledge management capability building may form a stable resilient resource caravan which enables firms to accumulate the resources and efficiently exploit the resources reservoir to buffer the resource loss and finally lead to positive performance in SCR.

Proposition 8b: The focus on supplier integration may also form a stable resilient resource caravan which enables firms to effectively acquire and leverage supplier resources to adapt to various uncertainty and finally lead to positive performance in SCR.

Proposition 8c: Due to the low exchangeability of two resource bundle strategies, organizations engaging in hybrid resource management strategies (both knowledge-based and relationship-based resource management) tend to be less resilient in performance.

In summary, by combining these eight propositions, this study has built a resource-based resilience-building framework (Figure 10.3). This framework explains why organizations may invest in resource management to mitigate the impact of risks and how organizations achieve resilience through different resource management strategies.

Building on COR and ambidexterity perspectives and closely linking to the RQ, this study builds a theory of **Resilient Resource Based View (RRBV)** of the supply chain.

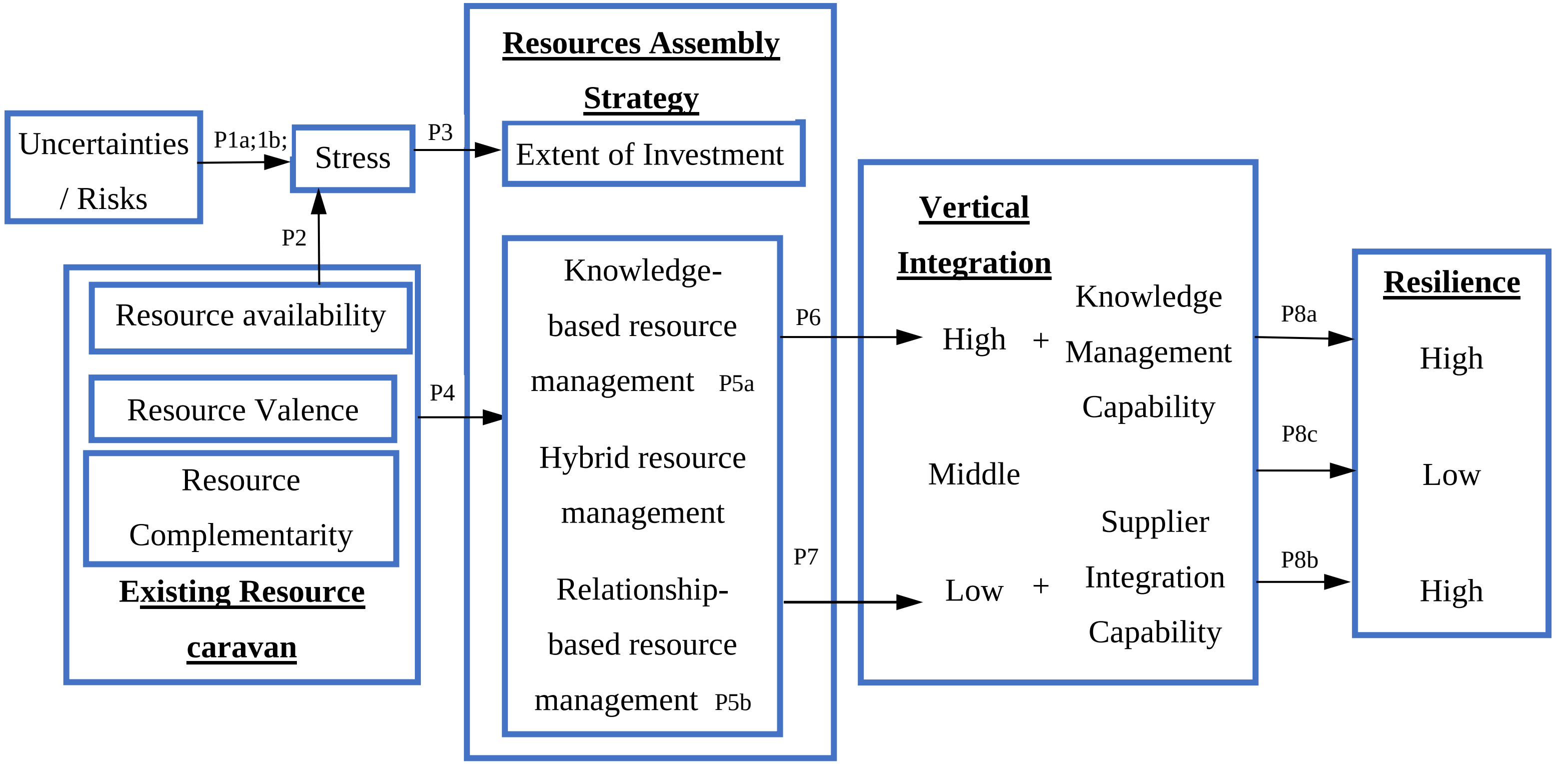

Figure 10.3 Framework for resources-based resilience building

10.7 Chapter Summary

This chapter discusses the relationship between constructs and develops eight propositions based on their causal relationships. Propositions 1 and 2 explain why organizations may engage in resource management strategy. Proposition 3 focuses on how organizations decide the extent of investment in resources strategy. Proposition 4 reveals how organizations make decisions on investment in different resource bundles to mitigate the risks. Proposition 5 explains the mechanism of two resource bundling strategies. Propositions 6 and 7 illustrate two resource bundling investment strategies that may lead companies to develop two different capabilities. Finally, Proposition 8 explains the impact of organizations' resource management strategies on resilience performance.

Propositions
The relationship between supply chain risks/ uncertainties and stress **Proposition 1a:** The unexpected risks or uncertainties (pig price fluctuation; disease and policy) may lead organizations to face the stress of direct or anticipated resource degradation and loss caused by direct loss of material and facility resources. **Proposition 1b:** The unexpected risks or uncertainties may lead organizations to face the stress of direct or anticipated resource degradation and loss caused by indirect loss of land, material, and facility due to the supply relationship disruption which adversely affects the inward flow of any type of resources for production.
The relationships among stress, existing resource caravan and resources bundle **Proposition 2:** The Resource availability of existing resource caravan negatively influences the level of a firm's stress. **Proposition 3:** The level of organizational stress is positively related to the extent of firms' effort on resources investment.
The resource management strategies **Proposition 4:** The perception of resource Valence (appropriateness) of senior management to mitigate the risks, the Resource availability of existing resource caravan and the complementarity of future invested resources toward the existing resources jointly leads to the investment in different resource bundling strategies. **Proposition 5:** Knowledge-based resource management strategy, relationship-based resource management strategy or hybrid strategy are adopted by firms to shepherd firms' resources in order to obtain, retain and protect existing resource reservoirs and offset net loss of resources. **Proposition 5a:** Knowledge-based resource management strategy indicates that firms consistently bundle internal knowledge and tangible resources (physical resources and financial resources) in order to efficiently accumulate, maintain and reconfigure the resources during the resource loss; Knowledge resources, coexist, leverage and bundle with the tangible resources to form an advanced production system.

Proposition 5b: Relationship-based resource management strategy indicates firms focus on managing a portfolio of relationships with various stakeholders (e.g., government, customers, and suppliers) in order to effectively acquire external resources to compensate for the resource loss.
The relationships between resource bundle strategy and supply chain strategies (wholly Vertical integration and strategic outsourcing) **Proposition 6:** Knowledge-based resource management strategy positively leads to a high level of vertical integration and strong knowledge management capabilities which enable organizations to accumulate resources and have full control of the production and distribution processes. Meantime, the efficient deployment and utilization of resources can be achieved. **Proposition 7:** Relationship-based resource management strategy positively leads to a low level of vertical integration but strong supplier integration capabilities so that not only do firms may obtain resources from individual suppliers, but also potential effective resource sharing and combination can be achieved.
Supply chain resilience strategy **Proposition 8a:** The focus on vertical integration and knowledge management capability building may form a stable resilient resource caravan which enables firms to accumulate the resources and efficiently exploit the resources reservoir to buffer the loss of resources and finally lead to positive performance in supply chain resilience. **Proposition 8b:** The focus on supplier integration may also form a stable resilient resource caravan which enables firms to effectively acquire and leverage supplier resources to adapt to various uncertainty and finally lead to positive performance in supply chain resilience. **Proposition 8c:** Due to the low exchangeability of two resource bundling strategies, organizations engaging in hybrid resource management strategies (both knowledge-based and relationship-based resource management) tend to be less resilient in performance.

