

Supply chain agility responding to unprecedented changes: Empirical evidence from the UK food supply chain during COVID-19 crisis.

Abstract

Purpose: The COVID-19 outbreak has imposed extensive shocks embracing all stages of the food supply chain (FSC). Although the magnitude is still unfolding, the FSC responds with remarkable speed, to mitigate the disruptive consequences and sustain operations. This motivates us to investigate how operationalising supply chain agility (SCA) practices has occurred amid the COVID-19 crisis and expectations for how those practices could transform the supply chain in the post-COVID-19 era.

Design: Following an exploratory case-based design, we examine the various agile responses that three supply chains (meat, fresh vegetables and bread) adopted and elaborate using the dynamic capability (DC) theoretical lens.

Findings: First, the findings demonstrate how, in the wake of the COVID-19 pandemic, each affected case pursued various agile responses through sensing and seizing capabilities. Sensing includes identifying and assessing the relevant opportunities and threats associated with the specific supply chain context. Seizing involves acquiring, combining and modifying the tangible and intangible resources at the firm and supply chain levels. Second, supply chain transformation is likely if firms and their supply chain develop the sustaining capability to ensure that the desirable changes outlast the crisis.

Originality: This study provides a novel and unique perspective on the role of SCA in crisis—in this case, the pandemic. We synthesise the empirical stories of the agile responses in the FSC and elaborate on the DC framework, to identify theoretical and practical implications. We establish the sustaining capability as the missing DC capability for enabling transformation in the post-COVID-19 era.

Practical contribution: This study provides an actionable guide for practitioners to develop agile responses to systemic changes in times of crisis and to sustain favourable changes so as to enable their outlasting the crisis.

Keywords: supply chain agility (SCA), dynamic capability, COVID19 outbreak, crisis management, food supply chain

1. Introduction

The endurance of the emergent COVID-19 pandemic has spawned a new era in the world while we still figure out the crippling impacts on various aspects of our daily life. As a necessity for human survival, the food sector is no exception and has its place in the spotlight (Rizou *et al.*, 2020), epitomised by the images of empty shelves inundating social media, the panicked shoppers queuing ahead of stores' opening hours (Telegraph.co.uk, 2020) or mad scrambles over essential products (BBC.co.uk, 2020a). Although food availability and price stability are constantly assured—'There is plenty of food in the supply chain' (BBC.co.uk, 2020b)—COVID-19 has laid bare inherent weaknesses in the resilience of the UK food supply chain (FSC) (Garnett *et al.*, 2020; Which.co.uk, 2020). Coupled with strict lockdowns, demand shifts due to closure of service outlets, food-hoarding behaviour, temporarily suspended production, logistics and trades of the staple products (FAO, 2020), the COVID-19 pandemic has imposed subtle and ubiquitous shocks in all stages of FSC, from input materials sourcing, farm production, food processing, grocery shops, transport and logistics, to demand patterns (OECD, 2020). Typically, in the early days of the outbreak, a million pounds worth of fresh produce was either left to rot or destroyed in fields (Theguardian.com, 2020); thousands of eggs were smashed and tons of milk dumped into manure pits (Independent.co.uk, 2020). This catastrophic loss is attributable to the rigid supply chain structure that is not equipped to cope with the paralysis of one key channel, the service outlet (Felix *et al.*, 2020; Wentworth, 2020). Due to the immediate, extensive and severe challenges that COVID-19 has brought about (Hartmann and Lussier, 2020), Cankurtaran and Beverland (2020) have labelled COVID-19 disruption as a 'wicked problem', ill-formulated and often full of conflict and ambiguity. Until the cure or vaccines become available, the financial implications for FSC cannot be fully recognised. While key bottlenecks, such as labour and raw material inputs for the entire network, persist in threatening to wreak further havoc on the global economy (OECD, 2020), increasing numbers of food businesses, including farmers, processors and supermarkets, have become 'COVID-19 clusters', threatening the safety of essential workers who contribute to bringing foods from farm to table. The updated timeline of new cases appears on the Grocery website (Thegrocery.co.uk, 2020).

