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A resilience model for cold chain logistics of perishable products

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A resilience model for cold chain logistics of perishable products

Abstract

Purpose – Most of the extant literature on resilience builds on normative, conceptual or silo approaches, thereby lacking an integrative approach to cold chain logistics risks (CCLRs) and resilience. This paper aims to bridge the current research gap by developing a model, based on broad empirical evidence, of the interplay between CCLRs, resilience and firm performance in perishable product supply chains (PPSCs).

Design/methodology/approach – A mixed method approach is used with qualitative data from interviews and quantitative data from a survey across the supply chain. The analysis is framed by contingency theory and resource-based theory.

Findings – Four significant sources of CCLRs and six resources used to build resilience are identified. Then, supply chain resilience (SCR) as a moderator of the negative relationship between CCLRs and firm performance is corroborated.

Practical implications – The findings will help improve managerial understandings of critical sources of risks in cold chain logistics and resources indispensable to build resilience. The scope of the research is cold chain logistics for PPSCs, which has relevance to other cold supply chains as well.

Originality/value – While some theoretical frameworks suggest resilience being moderator in the negative relationship between cold chain risks and performance, this study empirically tests this relationship using the survey across the entire supply chain. A new empirically and theoretically driven definition of SCR is also developed.

Keywords – Cold chain, logistics, risks, resilience, perishable products.

Paper type – Research paper

1. Introduction

Logistics plays a critical role in sustaining fresh food supply around the world. However, complex and lengthy supply chains, exposure to uncertain weather conditions and shorter shelf life of fresh foods make firms in perishable product supply chains (PPSCs) vulnerable to distinct logistics risks. As modern PPSCs are part of global networks (Shukla and Jharkharia, 2013), the disruption caused by a risk occurring at any point in their supply chain can have a ripple effect on food supply globally. For instance, a temporary delivery delay caused by the 2016 flood in New South Wales, Australia, resulted in spoilage of around AUD 500 million fresh food supply (Australian Broadcasting Corporation, 2016). These circumstances necessitate resilient logistics operations in PPSCs.

A PPSC encompasses a network of firms involved in the production and distribution of fresh and processed foods, from the point of production to the point of consumption, to meet the customer's requirement. The perishable food industry contributes significantly to the economy and society of many developing and developed countries of the world (Shukla and Jharkharia, 2013). This industry's share of the gross domestic product is 2.4% in Australia, 4.8% in America and 9.2% in China (World Bank, 2016). Likewise, its contribution to

employment accounts for 3% in Australia, 9.3% in America, and around 5% to10% in some European countries (World Bank, 2016).

Perishable products are transported through cold chain logistics within and outside country borders to preserve their value. Cold chain logistics involves uninterrupted transportation and storage activities within a low and controlled temperature range to extend or maintain the shelf life of the fresh food products. However, due to the nature of the PPSCs, cold chain logistics is not immune to distinct logistics disruptions. Drawing upon the widely accepted concept of logistics of the Council of Supply Chain Management Professionals (CCMP, 2017), we define logistics disruption as a failure in the flow of material or information caused by a critical risk. Logistics disruption in food supply can cause food waste, leading to food shortages and economic losses.

In today's dynamic and turbulent business environment, supply chain resilience (SCR) has emerged as a new capability in enabling an organisation to prepare, resist and rebound from disruption to its original or better state (Fiksel *et al.*, 2015; Jüttner and Maklan, 2011). Numerous researchers articulate the significance of SCR in coping with logistics risks (Handfield and McCormack, 2007; Nepal and Yadav, 2015; Ponomarov and Holcomb, 2009). However, most studies either build on generic frameworks highlighting the importance of SCR or debate the definition of resilience (Tukamuhabwa *et al.*, 2015). As such, there is a paucity of empirically and theoretically grounded comprehensive research in SCR (Kamalahmadi and Parast, 2016; Tukamuhabwa *et al.*, 2015). Specifically, the extant literature lacks the broader landscape and triangulation of findings on specific sources of cold chain logistics risks (CCLRs), resources intertwined to build SCR, and their interactive impact on firm performance, including PPSCs.

This paper addresses this knowledge gap in the current literature by using firms from the Australian citrus industry as representative of PPSCs. The citrus industry provides an interesting context for examining the phenomenon of risk and resilience, because citrus is one of the top globally exported fresh foods (United States Department of Agriculture (USDA), 2016). This industry plays a significant role in the economies and employment opportunities of many countries, including America, Australia, Brazil, China and Italy, among others (USDA, 2016). The activities of the citrus industry include the production, processing and distribution of a variety of perishable products, including mandarins, oranges, grapefruits, lemons, limes and tangerines, and their juices and jams (Horticulture Innovation Australia Limited, 2014). The Australian citrus industry has global supply chains and logistics operations with annual exports of around 165,000 (27.5%) out of total 600, 000 tonnes fruit to over 30 destinations including Hong Kong, Indonesia, the Middle East, China, Korea and Japan (Citrus Australia Limited, 2014). However, long transit times, swiftly changing quality standards and shorter product shelf life expose firms to distinct CCLRs, necessitating more resilient logistics operations. Given these circumstances, the main objective of this paper is to develop a holistic model that identifies specific CCLRs and resources necessary to build resilience and to safeguard PPSC performance.

2. Literature review and theoretical underpinning

The concept of risk has been widely discussed in diverse fields of study, such as economics (e.g. Willett, 1901; Knight, 1921), finance (e.g. Smith *et al.*, 1989; Schinasi *et al.*, 1999), strategic management (Thomas and Baird, 1990), international management (Miller, 1992), and supply chain management (Kraljic, 1983; Harland *et al.*, 2003). While the context of the studies might change across the field, the basic concept of risk remains the same; risk is a product of the probability of loss and consequences (Kraljic, 1983; Harland *et al.*, 2003).