Table 10.1 A summary of the propositions

Building on COR and ambidexterity perspectives and closely linking to the RQ, this study builds a theory of **Resilient Resource Based View (RRBV)** of the supply chain. This framework is used to illustrate how various supply chain resources are bundled on the condition of different levels of stress organization experiences to create different resilience capacity configurations or repertoire in the context of the Chinese pig industry and reveal how Chinese pig production companies build their SCR to deal with various risks.

The following chapter (Chapter Eleven) will reflect upon the extant literature in order to draw conclusions. The theoretical and practical implications will be summarized, and the research limitations and future research direction will be suggested.

Chapter 11. Conclusion

The core purpose of this chapter is to summarize the findings pertaining to this study and align them with the extant literature to draw conclusions. In light of the gaps in the literature (highlighted in Chapter Two literature review chapter) and empirical findings from the case analysis (presented in Chapter Ten findings and discussion chapter), this chapter addresses the significance of this research in terms of theoretical, policy and practical implications. Although the overall aim of the study is to *advance the understanding of supply chain system dynamics in the agri-food sector during unforeseen risk events from a social-ecological resilience perspective*, this research demonstrates a number of theoretical contributions and implications within the agricultural supply chain and supply chain resilience literature, which are discussed. Following this, the practical implications of the research are considered. Next, the limitations of this study are discussed, which is followed by directions for possible future research.

11.1 Conclusion of The Findings

After years of addressing issues on just-in-time and lean supply chains, businesses have been trying to eliminate non-value-added activities which help organizations to be more efficient and achieve cost reduction. However, it has also increased supply chains' vulnerabilities to disruption due to a lack of buffer capacity (Fiksel, et al. 2015). Meantime, the frequency and impact of sudden-onset natural and man-made disasters have significantly increased. The issue is particularly severe for the agricultural supply chain due to its specific characteristics. (Van der Vorst et al. 2009; 2011). However, anecdotal evidence suggests that not all firms were equally affected by these unpredictable events. The unforeseen disruptive events have highlighted the need to shift away from traditional risk management thinking as a static tactic to respond to disruptions and towards more dynamic nature strategies – supply chain resilience building which enables the supply chain to cope with perturbations and threats by absorbing the disturbance, adapting to the change and quickly recover so as to achieve business continuity (Flynn et al., 2021; Christopher and Peck, 2004).

Various research has defined and explored SCR in a number of different ways, indicating the complex nature of the phenomenon (Kamalahmadi and Parast, 2016; Altay et al., 2018). Some viewed SCR as the outcome of different capabilities such as agility (Christopher and Peck, 2004), visibility (Chopra and Sodhi, 2004), flexibility (Tang and Tomlin, 2008; Colicchia et al., 2010), redundancy (Craighead et al., 2007, Zsidisin and Wagner, 2010), velocity (Wieland and Wallenburg, 2013), and collaboration (Sinha et al, 2004, Jutter and Maklan, 2011). Others consider SCR as the attribute of a supply chain network which needs to be configured (Kim et al., 2015). However, these capabilities were overlooked since they just determine the potential to build better SCR and there is a lack of understanding of the mechanism of how resilience can be built especially considering resilience from a dynamic perspective as the capacity of the supply network to adapt to disturbance and secure a new desirable condition. Thus, responding to the call to explore and better understand the creation of SCR building and being framed by the contextual issues arising from the agriculture supply chain, the overarching purpose of this study was to advance knowledge in supply chain resilience beyond the traditional risk management and static resilience approach. More specifically, two research objectives were proposed:

1. Explore and advance the understanding of how organizations make decisions on resource investment and build SCR capabilities during risk recovery.
2. Discover how the supply chain co-evolves with its environment in terms of SCR building through analysing the organization's resources investment configuration strategies.

With the primary aim to build the conceptual foundation and explore the new knowledge domain, multiple case studies were adopted. Four pig production organizations and their supply chains which represent four types of pig production supply chains in China were chosen in this research. Due to the dynamic nature of resilient supply chains, it is difficult to map and visualize supply chain strategy formulation. To illustrate the changes in SCR and provide a better understanding of how those changes happen, the research drew upon a dense amalgamation of two strands of literature: supply chain resilience and resources theory. The existing supply chain resilience body of knowledge provided the theoretical foundation for the study. Conservation of resources and ambidexterity theory has been adopted to discover how supply chain resilience is built and how it co-evolves with the surrounding environment in turbulent events. Coevolution underscores the importance of two processes: resource loss and resource gain, both among the supply chain stakeholders and between supply chains and the environment during the process of achieving SCR. A systematic bibliometric literature review on supply chain resilience was conducted equating to a number of emergent research gaps in the current body of knowledge (which are presented in Chapter 2). Empirical findings (which are presented in chapter 10) were gathered from four pig production organizations. The propositions help to address the identified gaps in the academic literature.

To answer the first research question which sought to illustrate the underline resilience building mechanism and develop a supply chain resilience framework, the case study profiles presented in the findings chapter are analysed, providing an understanding of the SCR framework from the resource management perspective. Specifically, the results of the analysis revealed that the risks may lead to the possibility of supply chain disruption which comes from the loss of endowment resources either located inside of the firms or embedded in the firms' supply networks. When the consequence of risks exceeds the firm's existing coping capacity and affects the operation flow, firms may be confronted with the stress of resource uncertainty or loss. Such stress may trigger organizations to engage in resource management strategies. Our study reveals that the organization achieves the SCR by investing in different bundles of resources considering three resource factors within its supply chain, resource Valence (appropriateness), Resource availability of existing resource caravan and the complementarity of future invested resources toward the existing resources. Subsequently, aligned with exploration and exploitation orientation, two resource management strategies, knowledge-based resource management strategy and relationship-based resource management strategy were identified to enable organizations to replenish the loss of resources through either efficiently generating above normal resources return internally or flexibly acquiring resources from external sources. During the resource accumulation and acquisition process, firms also build up the capabilities to construct organizational systems in order to deploy, configure and coordinate resources effectively. Respectively, it is found that either focusing on vertical integration and knowledge management capability building or supplier integration may enable firms to achieve high resilience.

Research question two sought to capture the co-evolving change patterns of the supply chain during the resilience-building process and explore the interactions and inter-dependencies among different entities, processes, and resources. Although recognising the importance of the resilience-building process, the extant literature fails to analyse the resilience phenomenon from a dynamic perspective. In response to the void in the literature, the findings of research proposed the concept of resilient resource caravans which represent multiple stable resources status where firms build and maintain essential blocks of organizational resources with different quantities and types. These resilient resource caravans encourage organizations to develop a broad and varied repertoire of resources and routines for responding to uncertainty and complexity. Each resource caravan is the overall outcome of the resource loss and gain. During the risk event, the organization experiences resource loss and needs to invest resources, meanwhile has the resource gain to buffer the loss of resources. Thus, organizations shift from one resource caravan status to another after each risk event. Appropriate capability and resource reconfiguration is important to increase the adaptation to changes happening inside the supply chain.

11.2 Theoretical Contributions

This study was framed by the agrifood sector and used a case study approach, the core contribution of this study is advancing the literature and insights into supply chain resilience from a number of perspectives. Eight propositions were found that have provenance in practice and within the theory.

Firstly, this research advanced the current body of knowledge in risk management taking a dynamic social-ecological resilience perspective. More often, a great number of studies follow the traditional risk management approach focusing on preventing disruptions and assessing the possibility and impact of risks (Linnenluecke, 2017; Sullivan-Taylor and Branicki, 2011). However, some risks such as the risks identified in the case, price fluctuation, environmental policy uncertainty, and highly contagious animal disease are either unpredictable or difficult to prevent. Organizations survive and recover from stressful events by developing resilience capacity. This research applied a dynamic social-ecological resilience view to an SCR context, therefore, enriching this theory. We argued that SCR should be defined as the capacity of a supply chain to absorb disturbance and reorganize in a timely and resource-effective and efficient manner while undergoing change so as to still retain essential continuity of operations at the desired level of connectedness and control over structure and function. This definition represents an advance over notions of bouncing back, returning to the original or previous operation status, which is the static engineering resilience view.

The static resilience approach is akin to acceptance resilience but misses the fact that both adverse events and the organization's efforts to recover consume resources. Going back to the prior resource repertoire may not be possible. In addition, the static resilience view fails to consider that an organization's resources investments in response to adversity or resilience development may lead to new organizational resource configurations and goals. Considering from a social-ecological perspective, this research recognized that supply chain resilience (SCR) development could be viewed as a self-organizing process which reflects the interplay between supply chain disturbance, supply chain capabilities reorganizing, and internal resources sustaining and development.