Against this backdrop, the FSC stakeholders have quickly reorganised themselves to ensure the continued availability of food and functioning of FSCs, as well as delivery of foods to destinations that need them most (OECD, 2020). In the renowned, ultra-lean modern food system, where supermarkets barely carry any stock except what is left on the shelf (Garnett *et al.*, 2020), the swift reconfiguration to a nimbler system is quite extraordinary, with the nation in a state of emergency. This motivates us to revisit the concept of supply chain agility (SCA) and its significance as 'a comprehensive response to the challenges posed by a business environment dominated by change and uncertainty' (Goldman *et al.*, 1995, p. 3). Nandi *et al.* (2020) support the relevance of agility to the COVID-19 crisis, arguing that agility—a responsive strategy with speed—is suitably resilient in the fight against this COVID-19 outbreak, a rare event with catastrophic impact. This paper builds upon this base by aiming to provide empirical evidence for SCA effectiveness in mitigating the impacts of sudden changes in the time of crisis, a rare disruption. This paper also responds to the call for further research that examines SCA as a risk-mitigation initiative (Braunscheidel and Suresh, 2009; Sharma *et al.*, 2017) and a driver for greater resilience during this unprecedented time (Tukamuhabwa *et al.*, 2015). By examining three food supply chain cases, we seek to answer two research questions (RQs):

- RQ1: How have the SCA practices been operationalised by the FSC to cope with changes engendered by the COVID-19 crisis?

- RQ2: How are these SCA practices expected to transform the FSC in the post-COVID-19 period?

These two RQs allow us to draw the patterns emerging from agile practices that the three cases have adopted as a result of the COVID-19 situation. Since the literature identifies SCA as a dynamic capability (Chiang *et al.*, 2012; Eckstein *et al.*, 2015), we employed the dynamic capability (DC) theory (Teece *et al.*, 1997; Teece, 2007) as the theoretical lens for our analysis. Specifically, we apply the DC theory's tenets to the adopted SCA practices across the three cases, to answer the first RQ, and propose an addition to the DC theory to resolve the second RQ.

The study uses the UK FSC for several reasons. First, examining the FSC advances studies of the implications of the epidemic's impacts on the commercial supply chain, which have not received as much attention as the humanitarian aspects (Queiroz *et al.*, 2020). The second reason derives from the unique attributes of the FSC. On the one hand, the FSC shares typical traits of the modern commercial supply chain, involving a highly interconnected and complex network of supply, manufacturing, logistics and distribution activities (Srivastava *et al.*, 2015), making it vulnerable to COVID-19 impacts. On the other hand, the FSC possesses unique traits that set it apart from other manufacturing chains (i.e. automobile, textile) and hospitality chains (i.e. tourism, aviation). Specifically, three intrinsic attributes characterise the FSC—seasonality, supply spikes (or bulkiness) and perishability—which complicate risk management in the FSC, in comparison with the typical manufacturing chains (Behzadi *et al.*, 2018). In addition, FSC provides foods essential for human survival. Unlike the non-food chain, in which demand is plummeting during this crisis (Kumar *et al.*, 2020), the FSC has directed the focus towards keeping its chain functional, to keep up with skyrocketing demands (Aday and Aday, 2020). The third reason for choosing the UK FSC stems from its unique and interesting setting that includes a heavy reliance on European imports, with self-sufficiency concerns and the Brexit impact. Statistics have shown that 45% of the total food consumed in the UK is imported, and half of this comes from Europe, particularly key products such as fresh fruits, vegetables, meats and fish (Defra, 2020). Also, the lean sourcing with increasing supply-base reduction and the JIT delivery approach, relying substantially on the Dover Strait and Channel Tunnel routes to improve efficiency and freshness of foods (Garnett *et al.*, 2020; UK Parliament Post, 2020), expose the UK FSC to systemic shocks, such as the COVID-19 pandemic. As the UK reaches the end of the Brexit transition period, changes in British agriculture policy and the uncertain trade deals with the EU (Shanks *et al.*, 2020) further complicate the UK FSC.

This paper is organised as follows. Section 2 reviews the relevant literature on supply chain agility, the DC theory and FSC studies in the context of the crisis. The methodology we adopted appears in Section 3, followed by the findings of the within-case and cross-case analyses in Section 4. Next, Section 5 presented a discussion of practical implications and theoretical refinement. Finally, conclusions and limitations with possible opportunities for further research, are shown in Section 6.