Building on this concept of risk, supply chain risk management focuses primarily on identification and quantification of risks (Fiksel *et al.*, 2015). However, in reality, it is difficult to identify and quantify risks emerging from dynamic business environments (Fiksel *et al.*, 2015); hence, supply chain risk management lacks the ability to prepare a firm for unpredictable or unknown events (Pettit and Fiksel, 2010). Consequently, SCR has been identified as a key capability to address a myriad of predictable and unpredictable risks in a supply chain (Fiksel *et al.*, 2015; Ponomarov and Holcomb, 2009).

A resilient supply chain incorporates event readiness, provides an efficient and effective response and is capable of recovering back to its original or even better (Ponomarov and Holcomb, 2009; Jüttner and Maklan, 2011). Readiness is considered crucial to reduce the chances of a risk occurring (Ponomarov and Holcomb, 2009; Sharma and Srivastava, 2015); whilst response, recovery and growth are the actions taken after a risk unfolds (Ponomarov and Holcomb, 2009; Gunasekaran *et al.*, 2015). Ates and Bititci (2011) argue that resilience is a firm's ability to absorb disruptions and enables the supply chain network to return to its original state faster, thus having a positive impact on firm performance.

While research on logistics risk management has been progressing, much still remains to be learnt. Chopra and Sodhi (2004) propose a conceptual framework highlighting the issues of delivery delays. Manuj and Mentzer (2008) and Christopher *et al.* (2011) offer case studies on risk management in global outsourcing. Ishfaq (2012) propose a generic framework suggesting flexibility (multimode transportation) as an important antecedent to resilience. Sharma and Srivastava (2015) identified community resilience as a source to create resilient supply chains and logistics operations. Zsidisin *et al.* (2016) undertook a case study approach and assessed quality risk in the upstream supply chain of the food machinery industry. Urciuoli and Hintsa (2016) offer insights on variation in security risk perception between logistics firms and cargo owners. König and Spinler (2016) propose a conceptual framework for the impact of logistics outsourcing on supply chain vulnerabilities. Sahay *et al.* (2016) and Özdamar and Ertem (2015) offer frameworks for humanitarian logistics.

Although the prior studies made considerable contributions to literature, most of them rely either on case studies (Ali *et al.*, 2017; Ali and Shukran, 2016; Manuj and Mentzer, 2008; Christopher *et al.*, 2011; Zsidisin *et al.*, 2016; Urciuoli and Hintsa, 2016), conceptual frameworks (Chang *et al.*, 2015; Greening and Rutherford, 2011;König and Spinler, 2016) or on non–industry-specific frameworks (Chopra and Sodhi, 2004; Ishfaq, 2012; König and Spinler, 2016). Most current literature shows normative and silo approaches (Tukamuhabwa *et al.*, 2015), thereby lacking broad empirical evidence on disruption (risks) and recovery (resilience) mechanisms in a holistic manner. Existing silo-approaches discuss risk and resilience in isolation and predominantly focus on non-perishable products (Gualandris and Kalchschmidt, 2015); they fail to offer an integrative model of risks, resilience and firm performance.

A few studies that have focused on perishable products include Bogataj *et al.* (2005) and Stringer and Hall (2007), who highlight the importance of temperature control in food logistics. Scudder and Blackburn (2009) emphasise the significance of collaboration in mitigating food quality risk and Rong *et al.* (2011) express the need for efficient temperature adjustment in containers. Others focus on temperature-related issues (Kuo and Chen, 2010; Ali *et al.*, 2013; Aramyan *et al.*, 2007) or propose a conceptual framework of fresh food logistics (Shukla and Jharkharia, 2013). These studies show researchers' growing interest in the logistics challenges of firms in PPSCs, but their focus remains unidimensional (e.g. temperature control) or they offer mathematical/simulation models. Recently, a comprehensive review of the literature by Fredriksson and Liljestrand (2015) shows that the previous research on food logistics focuses on the topic of relationship management. Particularly, it is difficult to find a

study offering large-scale empirical evidence of the resources required to build resilience against specific CCLRs that are prevalent in PPSCs.

2.1 Theoretical underpinning

The empirical analysis of this paper builds on the insights from contingency theory (CT) and resource-based theory (RBT). These theoretical perspectives and their complementary characteristics in addressing supply chain risks, resilience and resulting firm performance are briefly discussed in the following section.

2.1.1 Contingency theory

The basic premise of CT is that efficiency and performance result when a firm matches its strategy or resources with the context or environment (Lorsch and Lawrence, 1967; Donaldson, 2001). The terms 'context' and 'environment' have been widely discussed in the strategic management and organisational behaviour literature. We use the notion of 'environment' offered by Duncan (1972) and characterised by risks in the field of supply chain risk management (Wagner and Bode, 2008; Trkman and McCormack, 2009). Thus, using CT, we identify CCLRs in the internal and external environment and their degree of influence on the firm's performance in PPSC.

Although CT facilitates the identification of CCLRs, this theory does not explicitly specify features of resources and capabilities used to deal with them. Therefore, in this paper, we complement CT with RBT to explore CCLRs as well as resources and capabilities crucial to safeguarding a firm's performance.

2.1.2 Resource-based theory

Penrose (1959, p. 75) first introduced the resource-based view (RBV) as a bundle of unique resources that reside in a firm, which could be a source of a competitive advantage. Subsequently, scholars observed that firms could achieve a competitive advantage by using their unique resources and capabilities (Barney 1991; Rumelt 1984). Twenty years later, the RBV had evolved into RBT, with the argument that the RBV had reached a level of sophistication and resembled a theory than a view (Barney *et al.*, 2011). Therefore, this paper uses the term RBT instead of RBV.