Secondly, a new methodological approach combining the conservation of resources and ambidexterity theory was adopted to examine the SCR phenomena within the context of the agri-food industry. Motivation theory addressing stress in psychology was adopted to supply chain disruption management and was proposed as a new lens to study supply chain resilience. To date, it is one of the first attempts that COR and ambidexterity theory has been extended to SCR literature to deepen understanding of the mechanism inside of SCR development. The application of multi-theoretical lenses may better comprehend the multi-dimension and complexity of the SCR phenomenon. By applying the principles outlined in the COR theory as a cognitive process, resources embedded in the organizations are heuristically evaluated. In outlining the process by which resources operate, this research suggested that a specific set of organizational behaviours and cognitions were observed.

Different from previous studies (Pettit et al., 2010) which claim that risks and vulnerability are the reason for resilience investment, in alignment with COR theory, this research argues that organizational stress instead of risks lead organizations to develop coping strategies and accumulate resource reservoirs. Organizational stress happens when existing resources are threatened or there are actual resources lost or a lack of resource gain following significant resource investment (Hobfoll, 2001).

In addition, by applying COR theory, this research resolved the debate of whether SCR is a capacity or a process. The organizational resource caravan composed of varied repertoires of resources and routines (capacity) is necessary for resilience and responding to uncertainty and complexity. Nevertheless, an organization's resilient behaviour (process) is defined in terms of resilience. It is evident that organizations behave according to the key principles of COR theory facing adverse events and invest in either knowledge or relationship resources. The Resource caravan, resource gain and resource loss spirals identified in this study vividly illustrate the dynamic change and evolving pattern of resource repertoire within the organization in response to stresses and strains. In line with resilience from a social-ecological perspective, we recognize that a firm's resilience-building process is a continuous resource sustain, acquisition, accumulation, and loss process across an organization's lifespan. This again reinforced the important role that resource loss and resource gain play in SCR development.

Thirdly, this study shed light on reconciling the paradox between exploitation and exploration oriented investment in enhancing SCR. Challenging or contradicting current research existing research on exploration and exploitation which argues that organisations should balance exploration and exploitation to obtain the most benefits (Gibson and Birkinshaw 2004; He and Wong 2004), this study revealed that the trade-offs between exploitation and exploration may provide organizations with resource constrained, or resource loss access to sufficient internal or externally located resources to minimize the effects of supply chain disruptions.

There is a growing camp in the literature that argues that exploration and exploitation should be balanced to enhance efficiency in the operation process, while also being flexible enough to adapt to the change in the environment (Gibson and Birkinshaw, 2004). However, most of the research was carried out in organizations with abundant resources. Little empirical effort has been made to examine the tendencies for exploration and exploitation in resource constrained organizations.

This research found in order to be able to resist and react under an environment characterized by high levels of stress and uncertainty, organizations must invest resources and develop certain capacities to withhold the stability of the operations. SCR is enhanced when the organizations have successfully acquired the capability of exploring and/or exploiting. The risks lead to resource loss within organizations (March 1991) and generate emotional pressure, which forces firms to repeatedly utilise existing resources or search for external resources to resist extreme events, recover and adapt. Although organizations with resource loss and constrained resources have limited resources. Some resources, such as knowledge may increase the efficiency of value generation of other resources. Also, organizations often have access not only to the resources that they own but also to resources located in external environments. Through establishing strategic alliances with other supply chain partners who possess complementary resources, organizations ease and compensate for the resource loss caused by disturbance. In this respect, the findings of this study provided a strong indication that organizations that are resource constrained, or experiences resource loss achieve high SCR by making the trade-off between exploration and exploitation, investing in either vertical integration and knowledge management capability building (exploitation orientation) or supplier integration (exploration orientation). Conversely, organizations engage in hybrid resource management strategies) is associated with lower SCR performance.

Finally, building on COR and ambidexterity perspectives, a theory of Resilient Resource Based View (RRBV) of the supply chain was developed. By doing so, we contribute to the existing SCR theory by emphasising that supply chain resources and capabilities are utilized in the SCR building process. This framework is used to illustrate how various supply chain resources are bundled on the condition of different levels of stress organization experiences to create different resilience capacity configurations or repertoire in the context of the Chinese pig industry and reveal how Chinese pig production companies co-evolve with its environment towards the building of their SCR. The perception of resource Valence (appropriateness) of senior management, the Resource availability of existing resource caravan and the complementarity of future invested resources toward the existing resources were found to be crucial when managers decide the resource investment strategies. Two resource management strategies were adopted in the cases to mitigate the risks. Knowledge-based resource management strategy represents firms consistently bundling internal knowledge and tangible resources (physical resources and financial resources) in order to efficiently accumulate, maintain and reconfigure the resources during resource loss. And relationship-based resources bundle represents that the firms focus on managing a portfolio of relationships with various stakeholders (e.g., government, customers, and suppliers) and aligns its supply chain processes in order to effectively acquire external resources to compensate the resource loss. Consequently, two capabilities - knowledge management capability plus vertical integration and supplier integration were found to allow firms to reconfigure the mix of resources and achieve SCR through either efficiently buffering the loss of resources at a lower cost or effectively replacing and acquiring resources.

The Resilient Resource Based View (RRBV) of the supply chain not only explains why organizations engage in different resource management behaviours during the risk event but also reveals two resource management strategies- knowledge management and relationship management plays pivotal roles in resilience building. In turn, two types of capabilities, either knowledge management or supplier integration enables organizations to deploy existing resources and develop new resources effectively in risk events.

The traditional RBV asserts that an organization can achieve competitive advantages through the bundling of resources to create capabilities (Barney, 1991). While the majority of the RBV literature examines resources and capabilities associated with creating value and/or competitive advantage, risk management is primarily a value protection activity (Paape & Spekle, 2012). RBV follows the logic that firms actively seek resources to increase the chance of success, but one that has been relatively ignored is how firms avoid the loss of required resources to survive. In a highly vulnerable environment, organizations seek to maintain the necessary resources reservoir to enable the normal flow of the operation (survive) rather than thrive. The RRBV rests on this later situation. It is suggesting that organizations will engage in different resource management behaviours that avoid resource losses since loss can have such a profound negative impact on the organization itself. The RRBV is concerned with the bundling of strategic resources and capabilities to create and protect competitive advantage. RRBV shares the same assumption of RBV and extends the RBV of the firm from a resilience perspective. It is explicitly predicated on the notion of strategic resource bundling and capabilities building to create and protect competitive advantage. The Resilient Resource Based View (RRBV) does not focus on aspiring firms to acquire unique resources over others to create competitive advantage but encourages the organization to actively seek resources to self-sustain and survive. RRBV can be introduced as a framework for understanding the consequences and coping strategies for major stress caused by supply chain risks. Specifically, it inherently states that when confronted with stress (caused by the significant consequence of direct resource loss), the organization strives to invest strategic resources and develop capabilities to minimize the net loss of resources. This framework provides a perspective to address the existing research gaps in SCR research and provides a more comprehensive and insightful understanding of resource management.

11.3 Practical Contributions

Many companies face challenges and unprecedented disruptions due to pandemics, strikes, war and natural disasters. New insights pertaining to this research offer practitioner implications. These practical implications are extremely useful and critical for resource-constrained organizations to manage supply chain management practices in turbulent business environments and in stressful events. The research provides practical recommendations during the decision-making of how organizations can achieve resilience and survive disruptions. Specific SCR strategies and associated capabilities are provided for pig supply chains in China.

Firstly, this research calls for a mindset change about how supply chain risks should be managed and viewed. Dynamic social-ecological resilience thinking should become an essential skill for managers to deal with uncertainties. Such mindset change involves two aspects: firstly, managers need to recognize that uncertainties and change are the natural characteristics of the supply chain. There is no permanent safe mode. Embracing volatility may create possibilities for not only survival but revive. Secondly, during risk events, the supply chain evolves in nonlinear ways and can no longer go back to its original status. The self-organizing nature of the supply chain does not mean that SCR will automatically be developed. Managers should reframe the perspectives on supply chain risk management and prepare for adaptation and transformation rather than predicting and planning risks.

Secondly, the findings of this study emphasise the importance of resource management can serve as useful guidelines that may help managers who consider investing resources to build resilience. An organization's survival ultimately depends on how to better manage its resources. Practitioners need to realize that an organization's resource management strategies are contingent upon the organizational stress and the internally controlled and externally accessible resources available to a firm, more specifically depending on the organization's existing resources base which includes resource availability, resource valence and resource complementarity. Developing risk mitigation strategies by only focusing on the vulnerabilities or observing competitors to gauge the situation may not be effective to foster resilience and overcome disruptions.

The manager should carefully identify the uncertainties and risks embedded in the supply chain. A thorough evaluation of the existing intangible and tangible available resources, the organization’s expectation on resources to help to mitigate the risks and the complementarity of the new resources to existing resources should be conducted before investments are made.