2. Literature review

2.1. Supply chain agility – Conceptual evolution

Over nearly three decades of development from its first introduction by Dove (1996), SCA has evolved significantly. This is signified by the number of literature review articles to develop its own conceptual framework (such as Li *et al.*, 2008; Sharma *et al.*, 2017; Al Humdan *et al.*, 2020) or discuss SCA in relation to other concepts (such as with leanness in Naim and Gosling, 2011; under resilience concept in Tukamuhabwa *et al.*, 2015; with flexibility in Fayezi *et al.*, 2017). However, its conceptual ambiguity has caused the literature to be quite fragmented (Gligor *et al.*, 2013; Al Humdan

et al., 2020) while SCA's scope is broad and contains 'multi-dimensional constructs' (Ngai *et al.*, 2011, p. 233). This review presents SCA's conceptual evolution, capturing salient trends to accentuate our approach in this paper.

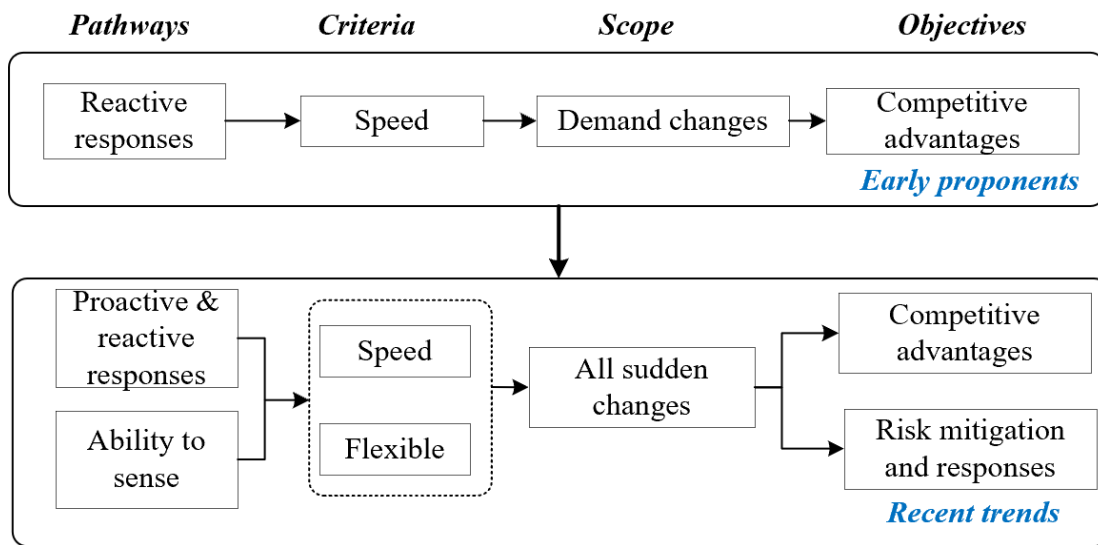


Figure 1: Supply chain agility - conceptual evolution (created by authors)

The concept of SCA has evolved into four fundamental aspects, namely, pathways, criteria, scope, and objectives (Figure 1). Early proponents refer to SCA's customer-responsive manner (Swafford *et al.*, 2008), constraining the concept to a reactive capability of providing speedy responses to sudden changes in demand, to gain competitive advantages. Recent conceptual adaptations have significantly widened SCA's boundary, particularly following the review by Li *et al.* (2008).

First, the pathway to SCA has expanded to include both the physical capability of taking reactive and proactive measures and the cognitive capability to become alert and quickly anticipate and detect both opportunities and disturbances. Cognitive capability also embraces market learning capability and innovation (Golgeci *et al.*, 2019). Studies assert that the cognitive capability complements physical capability, where the timely awareness of change is a precursor of effective responses (Li *et al.*, 2008; Wieland and Wallenburg, 2012). Although mentioned in an earlier study (e.g. Ismail and Sharifi, 2006), the cognitive capability was not included in the conceptual definition until the work of Li *et al.* (2008).

Second, speed is not the only criterion for assessing responses to change; the flexible manner is also added (Li *et al.*, 2008; Gligor, Holcomb and Stank, 2013; Eckstein *et al.*, 2015; Tse *et al.*, 2016).

Third, SCA addresses all types of sudden changes in the supply chain, either internal or external, not necessarily constrained to the demand side. Changes within SCA's scope are often immediate, sudden (Li *et al.*, 2015), uncertain, temporary, abrupt, unexpected (Eckstein *et al.*, 2015), as opposed to long-term or evolutionary. This also makes agility more pertinent in the volatile and fast-moving conditions that the COVID-19 pandemic has produced.