Since supply chain risks are inevitable, firms can use resources and capabilities to create resilience (Blackhurst *et al.*, 2011). Hence, using the RBT lens (Barney *et al.*, 2011; Rungtusanatham *et al.*, 2003), we identify key resources and capabilities used to create resilience in logistics operations. Barney (1991) suggests three categories of resources that can be used to create competitive benefits: (1) organisational and inter-organisational capital resources, (2) human capital resources, and (3) physical capital resources. Friedrichs (2003) and Becker (1964) suggest that organisational and inter-organisational capital resources, including planning and coordinating systems, and human capital resources, such as training and education, are intangible. While, Williamson (1977) believe that physical capital resources including inventory, equipment and technology, are tangible. As such, we explore both intangible and tangible resources that can be used to develop resilience to risks in cold chain logistics.

2.2 Research questions

The existing gap in the literature on supply chain risk and resilience and two theoretical perspectives (CT and RBT) have led to the development of the following three important research questions (RQs):

RQ1. What are the specific CCLRs and resources/capabilities required to build resilient logistics operations by PPSCs?
RQ1. How do cold chain logistic risks impact on firms' performance?
RQ1. How does SCR influence this relationship?

3. Research design and findings

In order to answer the stated research questions, this paper applies a mixed method approach in two sequential phases: qualitative followed by quantitative. The constructs and hypotheses developed in the qualitative phase are used to inform the quantitative phase. A sequential mixed-methods approach offers a broad landscape through triangulation of empirical results and overcomes potential limitations associated with a singular method (Creswell, 2013; Feilzer, 2009). Each phase of this study is discussed in the following sections.

3.1 Phase 1: Qualitative research

The qualitative research is of an exploratory nature and aims to answer RQ1: What are specific CCLRs and resources and capabilities required to build resilient logistics operations by PPSCs? Exploratory case study is the most appropriate method to answer 'what' and 'why' types of questions (Creswell, 2013; Yin, 2013).

Data for this phase were collected through semi-structured interviews. Based on the review of the current literature, an interview protocol was developed (Creswell, 2013) to understand how divergent risks and resources that intertwine to build resilience. Overall, 30 interviews were conducted at all levels of the supply chain, including producers, packers, wholesalers, processors, retailers and transporters. The contact list of interview participants was collected from a national industry body. From this list knowledgeable participants were selected, such as chief executive officers (CEOs), general managers, operations managers, managing directors, owner-managers and farm managers (see Appendix A), as suggested by Creswell (2013). The interviews lasted between 40 and 60 minutes until saturation of information was achieved, as advised by Yin (2013). The interviews were recorded and transcribed verbatim. The data were analysed using a content analysis technique. In order to enhance the analysis process and view the relationship among variables more vibrantly, NVivo software was used. Various themes related to CCLRs and resources used to develop resilience were identified and clustered to develop constructs of risk and resilience. The relationships between these constructs are presented through hypotheses.

The reliability and validity of the qualitative findings were checked by adopting the widely used four rules of Guba (1981) and Guba and Lincoln (1994): (1) credibility—the participants were asked to review the interview transcripts and provide feedback on any misunderstandings or omissions; (2) transferability—different participants were chosen to present variation in position type and responsibilities; (3) dependability—the developed codes were compared with the codes by the other researchers for the same transcript and the inter-code comparison was found satisfactory with 82% similarity; and (4) conformability—the findings were supported by quotes, regular review of data and analysis procedures.

3.2 Findings of the qualitative research

3.2.1 Cold chain logistic risks

Given the shorter product life cycle, perishable products require a highly sophisticated cold chain transportation system (Kuo and Chen, 2010). Despite its potential benefits, cold chain

logistics is found to be highly vulnerable to the risks (Bogataj *et al.*, 2005). Contingency theory suggests that a firm's competitive success relies on its ability to effectively recognise risks (contingencies) in the environment (Lorsch and Lawrence, 1967). Building upon CT, we identified four critical risks (contingencies) to the cold chain logistics of PPSCs.

The first significant risk to cold chain logistics identified from the interview data is temperature breakdown. Efficient temperature control and adjustment is integral to maintaining the product's shelf life (Stringer and Hall, 2007; Sahin *et al.*, 2007); however, the general managers of Firms 12 and 27 and an operations manager from Firm 15 frequently mentioned that in sea transportation, as a container moves towards the equator, the external temperature becomes hotter. At a critical point, operators need to adjust the container's internal temperature quickly. Nonetheless, temperature breakdowns happen due to negligence or lack of trained operators, leading to the risk of consignment failure (managers of Firms 13, 15, 16, 20 and 30). The analysis of the interview data showed that 60% of managers (18 out of 30) considered temperature breakdown a serious source of risk to cold chain logistics.

The second critical risk identified from the interview data is substandard packaging. Good quality packaging material is essential in maintaining the desired value of fresh foods (Vasileiou and Morris, 2007; Aramyan *et al.*, 2007; Bourlakis *et al.*, 2014); however, many managers (e.g. of Firms 3, 4, 10 and 29) reported substandard packaging as an important concern. For instance, the CEO of Firm 26 lamented that the packaging material used for the boxes has weak stacking strength and cannot withstand chilling temperatures in containers. He stated that:

> Packaging material has an insufficient stacking strength and cannot resist [the] injuries caused by extremely low temperatures and the highly humid environment in the container, resulting in product quality deterioration including tissue darkening, surface pitting and discolouration.

From the interview data, the majority of the firm managers (19 out of 30) deemed substandard packaging to be among the major sources of food damage and consignment failure in cold chain logistics.

The third critical risk to the cold chain logistics from the interview data is natural disaster. In Australia the major cities are in the coastal areas, which are prone to frequent disruptions caused by natural disasters such as floods, storms, cyclones and hurricanes (managers of Firms 1, 2, 3 and 30). When these incidents occur, they completely disrupt the logistics operations. The manager of Firm 29 reported that natural disasters destroy infrastructure and disrupt the cold chain logistics operations. He commented as:

> Disruptions caused by floods, heavy rains, hurricanes and cyclones are rather frequent in Australia, leading to the breakdown of infrastructure (roads, bridges and communication systems) and failure of the cold chain logistics.