Finally, the theory and hypotheses presented in this research may guide the managers in the agrifood sector on their choices about how to allocate their resources, time, and effort in building capabilities to build SCR. Our results indicate that based on different resource investing strategies, organizations should pay attention to both the structure of the supply chain and supply chain capabilities to create and sustain SCR. Two supply chain capabilities which respectively represent exploitation and exploration-oriented capabilities are fundamental for SCR. Prior research has left it unclear whether managers should make the trade-off or seek to achieve a balance between exploration and exploitation related capability building. Our research provided the answer with strong evidence that for the agrifood industry when firms face major risks identified in this research, price fluctuation, animal diseases and policy uncertainties, managers in resource-constrained contexts need to either focus on building vertical integration and knowledge management capability or place attention on supplier integration. Specifically, firms that invest in knowledge and tangible resources should work towards vertical integration and invest more in production capability development, product quality improvement, production cost reduction, production process integration and internal knowledge building. Organizations that invest in relationship resources should encourage collaborations from the perspective of supplier relationship development and outsourcing, so that firms may benefit from flexible coordination and a higher possibility of acquirement of core resources like materials, facilities, and knowledge for production.

In sum, this study provides a new perspective and framework to understand and achieve resilience for countering supply chain disruptions. Managers can take advantage of the outcomes of this research to renew, acquire and configure resources, and build capabilities in response to adverse events.

11.4 Limitations and Future Research Directions

This study is not without limitations. However, these limitations may suggest avenues for future research.

Firstly, this study adopts the case study method by selecting the supply chains of four focal organizations in the pig production industry. Although case studies may provide nuanced, empirically rich, holistic information to analyse SCR mechanism in-depth and generate plenty of insights, this study still acknowledges the limitations of exploring a small number of cases which can be criticised for its ability to generalize the findings. However, the rationale behind conducting case studies lies in analytic generalization rather than statistical generalization to enable theory building. In addition, case studies are appropriate for exploring complex and relatively under-explored phenomena which SCR exactly represents. To amplify the external validity and replicability of the case study, this study strictly followed Yin (2008)'s tests on reliability and validity measures. Eight propositions which form the SCR framework were developed in this research, which leaves opportunities for further testing in different research settings so as to add more validity to the findings. In addition, the case studies were employed to address the questions of how organizations build their SCR through resource investment and how the supply chain co-evolves with its environment in terms of SCR building. Further research can explore to what extent the constructs and resource management strategies can affect resilience performance.

Secondly, in this study, the SCR is examined from the perspective of the focal organizations due to their power in the supply chains and essential roles in the risk mitigation process. Mainly, SC risks associated with these focal organizations were considered. By adopting the perspective of a focal firm and examining the upstream and downstream of the supply chain to evaluate the resource configuration and resilience, SCR was evaluated specifically to the operational scope and interests of focal organizations. In addition, the boundary of the supply chain decides how SCR is measured and stakeholders involves. This study acknowledges that exploring SCR considering supply chain partners such as upstream farmers and suppliers, downstream middlemen, food processing companies, distributors and retailers may present distinct findings and a whole picture of how the supply chain evolves and change during a disruption. Particularly, future research may explore how the SCR differs or relates at different levels of the SC network.

Thirdly, how to measure SCR is a further research avenue. Taking equilibrium-based perspectives, the majority of the SCR research uses recovery speed as the index to measure SCR. Pre and post risk steady states were used as a baseline for comparison and measurement. This approach largely ignored the dynamics within and between the stocks and flows, spatial-temporal scales of supply chains, or socioeconomic and ecological dimensions of the metabolism. This gives opportunities for researchers to further develop an SCR measurement by taking an evolutionary resilience view.

Finally, due to the time limitation for PhD study, the observation of SCR in this research was completed over a period of one year with two field visits and follow-up occasional meetings for additional information. Issues of time have not been adequately addressed in this study. The SCR outcomes are linked to the total time and resources invested. As resource loss spirals and investment of resources occur continuously over a long-time span. During this process, SCR involves continuously adapting to not only immediate but also chronic threats. Thus, SCR development is a dynamic process. It would be interesting to explore how the interplay between resources and situational needs changes over time. In addition, SCR development may be not only based on a discrete disruptive event but due to the combined effect of a series of risk mitigation actions over time. Thus, it would be valuable for further studies to take a longitudinal approach to look at resilience, which would allow us to understand how resilience is gained or lost over time. Furthermore, due to continuous adaptations and co-evolution, it is expected that organizations may not only adapt to the risks but learn from the risk mitigation experiences. This could mean that SCR may present differently over time when similar disruption happens. A longitudinal study is appropriate to further investigate this conjecture.

11.5 Final Words

Dealing with uncertainty and unpredictable turbulence is turning into a normal daily status quo for companies. Evolutionary resilience thinking tells us that uncertainties are necessary features of life, which lead to sometimes painful, sometimes surprising consequences. We tend to stay and build up our safety zone by setting a known objective and performance measurement that can indicate the direction of improvements and enable optimal results. We also design routines and contingency plans to avoid adverse events. All these strategies have the assumption that everything is predictable and can be under control. However, unexpected incidents will always be inevitable. Such events force us to change, adapt, move out of the safety zones, and transform into a new status. Building resilience enables us to allow and embrace uncertainties. We need to always keep in mind to be altered to the possible uncertainties around us and prepare ourselves for those challenges, instability, and complexity. Success in the past does not guarantee continuation. However, focusing on self-reinforcement rather than comparing with others, and developing strategies and solutions that fit personally can always be beneficial to improve ourselves, move forward and achieve self-growth so that we can better prepare for the unknown future.

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Appendix

Appendix A: Research Cover Letter

中国猪肉供应链抗风险能力及其机制研究

Research on the Mechanism of risk mitigation and resilience building in the Chinese Pig Supply Chain

项目介绍 Research background

这个项目的核心目的是研究猪肉企业如何通过整合供应链资源，自身能力建设来应对疾病，环境政策和价格波动等带来风险，最终实现猪肉产业链的竞争力。 为回答这个问题，我们主要从以下三个方面进行探讨：

The main objective of this research is to study how pig production organization builds their resilience to deal with various risks embedded in the pig supply chain and how organizations change during the risk mitigation process. To answer this question, we mainly discuss the following three aspects:

一． 以龙头公司领班的猪肉供应链的主要组织结构，以及和上下游各成员之间的相互关系；
The supply chain structure of the pig supply chain is led by the leading focal organization, and the relationship with upstream and downstream members;

二． 龙头企业猪肉供应链主要面临的风险源的研究；
Main sources of risks and uncertainties embedded in the current Chinese pig supply Chain;

三． 各个成员在面对这些风险时的应对策略（供应链风险能力建设）以及所遇到的问题和所取得的成效；
The coping strategies when facing the risks, the problems encountered and the results achieved;

四． 分析猪肉供应链中应对各类风险所需要的主要能力和资源，以及如何在一定成本的前提下，通过增强最重要的供应链弹性能力来最大化猪肉供应链的抗风险能力。
Analyse the main capabilities and resources required to deal with various risks in the pig supply chain, and how to maximize the risk resistance by investing in supply chain resilience under the constraint of budget).

形式： 1-2 小时左右的面对面访谈

Format: Face-to-face interview of around 1-2 hours

采访者：孙蕙 博士研究生 英国谢菲尔德大学

Interviewer: Hui Sun PhD researcher at the University of Sheffield School of Management

Email: Hsun19@sheffield.ac.uk;

孙蕙在英国莱斯特大学取得硕士学位，目前在英国谢菲尔德大学管理学院攻读供应链管理博士学位。孙蕙拥有多年经验跨国公司工作经验，曾参与多项跨国可持续供应链管理和研究项目。

Sun Hui obtained her master's degree from the University of Leicester, UK, and is currently studying for a PhD in supply chain management at the School of Management, University of Sheffield, UK. Sun Hui has many years of experience working in multinational companies and has participated in many international sustainable supply chain management research projects.

被采访人：猪肉生产企业或养殖企业的高级和中级管理者（运营，供应链，采购，营销，财务，猪场主要负责人）

Interviewees: Senior and mid-level managers from pig production organizations and their suppliers (such as chief manager in operations, supply chain, procurement, marketing, finance department, farmers, feed plant managers, and middleman)

产出成果：针对企业供应链风险管理的评估报告一份，期刊论文发表，博士论文
Deliverable Research Outputs: A case report on supply chain risk management, Journal publications, Doctoral Dissertation

主要访谈问题: Sample interview questions

- 公司的猪肉供应链的组织结构。
  Structure of the company's pig supply chain.
- 在猪肉生产各个环节管理过程中有遇到的主要风险。
  major risks encountered in pig production.
- 现存的风险管理机制。
  Existing risk mitigation strategies
- 应对风险的措施。具体如何执行的？
  How to respond to the risks and the implementation process
- 在这个过程中，都遇到的困难。 如何解决的？成本如何？
  Difficulties encountered. How to solve it? What is the cost?
- 为什么考虑这些应对措施？
  Why are these strategies chosen?
- 有没有考虑过预防措施，公司内部做什么改变，避免未来遇到同样风险？
  Any risk prevention measures, what changes are made within the company to avoid the same risks to happen in the future?

研究伦理：我们恪守谢菲尔德大学严格的研究伦理。您的名字和公司名字只会在得到您允许后出现在出版物中。我们从贵公司收集任何信息将只作为研究用途。

Research Ethics: We strictly adhere to the research ethics of the University of Sheffield. Your name and company name will only appear in publications with your permission. Any information we collect from you and your company will only be used for research purposes.

Appendix B: Interview Protocol

访谈提纲 (Interview protocol)

回答者信息：

工作年限？工作职责？

Interviewee Information: how many years of working experience? Position in the organization and job responsibilities?

组织模式相关问题：Organization structure and Supply chain related questions

1) 公司的组织结构 和发展过程
   The organizational structure and history of the company (chief milestones of the company's development)

2) 你们公司的猪肉产业链是什么结构？处于产业链什么位置 （哪个环节会有较高风险？什么风险？具体。那几个环节是有较大优势的。为什么?
   What is the structure of your company's pig supply chain? Which position your company is located within the supply chain? Which chain member has higher risks? What risks? Be Specific. Which chain members have greater advantages? Why?

3) 公司与子公司的关系，公司和养猪场关系（猪肉自产还是外购，猪场全部供应自己公司还是还外卖， 都自己加工还是也找别人 加工完去哪儿？养猪场的种猪购买资金从哪儿来，饲料哪儿来，疫苗哪儿来？和加工厂是立刻结清？
   What is the relationship between the company and your subsidiaries, the relationship between the company and the pig farm? Whether the pig is self-raising or contracted to farmers? Where do the piglets, feeds and vaccines come from? How do you sell the pigs?

4) 上下游合作方式？公司与生猪经纪人是怎么合作的？为什么？和食品公司关系。
   How do you cooperate with upstream and downstream suppliers? How does the company work with pig brokers? Why? What is your relationship with food companies?

5) 如何选择上游供应商和下游分销商？如何评价供应商的绩效？这其中是否存在风险？是否对风险进行预防？为什么？怎么预防？如果发生，怎么办？举例
   How do you choose upstream suppliers and downstream distributors? How to evaluate supplier performance? Are there risks embedded? How do you prevent and deal with these risks? Why? Please specify by examples.

6) 与上下游的治理结构有没有发生变化？（一体化或者分离？）

Has your supply chain structure changed? Why?

7) 上、下游或者与企业、农户之间的关系对于公司发展是否有影响？怎样影响？

   Does the relationship between you and upstream, and downstream suppliers have an impact on the development of the company? How?

8) 如何对合作关系进行管理？（与农户的关系，供应商、屠宰加工企业等。与上下游建立合作关系时有没有进行专用性投资？

   How do you manage the partnership? (Relationship with farmers, suppliers, slaughterhouses, processing enterprises, etc.) Is there any special investment when establishing cooperative relations with upstream and downstream suppliers?

9) 是否对子公司或者养猪场提供培训（采购、生产、加工、销售、仓储物流、研究开发各环节的服务），有什么培训，为什么培训？怎么培训？这些培训对风险控制有作用吗？

   Whether to provide training for subsidiaries, farmers, or pig farms? what training is provided, and why? How do you carry out training? Are these training useful for risk control?

10) 是否还和其他组织，比如大学，政府，媒体，环保组织合作。为什么？怎么合作？

   Do you also cooperate with other organizations, such as universities, governments, media, and NGOs? Why? How to cooperate?

风险相关问题： Risk related questions

1) 对于公司的猪肉供应链，有哪几个事件您觉得比较重要，给公司带来比较大影响？

   Which events do you think had a greater impact on the company?

2) 主要风险有哪些？

   What are the main risks in the pig supply chain?

3) 针对以下风险，您觉得哪些对公司的供应链有影响？（猪周期，猪疾病，环保政策，自然灾害，种猪或者是饲料市场的价格变化）分别对哪些公司会受影响？多大影响？为什么对你们影响不大？为什么影响大？

   How did the risks affect the company’s production? To what extent have these risks affected your company? Why?

4) 你觉得公司已经有哪些能力和资源是最基本要具备的,考虑到风险问题？

   What existing resources and capabilities were important when the company faces these risks?

5) 是否会提前为风险做准备，预测？比如储备猪，你们用不用什么风险管理的工具，比如软件，发生的概率预测等等

Do you prepare for these risks in advance?

6) 现阶段公司内有没有风险控制机制，或者应急计划（物流，库存，资金，技术，IT， 主要员工安排或者特殊安排的培训或者活动。

Is there any existing risk control mechanism or emergency plan (logistics, inventory, capital, technology, IT, key staff arrangements or special arrangements for training or activities in the company currently?

7) 你们怎么制定应对风险的公司内部决策？

What is your internal decision-making process regarding risk mitigation?

8) 针对每一种风险，请具例子阐述风险恢复过程

For each risk, please provide examples of the risk recovery process and how you mitigated the risks.

- 什么时候开始意识到风险给公司带来影响？什么样的影响？有没有影响到公司的上下游供应商？为什么？

  When did you start realizing that the risks had affected the company? What kind of impact? Has it affected the company's upstream and downstream suppliers? Why?

- 具体有什么应对策略？实施中间有没有遇到什么困难？组织结构或者哪些能力帮助公司快速恢复？

  What are the specific coping strategies? What resources did you invest? Did you encounter any difficulties? Has the organizational/supply chain structure changed?

- 你们如何决定应该投资什么资源和多少资源去抵抗风险？

  How do you decide what resources should be invested? And how many resources should be invested?

- 你们有和供应商，和 partner 合作抵御风险吗? 他们有起什么作用吗？

  Did you cooperate with suppliers to mitigate the risks?

9) 如何判定公司从这次风险中恢复了？

How to determine that the company has recovered from this risk? How do you measure your company’s resilience?

10) 风险之后，公司是否增加了什么新的能力？供应链有发生什么变化？

Did the company develop any new capabilities after the risk? Are there any changes in the supply chain or organization?

11) 之后有没有总结为未来风险再次发生做准备？

How do you evaluate your company’s risk mitigation strategies?

12) 如果现在同样的风险再次发生，你觉得公司有能力抵御吗？

If the same risk happens again now, do you think the company have the ability or resources to buffer or deal with it?

13) 你觉得现在的风险机制或者公司政策有缺陷吗？

Do you think the current risk mechanism or company policy/ risk mitigation procedure has shortcomings?

14) 哪些能力在你看来在风险来之前是最重要的?哪些是在事件发生过程中是最重要的？之后？

What resources and competencies, in your opinion, are the most important before during and after the risk?

资金相关问题： Capital-related questions

1) 主要的融资渠道有哪些？有什么困难？
   What are the main financing channels? What's the difficulty?
2) 整个养猪产业链，利润怎么分配？是需求决定供给还是相反？
   How is the profit distributed within the pig supply chain?

信息沟通相关问题： Information-related questions

1) 公司内部有没有信息管理系统。什么时候引进？为什么？对抵抗风险有什么作用？
   Does the company have an internal information management system or ERP system? What is its role in the risk mitigation process?
2) 公司是否与上下游或者合作伙伴分享信息？分享什么样的信息？
   Does the company share information with upstream and downstream suppliers? What kind of information do you share?

物流相关问题：land and locations related questions

1) 公司如何获得土地？
   How do you acquire land for production?
2) 公司如何进行子公司或者养殖场的选址决策？
   How does the company make decisions on the location of pig farms? Or choose farmers?

创新相关问题：R&D related questions

1) 公司是否有专业的研发部门？多少人？主要从事哪方面的研发？公司研发投入的比例大概是多少？

   Does the company have an R&D department? how many people? What kind of research and development are you mainly engaged in? How much does the company invest in R&D?

2) 您认为行业技术更新频率快么？复制性高么？主要的技术更新集中在哪些方面？技术创新对抵抗风险有什么作用？举例

   What is the role of technological innovation in risk mitigation? Please give specific examples.

企业绩效：Performance measurement related questions

1) 公司用什么衡量企业绩效？

   How does the company evaluate company's performance?