The general managers of Firms 12, 13 and 17 stated that in January 2013, the flooding of the Burnett River caused severe infrastructure damage in the north-west of Brisbane, Queensland. This area is the second largest exporter of fresh fruit in Australia. However, the breakdown of infrastructure halted the supply of product to downstream supply chains, leading to huge financial losses. The analysis revealed that 77% of the firms (23 out of 30) encountered at least one disruption from natural disaster during the past three years.

The fourth critical risk that emerged in the cold chain logistics of perishable products is deterioration of product quality due to delivery delays. An efficient and agile transportation

mechanism is deemed imperative to maintaining the value and marketability of perishable products (Aramyan *et al.*, 2007; Ishfaq, 2012) The owner–managers of Firms 8, 11 and 17 stated that current supply chain structures are fragmented and fragile. Poor collaboration and communication systems can result in these products not being transported immediately after harvest, thus reducing products' total shelf life and desired quality. The operations manager of Firm 15 commented that:

> Post-harvest delivery delays at the farm level are quite common. Such delays result in decreased overall shelf-life of food products and increased risk of quality loss (e.g. nutritional value, colour, flavour and taste) in the downstream supply chain.

Overall, around 67% of managers (20 out of 30) indicated that product quality deterioration is among the critical CCLRs.

Another product quality–related challenge for the PPSC over the past two decades has been trade liberalisation, which has led to the development of stringent quality standards for exporters (Shukla and Jharkharia, 2013). The managers of Firms 11, 27, 29 and 30 lamented that the stringent food quality standards by some countries create new challenges in terms of compliance. The above discussion leads to the development of the following hypothesis:

> H1 CCLRs, including temperature breakdowns, substandard packaging, natural disasters and quality deterioration, have significant negative impacts on a firm's performance in PPSCs.

3.2.2 Supply chain resilience

Research-based theory suggests that firms possess a bundle of tangible and intangible resources that can help them gain competitive benefit (Barney and Clark 2007). Using RBT, we identified six tangible and intangible resources used by the firms whose personnel we interviewed to build resilience: business certifications, multi-skilled workforce, a quality management system, multi-sourcing, public–private collaboration and globalised operations.

Business certifications. Respondents almost uniformly mentioned that they obtained business certifications (accreditation) such as Hazard Analysis and Critical Control Points, Freshcare, Good Manufacturing Practice (GMP) and Bureau Veritas Quality International (BVQI). Business certifications affirm that suppliers are quality conscious and they may work as an order qualifier (Hill, 1995). The pursuit of business certifications reinforces the commitment to continuous process improvement (Giacomarra *et al.*, 2016), thereby developing redundancy to the risk of demand disruption.

Multi-skilled workforce. During the interviews, worker training and a skilled workforce emerged as an important antecedent to firms' resilience. Many firms' managers (Firms 4–15) mentioned that their workers' training and education programs were regularly arranged by a national industry body of which the firms were members. Consequently, a multi-skilled and adaptable workforce helps businesses not only reduce the chance of failure in daily operations but also rebound quickly from unforeseen disruptions (managers of Firms 7–17).

Quality management system. The quality of perishable products can directly affect consumers' health and safety; accordingly, customers' tolerance of decline in quality has been reducing (Wognum *et al.*, 2011). Under such circumstances, respondents from downstream firms stated that they deal with risks to quality by selecting suppliers with a strong quality focus and a quality management system in place (managers of Firms 20–25). Alternatively,

respondents from upstream firms mentioned that as part of their quality management system, they involve downstream firms in production planning and seek continuous feedback on their products' quality conformance (managers of Firms 2, 8, 11 and 12). Such buyer–supplier (upstream–downstream) collaboration augments the supplier's quality focus (Zsidisin *et al.*, 2016), as information on customers' changing requirements flows swiftly between buyers and suppliers. As a result, suppliers adapt quickly to meet changing customer needs, achieving more trust and market share. The managers of Firms 2, 7, 8 and 9 further reported that they conduct product quality tests before dispatching each consignment, thus avoiding potential risks of consignment rejection.

Multi-sourcing. The managers of Firms 12, 13 and 16 stated that to avoid the risk of supply failure or shortage from a single source, they have established business relationships with multiple suppliers. 'When disasters are localised, suppliers from the other states are used to make up supply shortfalls' (operations manager of Firm 15). Thus, multi-sourcing strategies enable firms to continue operations when the supply from the primary supplier is suddenly disrupted, thereby developing redundancy to supply failure (Tang, 2006; Burke *et al.*, 2007).

Public–private collaboration. The interviews revealed that many firms use public–private collaboration and information sharing as an effective mechanism to deal with disruptions caused by natural disasters. The owner-manager of Firm 9 stated that 'in the wake of a disruption caused by floods or cyclones, public agencies help us technically and financially to recover and continue operations in a normal way'. Public agencies also help private businesses in signing new trade agreements with international markets, thereby offering opportunities for business growth (operations manager of Firm 15).

Globalised operations. The managers of Firms 13 and 16 mentioned that in the face of intense competition in domestic markets, they exploit opportunities in international markets. Globalised business operations not only enable firms to gain economies of scale (Shukla and Jharkharia, 2013; Narasimhan and Talluri, 2009), but also help to develop redundancy to buyers' monopoly in the local markets. The operations manager of Firm 16 stated that:

> Globalisation supports our business twofold: first, due to monopoly of supermarkets in domestic markets, we can sell our products in international markets on even better prices; and secondly, interaction with international markets enables our business to learn new production and processing methods, resulting in the production of premium-quality products and more market share.

Drawing upon insights from RBT, we explored four tangible resources (business certifications, quality management system, multi-sourcing and globalised business operations) and two intangible resources (multi-skilled workforce and public–private collaboration) utilised by the firms to develop resilience to combat CCLRs.

Overall in the qualitative analysis, the use of CT (Lorsch and Lawrence, 1967) shows evidence of risks (CCLRs) negatively affecting firm performance; whereas the use of RBT provides evidence that firms bundle tangible and intangible resources to generate a key capability (resilience) and counteract the impact of risks (Barney and Clark, 2007). The integration of CT with RBT would thus suggest that negative impact of CCLRs on firm performance is influenced (moderated) by key resources and capabilities (resilience) possessed by firms within the supply chain. Hence, we propose the following hypothesis:

H2 The negative impact of CCLRs on a firm's logistics performance is inversely moderated by SCR.

3.3 Phase 2: Quantitative research approach

The second phase of this study responds to RQ2 and RQ3 by using quantitative data collection and analysis. The quantitative data were collected using three sources: (1) online survey questionnaires via Qualtrics, (2) by-post, and (3) face-to-face from two industry forums. The target population was firm managers in the Australian citrus industry. A pilot test was conducted using 48 respondents to ensure reliability of the questionnaire (Churchill, 1979) before carrying out the main survey. In total, 800 questionnaires were distributed and 249 usable responses were received; the 31% response rate being higher than other survey-based research in the area and considered satisfactory (Wieland and Wallenburg, 2013; Prajogo and Olhager, 2012). The analysis of demographic data reveals that nearly half of the respondents (50%) held a position as: owner–managers, 19% general managers, 13% operations managers, 8% supply chain managers, 5%, directors and 5% managing directors. The analysis of firm size characteristics reveals that 60% respondents came from small firms (<19 employees), nearly 35% from medium-sized firms (20–200 employees), while the remaining 5% were from large firms (> 200 employees). This evidence suggests heterogeneity in the sample.

3.3.1 Measurement scales

The scales for 'firm performance' were adapted from Li *et al.* (2006) and Aramyan *et al.* (2007). No suitable measurement items were identified for the constructs of CCLR and resilience. Therefore, items for both constructs were generated from a three-step approach suggested by Wagner and Bode (2008):

1. An initial pool of the scale items for each construct was generated from an extensive review of the literature.
2. The scale items were checked for their relevance, wording and direction with academics and practitioners (industry managers).
3. Scale items were further refined based on the analysis of the interview findings, resulting in the final version of the questionnaire.

The CCLR construct was measured with four items that emerged from the interviews and which were confirmed by the literature: temperature breakdowns (Williams, 2012; James *et al.*, 2006), substandard packaging material (Christopher, 2016; Bosona and Gebresenbet, 2013), natural disasters (Colicchia *et al.*, 2010; Sheffi, 2001) and product quality deterioration (Zhao *et al.*, 2013; Bogataj *et al.*, 2005). The supply chain resilience construct was measured using six items from the interview findings, which were supported by the literature: business certifications (Giacomarra *et al.*, 2016), multi-skilled workforce (Blackhurst *et al.*, 2011), quality management (Wognum *et al.*, 2011), multi-sourcing (Tang, 2006), public–private collaboration (Fiksel *et al.*, 2015) and globalisation (Shukla and Jharkharia, 2013).

A 7-point Likert scale was used to measure each item, which captures a wider range of data and is deemed more compatible with modern statistical techniques (Givon and Shapira, 1984). Using this scale, CCLRs were measured by asking the respondents to rate the extent of risk from 1 to 7, where 1 = not at all and 7 = very great extent, whilst SCR and firm performance (FP) were assessed using the rating from 1 = strongly disagree to 7 = strongly agree.

3.3.2 Quantitative data analysis

The quantitative data were analysed using exploratory factor analysis and confirmatory factor analysis (CFA), including test for missing values, common method bias, non-response bias, reliability and validity of scales, and hypothesised relationships.

The test for missing values indicated that out of 260 responses received, 11 cases had missing data. Of these 11 cases, nine had missing data in the FP construct. This missing data might be due either to the reluctance to respond to items related to their firm's growth and

profitability or to lack of knowledge on the items related to average firm performance in the industry. In the remaining two cases, respondents had not attempted the last section of the questionnaire, possibly because of a busy schedule. These cases with missing data were deleted following guidelines by Hair (2010). Consequently, 249 usable responses were retained in the dataset for further analysis.

Common method bias was checked using Harman's single factor test (Chu *et al.*, 2016), where average variance caused by the single factor was 30%, which is lower than the threshold value of 50% (Harman, 1976). Common method bias was also checked using the CFA marker technique (Williams *et al.*, 2010). The results indicated that factor loadings were much lower (0.3) than the threshold value of 0.5 (Sadikoglu and Zehir 2010). The measures were drawn from different sources (the literature and interviews with experts) to assure respondents' anonymity, as suggested by Podsakoff and Organ (1986).

Non-response bias was tested by comparing the early 125 responses with the late 124 responses following a guideline by Mentzer and Flint (1997). The independent sample *t-test* indicated no significant difference between the means. Hence, non-response bias was discounted in this study.

3.3.3 Tests for reliability and validity

Tests for reliability and validity are essential to ensure accuracy and consistency of measurement scales (Joseph *et al.*, 2010; Hair, 2010). The most appropriate measures to validate scales of measurement are reliability, unidimensionality, convergent validity and discriminant validity (Hair, 2010).

Reliability of the scales was measured using Cronbach's Alpha ($\propto$), where values surpassed the threshold level of 0.7 (Hair, 2010), as shown in Table 1.