政策相关问题：Policy related questions

1) 国家的相关政策（污染、无害化处理、规模场建设、补贴等）对公司的战略制定或经营是否有影响？具体体现在哪些方面？

   How do government environmental policies (regarding pollution control, harmless treatment, subsidies, etc.) affect the company? Examples.

2) 是否有应对政策变化的机制，可以灵活应对政策的变化？举例

   Is there a mechanism or strategy for responding to policy? Examples.

Appendix C: Informed Consent

Informed Consent

(To be read at beginning of each interview)

I am a PhD researcher at the school of management the University of Sheffield. I am conducting research looking at risk mitigation and resilience building in the Chinese pig supply chain. You are invited to take part in this research project. This is not a clinical or diagnostic interview, but purely an interview to grasp your views on resilience building and risk management in your organization.

Your participation is voluntary, and you will not receive any compensation for your time. You may refuse to answer any questions, participate in this interview and are free to withdraw at any time, without giving any reason.

The interview is confidential, and your anonymity will be maintained throughout the research. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. I will ask you to record the interview, but this is at your discretion. I will destroy the electronic recording of the interview as soon as my thesis is completed. If you do not want me to record your responses, then I will just take notes. Identifiable data will be stored securely for 3 years. Other research data will be stored for 5 years after publication or public release of the work of the research. Only the researcher and research team will have access to the research data.

As well as in the final thesis, the findings from this research may be presented at the conference and published in academic journals. I/ We would like your permission to use direct quotations and for your name to be attributed to these/ but without identifying you in any research outputs. You have the choice of whether your name will be identifiable from the research outputs. Also, I will provide you with a copy of my results with the aim to support best practices and improvement in respect of your organization's resilience building.

This study has received ethics approval from the University of Sheffield Research Ethics Committee.

If you have any concerns or questions about any aspect of this study, please do not hesitate to contact me. My contact details are Hui Sun at the School of Management, University of Sheffield. Email: Hsun19@sheffield.ac.uk;

Alternatively, you can contact my first supervisor, Professor Lenny Koh (email: S.C.L.Koh@sheffield.ac.uk) and we will do our best to answer your query.

The three-year PhD research study is funded by the Economic and Social Research Council White Rose Consortium.

Appendix D: Interview Photos

Muyuan's pig production

Figure 1 Muyuan's office building in Nanyang city

Figure 2 Muyuan's pig price and sales volume monitoring sytem

Figure 3 Muyuan’s internal leafleat to promote food safety

Figure 4 Muyuan’s feeds

Figure 5 Muyuan’s feeds plant

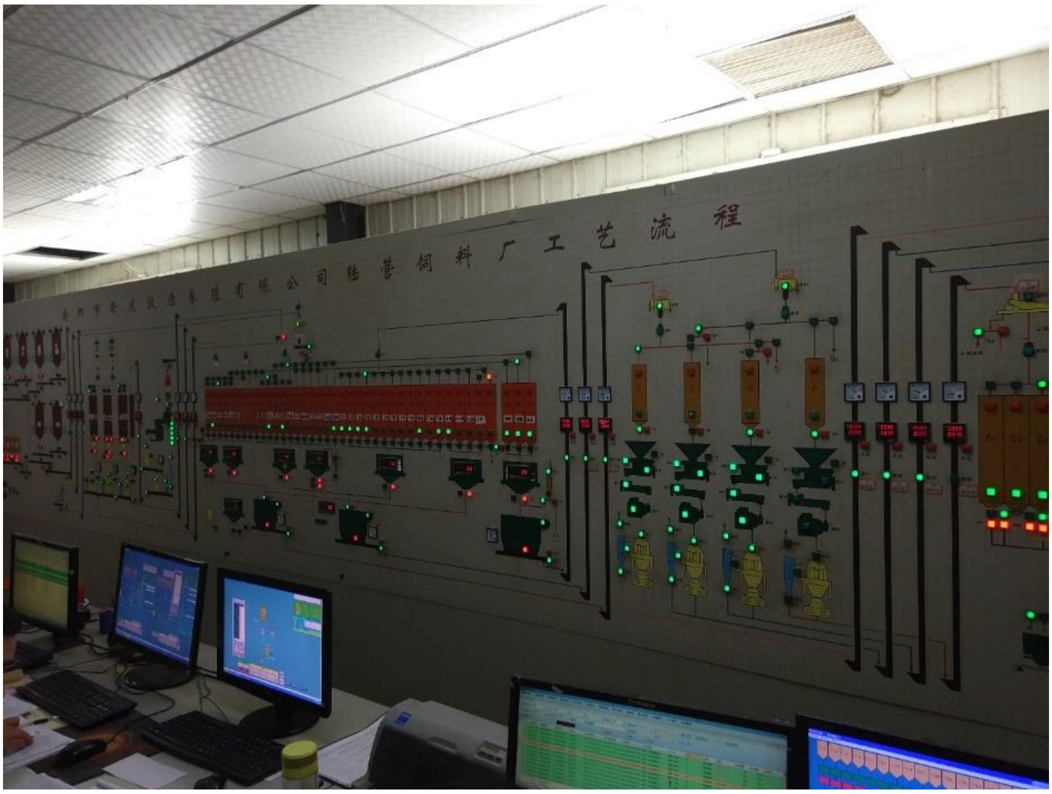


Figure 6 Muyuan’s production process monitoring system

Lihua's pig production

Figure 7 Lihua's office building in Changzhou city (the top line is company's name, the second line says trust, cooperation, innovation and regulation)