< Insert Table 1 here >

Unidimensionality was assessed by factor loading, which surpassed the cut-off value of 0.5 (Sadikoglu and Zehir, 2010). Overall model fit results suggested acceptable outcomes, thus confirming convergent validity (see Table 2). Discriminant validity was checked through average variance extracted (AVE), following Fornell and Larcker (1981). The results demonstrated that AVE for respective constructs is greater than squared correlation value, as shown in Table 3.

< Insert Table 2 here >

< Insert Table 3 here >

3.3.4 Hypothesis testing

Structural equation modelling with Amos 23 was performed to validate the resilience model as shown in Figure 1. Multiple criteria were drawn (Table 2) from the literature to assess the goodness of model fit, as of Garver and Mentzer (1999).

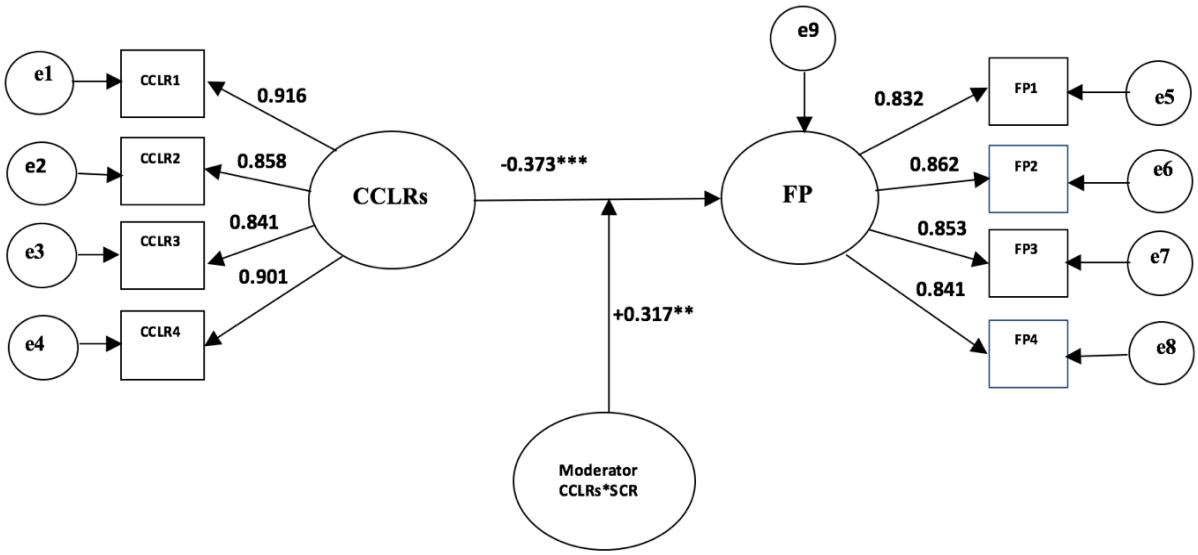


Figure 1. A validated resilience model

The results of Table 2 indicate that all indices of model fit are below the values recommended by Hair (2010), indicating a good model fit and hence satisfactory results. We adopted a two-step analysis approach following Mandal and Mandal (2017): CCLRs → FP; moderator → FP. The data analysis (Table 4) revealed that the path coefficient from CCLRs to the FP is negative ($\beta = -0.373$) and highly significant ($p < 0.001$). Thus, H1 is supported—CCLRs significantly undermine the firm's performance. In order to test the moderating impact (H2) of SCR on the relationship between CCLRs and FP, a product term (CCLRs*SCR) was created, as of Ambulkar *et al.* (2015). The predictive variables (CCLRs and SCR) were mean-centred to reduce multi-collinearity (Ambulkar *et al.*, 2015). The path coefficient from resilience as a moderator to FP is positive ($\beta = 0.317$) and significant ($p < 0.05$). Thus, H2 is supported—SCR inversely moderates the negative relationship between CCLRs and FP.

< Insert Table 4 here >

The interactive effect of risk and resilience on FP is further demonstrated in Figure 2. The trend line with dashes (steeping downward) indicates that at a low level of resilience, the strength of the negative relationship between CCLRs and FP is very high. Alternatively, the solid line depicts that at a high level of resilience, the strength of the negative relationship between CCLRs and FP is weak. Thus, SCR inversely moderates the negative impact of risks on a firm's logistics performance.

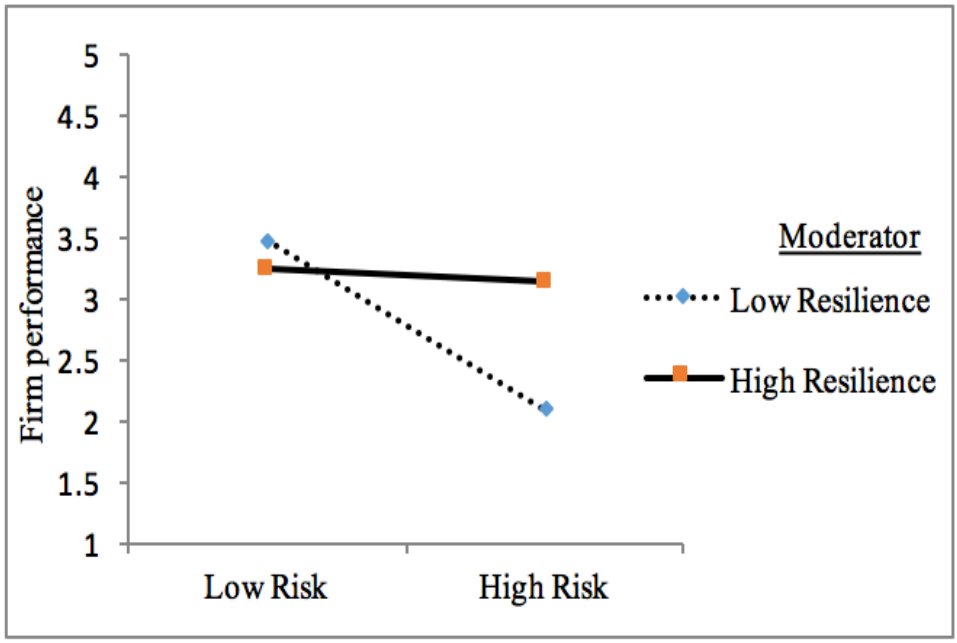


Figure 2. The moderating impact of resilience on the relationship between CCLRs and firm performance.

4. Discussion

Although resilience of cold chain is a poorly understood concept among managers in the citrus industry, the interviews with senior managers at various levels of the supply chain revealed key resources for building resilience and coping with cold chain risks posed by the turbulent business environment. For example, business certifications emerged as a significant resource for gaining better image and customer satisfaction, thereby reducing the risk of consignment failures. These findings empirically verify previous studies highlighting the importance of business certifications in ensuring quality conformance (Giacomarra *et al.*, 2016; Hill, 1995). Blackhurst *et al.* (2011) and Tang (2006) posit the link between training and a firm's resilience, and our research empirically validates this relationship. We find that a cross-trained workforce helps firms to reduce the risk of operations failure, gaining more efficiency and productivity. While food safety and quality are deemed critical risks (Collins *et al.*, 2012), we find that firms create resilience to these risks by adopting quality management systems such as continuous improvement processes, buyer–supplier integration and regular quality tests before product delivery.

Burke *et al.* (2007) and Tang (2006) claim that multi-sourcing can create flexibility and redundancy to supply disruption. This research finds that, facing risks of supply disruptions caused by floods, hurricanes and cyclones, the firms, who established relationships with multiple suppliers (multi-sourcing) from different states, maintained continuity of supply in case of sudden supply failure from the main supplier. Unlike many studies on PPSCs (Bogataj *et al.*, 2005; Rong *et al.*, 2011; Kuo and Chen, 2010), which adopt silo approaches (a one-sided perspective), this paper undertakes a holistic view on diverse risks and an array of resources that can be used to build resilience and satisfy firm performance. Further, in the current business environment, firms cannot gain a competitive advantage in isolation (Ali et al., 2017). Therefore, we advocate the need for more collaborative work by internal and external supply

chain partners in order to build resilient PPSCs that can serve the needs of the end consumer in a timely manner, even during a disruption.

5. Conclusion and contributions

The PPSCs, represented mainly by small and medium enterprises (SMEs), significantly contribute to the global economy and need a resilient system to thrive in the turbulent business environment. Although the literature on resilience is growing, the empirical research on building resilient cold chain logistics and supply chain operations in PPSCs is still in the early stages. Through interviews, we explored the critical risks in cold chain logistics and the resources essential for creating resilience. We then empirically tested the impact of risks on firm performance (in PPSCs) and the moderating influence of resilience on this relationship.

5.1 Theoretical contributions

This paper provides several useful theoretical and practical contributions. Addressing RQ1, the qualitative findings add new knowledge to the literature on specific CCLRs and resources required to build resilience. Responding to RQ2 and RQ3, the unified resilience model proposed in this paper empirically confirms that the resilience factors are significant moderators of the negative relationship between supply chain risk and FP. A high level of resilience greatly reduces the negative impact of CCLRs on firm's performance. By doing so, this paper responds to the repeated calls in the literature for empirical research on SCR (Tukamuhabwa *et al.*, 2015; Kamalahmadi and Parast, 2016) and transportation/logistics risks (Ho *et al.*, 2015).

While most existing definitions of resilience are based on either review of previous literature or the authors' own perceptions of a specific phenomenon (Tukamuhabwa *et al.*, 2015; Kamalahmadi and Parast, 2016), integrating CT with RBT and deducting themes from interviews with senior managers, we offer a distinctive empirically and theoretically grounded definition of SCR:

> An ability of firms in a supply chain to reconfigure tangible and intangible resources into operational capabilities and to anticipate, resist and cope with contingencies, thereby maintaining continuity of operations to the end consumers.

The tangible resources comprise business certifications, quality management systems, multi-sourcing and globalised business operations; intangible resources include a multi-skilled workforce and public–private collaboration, thus responding to RQ1.

This paper also contributes to the debate on the difference between resources and capabilities in a supply chain context. While firms have a number of resources, the difference between top performers and the laggards lies in the way by which they bundle and process resources into capabilities to neutralise risks and exploit opportunities.

Contrary to existing studies focusing on a specific dimension of logistics challenges of PPSCs, this research offers an empirically driven holistic resilience model. We argue that risks in cold chain logistics operations are interconnected and disruption at any node in the supply chain will have a ripple effect on the entire supply chain. Therefore, managing logistics risks and building resilience requires firms to adopt a system-wide approach, rather than focusing on a part of supply chain. We stress the need for a strong collaboration and resource-sharing mechanism among internal as well as external supply chain partners (e.g. government agencies) to meet the needs of consumers.

Given the paucity of survey-based research in the current literature of supply chain risk (Ho *et al.*, 2015) and resilience (Kamalahmadi and Parast, 2016; Hohenstein *et al.*, 2015; Tukamuhabwa *et al.*, 2015), the literature lacks established scales. This paper contributes to the SCR literature by introducing a validated survey instrument for the empirical research on risk and resilience.