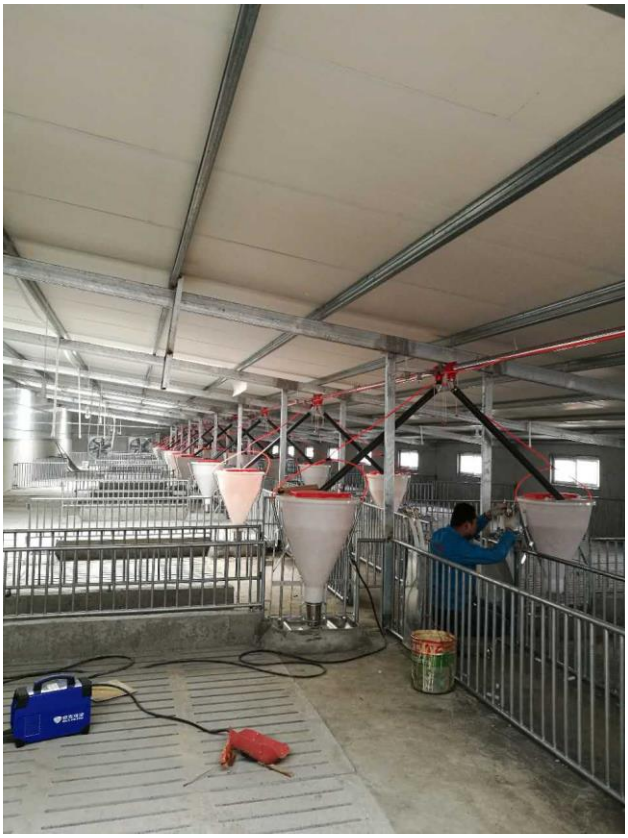


Figure 8 Lihua's newly built pig house

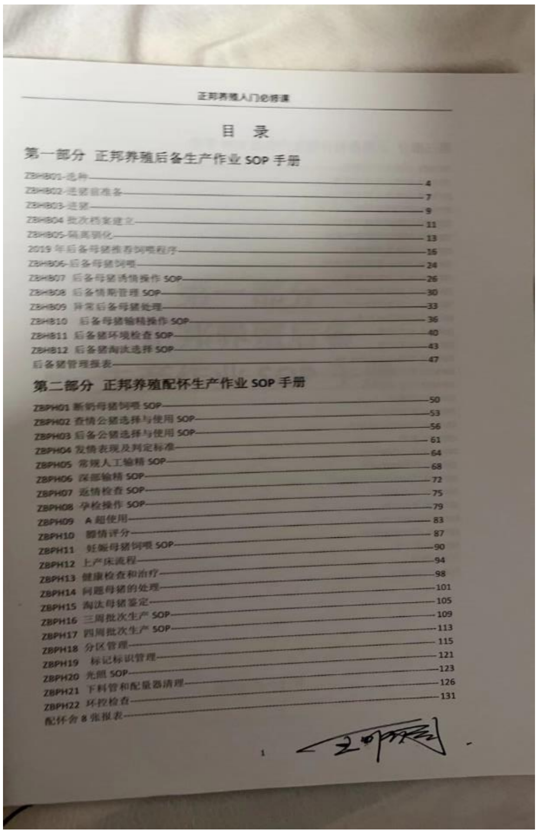
Figure 9 Lihua’s pig pen

Hanshiwei’s pig production

Figure 10 Hanshiwei’s office building in Bangpu city

Figure 11 Hanshiwei's feeds plant

Figure 12 Hanshiwei's truck to deliver the pigs



正邦养殖入门必修课

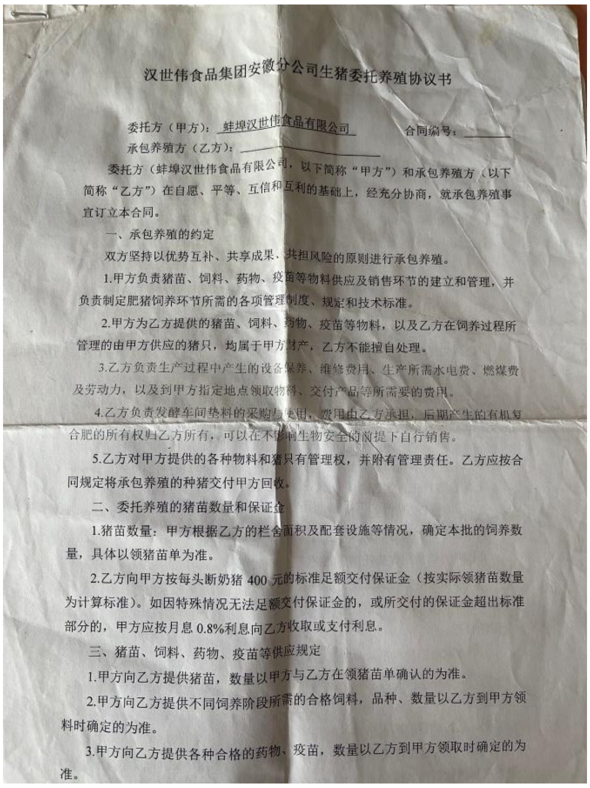
目 录

第一部分 正邦养殖后备生产作业 SOP 手册

第二部分 正邦养殖配怀生产作业 SOP 手册

1

Figure 13 Hanshiwei’s internal training materials



汉世伟食品集团安徽分公司生猪委托养殖协议书

委托方（甲方）：蚌埠汉世伟食品有限公司　　合同编号：________

承包养殖方（乙方）：________________

委托方（蚌埠汉世伟食品有限公司，以下简称“甲方”）和承包养殖方（以下简称“乙方”）在自愿、平等、互信和互利的基础上，经充分协商，就承包养殖事宜订立本合同。

一、承包养殖的约定

双方坚持以优势互补、共享成果、共担风险的原则进行承包养殖。

1.甲方负责猪苗、饲料、药物、疫苗等物料供应及销售环节的建立和管理，并负责制定肥猪饲养环节所需的各项管理制度、规定和技术标准。

2.甲方为乙方提供的猪苗、饲料、药物、疫苗等物料，以及乙方在饲养过程所管理的由甲方供应的猪只，均属于甲方财产，乙方不能擅自处理。

3.乙方负责生产过程中产生的设备保养、维修费用、生产所需水电费、燃煤费及劳动力，以及到甲方指定地点领取物料、交付产品等所需要的费用。

4.乙方负责发酵车间垫料的采购与使用，费用由乙方承担，后期产生的有机复合肥的所有权归乙方所有，可以在不影响生物安全的前提下自行销售。

5.乙方对甲方提供的各种物料和猪只有管理权，并附有管理责任。乙方应按合同规定将承包养殖的种猪交付甲方回收。

二、委托养殖的猪苗数量和保证金

1.猪苗数量：甲方根据乙方的栏舍面积及配套设施等情况，确定本批的饲养数量，具体以领猪苗单为准。

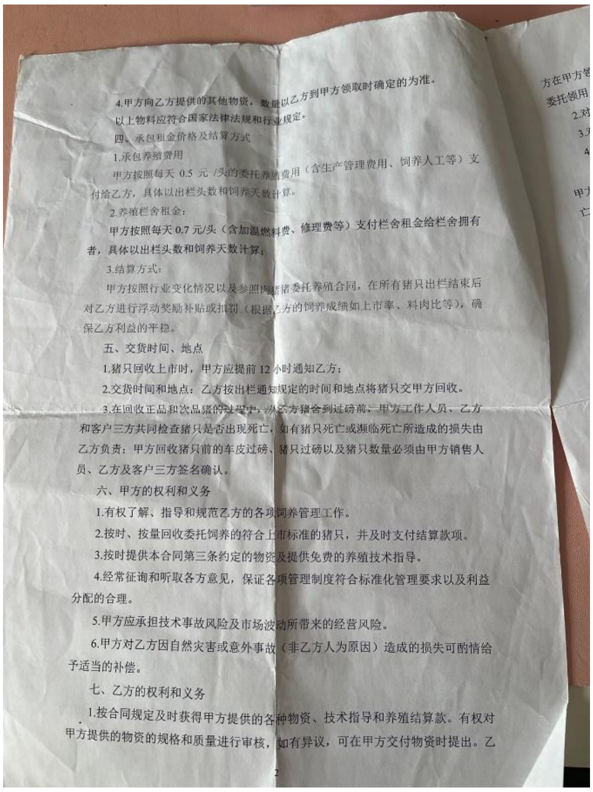
2.乙方向甲方按每头断奶猪 400 元的标准足额交付保证金（按实际领猪苗数量为计算标准）。如因特殊情况无法足额交付保证金的，或所交付的保证金超出标准部分的，甲方应按月息 0.8%利息向乙方收取或支付利息。