5.2 Managerial implications

The findings of this research provide seven practical insights for supply chain and logistics managers. First, the proposed resilience model will enable managers to understand potential CCLRs and resources that can be harnessed to build resilience and safeguard firm performance. We argue that in an exposure to potential risks, a firm's ability to acquire new resources or reconfigure existing resources is a distinctive capability leading to the source of competitive advantage. Second, as consumers are increasingly quality conscious (Collins e*t al.*, 2012), managers should pay special attention to product quality management systems such as buyers' involvement in a continuous improvement process, business certifications/accreditation and quality tests before each delivery. Special care should be provided when loading and unloading at air-conditioned warehouses and containerised transport as the temperature may vary and exceed the upper limit during transport. Although this temperature variance may only be for a short time, it can pose significant negative impacts on product quality. The third implication is that, given the significance of workforce training and development (Blackhurst *et al.*, 2011), firms need to invest in appropriate training programs for workers, as trained employees use resources more efficiently when responding to a disruption. Fourth, more collaborative communication is needed between upstream suppliers (farmers, packers) and downstream buyers (wholesalers and retailers) to reduce delivery delays, which are detrimental to product shelf life and quality conformance. To avoid disruption caused by natural disasters, firms should use more reliable and global cold chain logistic providers, who can offer an alternate mode of transportation in the wake of a disruption. Fifth, owing to the increasing risks of chilling injuries (extremely low temperature) to the substandard packaging material, firms need to source packaging material from certified box suppliers. Perhaps the use of high-quality waxed fibreboards could better resist high humidity and avoid product quality decay, instead of wooden boxes, which have weak stacking strength when absorbing moisture. Sixth, in the face of intense competition and saturated local markets, supply chains should transform from regional and local to globalised business operations. Particularly, globalisation provides potential for business growth to the Australian citrus industry. Australian weather conditions are the opposite of those in the northern hemisphere; hence, there is an opportunity to sell seasonal fruits to world markets when they are not able to be supplied by other countries. If managers leverage the operational expertise of internal and external supply chain partners in combating risks and creating resilience, a competitive advantage would be gained not only for their own firm but also for the entire supply chain.

Finally, in the face of rapidly changing customer needs and an intense food quality competition in the global markets, we emphasise perishable food industry, in particular Australian citrus industry, to make logistics operations more customer service oriented (delivery-time, lead time, packaging, and quality) rather than cost (cheaper transportation).

6. Limitations and future research directions

This study is conducted in a particular country and on a specific industry supply chain, thus there are geographical and sampling limitations. To generalise the findings, this research could

be replicated in other countries and with different industries that rely on cold chain logistics, such as seafood, flowers, processed meat and other items that need to be temperature-controlled while in transit or storage. Most survey participants for this study were from SMEs (95%). Owing to a relatively lower proportion of participants from large firms, this study was not able to test the moderating impact of firm size. However, there may be a difference between the risk and resilience profiles of SMEs and large firms because of SMEs' specific resource limitations and capabilities. Future research can empirically test the moderating impact of firm size on the relationship between risk and firm performance. Future research can also use multiple methods to test the moderating role of other factors, such as managers' experience and positions, which could enhance theory development and testing. Given the limitation of cross-sectional analysis, future research could be undertaken using a longitudinal study to observe if frequency and impact of risks and resilience on firm performance changes over time.

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Table 1. Scale reliability and validity

Construct	Items	Factor loadings	Cronbach's alpha ($\propto$)
CCLRs	CCLR1: Temperature breakdowns	0.916	0.91
	CCLR2: Substandard packaging	0.858	
	CCLR3: Natural disasters	0.841	
	CCLR4: Product quality deterioration	0.901	
SCR	SCR1: Our business is certified.	0.802	0.89
	SCR2: We have a multi-skilled workforce.	0.756	
	SCR3: We have a good quality management system.	0.777	
	SCR4: We use multiple supply sources.	0.931	
	SCR5: We have a strong collaboration mechanism with government agencies.	0.958	
	SCR6: We have global business operations.	0.831	
FP	FP1: Our firm has had a better return on investment over the past three years.	0.832	0.85
	FP2: Our firm has had better customer satisfaction over the past three years.	0.862	
	FP3: Our firm gained growth in market share over the past three years.	0.853	
	FP4: Our firm has a better competitive position in the industry over the past three years.	0.841	

Table 2. Model fit indices

Model fit indices	Analysed values	Recommended value
Chi-square ratio (CMIN/df)	2.21	< 5
CFI	0.97	0.90
Tucker-Lewis index	0.96	0.90
NNFI	0.95	0.90
The root mean square error of approximation	0.078	0.05 and 0.08

Table 3. Average variance extracted

	CCLRs	FP	SCR
CCLRs	0.944		
FP	-0.254	0.938	
SCR	-0.101	0.734	0.899

Table 4. Structural model statistics

Hypothesised relationship			Estimates (β)	P	Results
CCLRs	⟶	FP	-0.373	***	Supported
Moderator (resilience x risk)	⟶	FP	0.317	0.02*	Supported

***p < 0.001; **p < 0.01; *p < 0.05

Appendix A: Participant information

Codes	Firm type	Respondent's position	Firm size
Firm 1	Producer	Chairman, producers' association	Small
Firm 2	Producer	Farm manager	Small
Firm 3 to 7	Producer	Owner-manager	Small
Firm 8	Producer	Farm manager	Small
Firm 9	Producer	Owner-manager	Small
Firm 10	Packer	General manager	Small
Firm 11&13	Packer	General manager	Small
Firm 14	Packer	Plant manager	Small
Firm 15 & 16	Wholesaler	Operations manager	Medium
Firm 17 & 18	Wholesaler	Owner-manager	Small
Firm 19 &20	Retailer (supermarket)	Operations manager	Medium
Firm 21	Retailer (supermarket)	Sales manager	Small
Firm 22 & 23	Greengrocer	Owner-manager	Medium
Firm 24	Processor	Managing director	Medium
Firm 25	Processor (juices and jams manufacturer)	Operations manager	Medium
Firm 26	Processor (juices and jams manufacturer)	CEO	Medium
Firm 27	Third-party logistics	General manager	Medium
Firm 28	Industry association	Marketing manager	Medium
Firm 29	Department of Agriculture	Research officer	Medium
Firm 30	Consultancy firm	CEO	Small