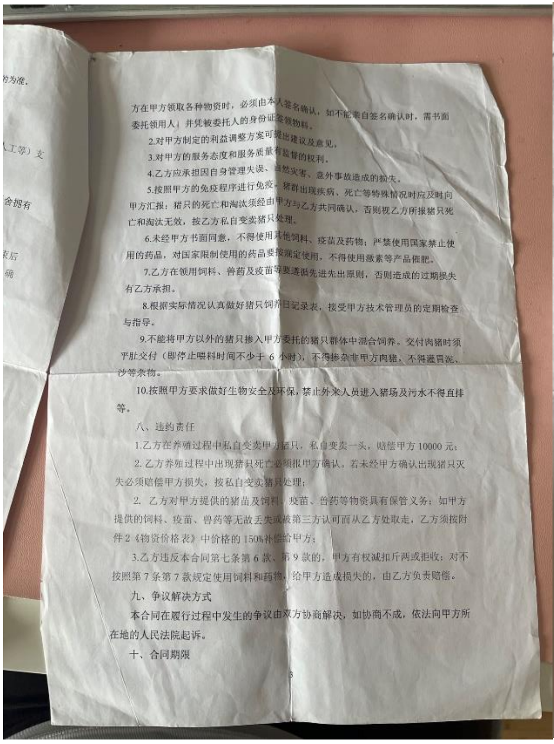
三、猪苗、饲料、药物、疫苗等供应规定

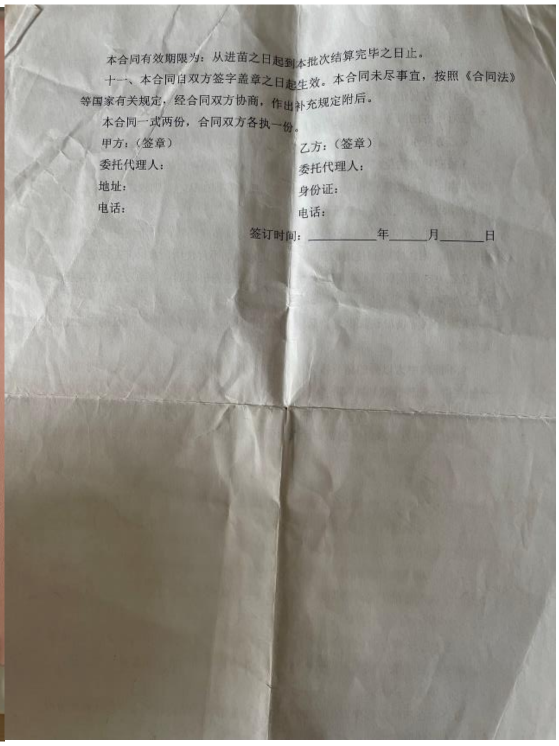
1.甲方向乙方提供猪苗，数量以甲方与乙方在领猪苗单确认的为准。

2.甲方向乙方提供不同饲养阶段所需的合格饲料，品种、数量以乙方到甲方领料时确定的为准。

3.甲方向乙方提供各种合格的药物、疫苗，数量以乙方到甲方领取时确定的为准。


4.甲方向乙方提供的其他物资，数量以乙方到甲方领取时确定的为准。
以上物料应符合国家法律法规和行业规定。
四、承包租金价格及结算方式
1.承包养殖费用
甲方按照每天 0.5 元 /头的委托养殖费用（含生产管理费用、饲养人工等）支付给乙方，具体以出栏头数和饲养天数计算。
2.养殖栏舍租金：
甲方按照每天 0.7 元/头（含加温燃料费、修理费等）支付栏舍租金给栏舍拥有者，具体以出栏头数和饲养天数计算；
3.结算方式：
甲方按照行业变化情况以及参照肉猪猪委托养殖合同，在所有猪只出栏结束后对乙方进行浮动奖励补贴或扣罚（根据乙方的饲养成绩如上市率、料肉比等），确保乙方利益的平稳。
五、交货时间、地点
1.猪只回收上市时，甲方应提前 12 小时通知乙方；
2.交货时间和地点：乙方按出栏通知规定的时间和地点将猪只交甲方回收。
3.在回收正品和次品猪的过程中，从乙方猪舍到过磅前，甲方工作人员、乙方和客户三方共同检查猪只是否出现死亡，如有猪只死亡或濒临死亡所造成的损失由乙方负责；甲方回收猪只前的车皮过磅、猪只过磅以及猪只数量必须由甲方销售人员、乙方及客户三方签名确认。
六、甲方的权利和义务
1.有权了解、指导和规范乙方的各项饲养管理工作。
2.按时、按量回收委托饲养的符合上市标准的猪只，并及时支付结算款项。
3.按时提供本合同第三条约定的物资及提供免费的养殖技术指导。
4.经常征询和听取各方意见，保证各项管理制度符合标准化管理要求以及利益分配的合理。
5.甲方应承担技术事故风险及市场波动所带来的经营风险。
6.甲方对乙方因自然灾害或意外事故（非乙方人为原因）造成的损失可酌情给予适当的补偿。
七、乙方的权利和义务
1.按合同规定及时获得甲方提供的各种物资、技术指导和养殖结算款。有权对甲方提供的物资的规格和质量进行审核，如有异议，可在甲方交付物资时提出。乙
2


方在甲方领取各种物资时，必须由本人签名确认，如不能亲自签名确认时，需书面委托领用人，并凭被委托人的身份证签领物料。
2.对甲方制定的利益调整方案可提出建议及意见。
3.对甲方的服务态度和服务质量有监督的权利。
4.乙方应承担因自身管理失误、自然灾害、意外事故造成的损失。
5.按照甲方的免疫程序进行免疫。猪群出现疾病、死亡等特殊情况时应及时向甲方汇报；猪只的死亡和淘汰须经由甲方与乙方共同确认，否则视乙方所报猪只死亡和淘汰无效，按乙方私自变卖猪只处理。
6.未经甲方书面同意，不得使用其他饲料、疫苗及药物；严禁使用国家禁止使用的药品，对国家限制使用的药品要按规定使用，不得使用激素等产品催肥。
7.乙方在领用饲料、兽药及疫苗等要遵循先进先出原则，否则造成的过期损失有乙方承担。
8.根据实际情况认真做好猪只饲养日记录表，接受甲方技术管理员的定期检查与指导。
9.不能将甲方以外的猪只掺入甲方委托的猪只群体中混合饲养。交付肉猪时须平肚交付（即停止喂料时间不少于 6 小时），不得掺杂非甲方肉猪，不得灌胃泥、沙等杂物。
10.按照甲方要求做好生物安全及环保，禁止外来人员进入猪场及污水不得直排等。
八、违约责任
1.乙方在养殖过程中私自变卖甲方猪只，私自变卖一头，赔偿甲方 10000 元；
2. 乙方养殖过程中出现猪只死亡必须报甲方确认。若未经甲方确认出现猪只灭失必须赔偿甲方损失，按私自变卖猪只处理；
2. 乙方对甲方提供的猪苗及饲料、疫苗、兽药等物资具有保管义务；如甲方提供的饲料、疫苗、兽药等无故丢失或被第三方认可而从乙方处取走，乙方须按附件 2《物资价格表》中价格的 150%补偿给甲方；
3.乙方违反本合同第七条第 6 款、第 9 款的，甲方有权减扣斤两或拒收；对不按照第 7 条第 7 款规定使用饲料和药物，给甲方造成损失的，由乙方负责赔偿。
九、争议解决方式
本合同在履行过程中发生的争议由双方协商解决，如协商不成，依法向甲方所在地的人民法院起诉。
十、合同期限
3


本合同有效期限为：从进苗之日起到本批次结算完毕之日止。
十一、本合同自双方签字盖章之日起生效。本合同未尽事宜，按照《合同法》等国家有关规定，经合同双方协商，作出补充规定附后。
本合同一式两份，合同双方各执一份。

甲方：（签章）	乙方：（签章）
委托代理人：	委托代理人：
地址：	身份证：
电话：	电话：

签订时间：__________年______月______日

Figure 14 Hanshiwei’s sample contract with farmers

Figure 15 Hanshiwei’s vehicle sanitise pool

Figure 16 collaborated farmer’s pig house

Figure 17 Hanshiwei's tea garden (use organic fertilizers made of pig manure)

Figure 18 pipe to transport the liquid fertilizers

Figure 19 Septic tank

Figure 20 Solid-liquid separator

Figure 21 Anaerobic pool covered by black film

Figure 22 fermentation tank

Figure 23 manure fermentation process

Nanchuanhe cooperative’s pig production

Figure 24 Nanchuanhe cooperative’s office in Liuyang city

Figure 25 internal materials on the wall

Figure 26 2016 Outstanding cooperative award (Granted by the Economic and Technical Professional Committee of Rural Cooperatives)

Figure 27 Cooperative member's house (also one of the Nanchuanhe's training bases)

Figure 28 CCTV system in pig house

Figure 29 Cooperative member's pig house

Figure 30 Biogas tank in Cooperative member’s pig house

Figure 31 Nanchuanhe helped its member to sell pigs

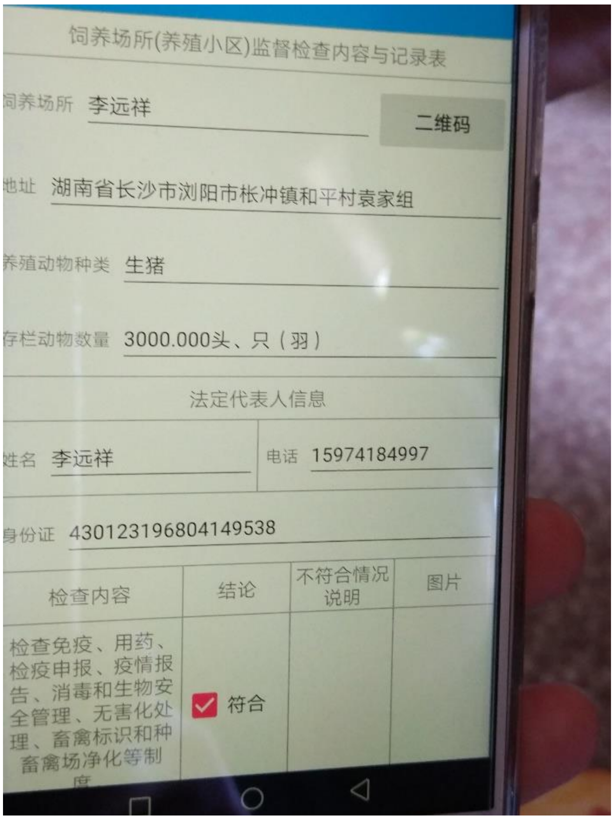


Figure 32 Pig raising supervision and inspection sheet (including member’s information, production capacity, pig vaccination details)

Appendix E: Publications and Publications In Preparation

Conference paper

Sun, H., Koh, L., Jia, F. and Choudhary, S (2017) "Resilience in Agricultural Supply Chain: An Evidence-Based Research with Bibliometrics Analysis". The 24th European Operations Management Association Conference. Edinburgh, China, July 2017

Papers in preparation based on my PhD

Sun, H., Koh, L. and Choudhary, S. Resilience in Agricultural Supply Chain: A literature review and Meta-analysis. To be submitted *International Journal of Operations and Production Management* in 2022.

Sun, H. and Koh, L. Resilience in Agricultural supply chain: conservation of resources perspective. To be submitted *Journal of Operations Management* in 2023.

Sun, H., Koh, L. and Choudhary, S. Evolution of Business Models and Sustainable Development of Cooperatives: The Case of NCH Cooperative in China. To be submitted *Emerald Emerging Markets Case Studies* in 2022.