Finally, concerning the overarching goal, SCA possesses the prominent virtue of enabling firms to attain competitive advantage (Yusuf *et al.*, 2004) and, therefore, improving such competitive metrics as operational performance indicators (i.e. product innovation, lead time reduction, service quality), strategic performance indicators (i.e. competitiveness, financial, relational, marketing performance) (Whitten *et al.*, 2012) or sustainable outcomes (Geyi *et al.*, 2020). Another significant objective of SCA, scarcely discussed in the extant literature, is to manage risk and disruption, referring to the

capability of responding to sudden disruption and adapting rapidly (Khan and Pillania, 2008). Arguably, the goal of SCA has extended beyond gaining competitive advantages. Advocates incorporate SCA in business continuity (Fayezi and Zomorodi, 2015) and embrace opportunity-seeking in times of turbulence (Sharifi and Zhang, 1999), which become the risk-mitigation initiatives (Braunscheidel and Suresh, 2009; Wieland and Wallenburg, 2012).

In this paper, we espouse the contemporary concept of SCA and integrate the cognitive capability with the responding capability to timely sense the crisis-engendered changes (opportunities/challenges) and mobilise resources to provide the reactive responses to these changes.

2.2. Dynamic capability as a theoretical lens for supply chain agility

Dynamic capability (DC) refers to the ability to ‘integrate, build, and reconfigure internal and external competences to address rapidly changing environments’ (Teece, 1997, p.516). It is considered an advancement of the resource-based view (RBV) (Augier and Teece, 2009; Katkalo *et al.*, 2010), with attention on value creation as opposed to a mere value capture of mainstream RBV. Such activities as new product development, new business models, new organisational forms and new supply chain networks often achieve value creation (Ambrosini and Bowman, 2009). The dynamic capability allows these activities to proliferate, particularly in turbulent times when changes are ubiquitous, by rapidly aggregating, renewing and transforming resources into new competencies to capitalise on these changes (Li *et al.*, 2009; Blome *et al.*, 2013). Three micro-foundations form a firm’s dynamic capabilities: sensing (identification and assessment of threats and opportunities), seizing (mobilisation of resources to capture value) and transforming (continued renewal of tangible and intangible assets) (Teece, 2007; Bledy *et al.*, 2018).

As analysed in Section 2.1, SCA facilitates sensing and mobilises resources to respond to changes; thus, SCA is conceptualised as a dynamic capability. The DC theory has successfully served as a theoretical anchor to enable a better understanding of SCA (such as in Chiang *et al.*, 2012; Whitten *et al.*, 2012; Blome *et al.*, 2013; Eckstein *et al.*, 2015; Gligor *et al.*, 2016; Dubey *et al.*, 2018). The literature has not reached a consensus on DC micro-foundations of SCA. While Gligor *et al.* (2016) argue that SCA satisfies three capabilities in the DC micro-foundations, Eckstein *et al.* (2015) and Dubey *et al.* (2018) limit SCA to the sensing and seizing capabilities only. In this paper, we follow Eckstein *et al.* (2015) and Dubey *et al.* (2018) in positioning SCA as sensing and seizing capabilities because of their adoption in the supply chain cases early in the outbreak, as change-responsive practices at an operational rather than a strategic level. Hence, we elaborate the empirical evidence of the SCA practices as sensing and seizing capabilities (RQ1) while seeking an answer to how to translate these practices into the transforming capability (RQ2).

Teece—the founder of DC theory—also recognises the relevance between the agility strategy in an unknown-unknown situation and DC theory. Teece *et al.* (2016) argue that agility is crucial in managing deep uncertainty or an unknown-unknown event, such as this COVID-19 pandemic, while the DC framework is a suitable framework for borrowing to provide practical guidelines for developing agility. As such, we believe that DC theory is a promising avenue for investigating SCA practices during the COVID-19 crisis, which allows for theoretical refinement.

2.3. Food supply chain in the crisis

Supply chain risk is often dichotomised into operational risk (high probability, low impact) and disruptions (low probability, high impact) (Tang, 2006; Sodhi *et al.*, 2012; Ho *et al.*, 2015). As the COVID-19 epidemic is a rare event with catastrophic impact, it belongs among disruption risks. While a considerable body of literature deals with managing operational risks in the FSC using

various methods, such as quantitative modelling (Kim *et al.*, 2014), empirical case study (Leat and Revoredo-Giha, 2013) or extensive literature review (Septiani *et al.*, 2016; Behzadi *et al.*, 2018), the management of disruption attracts much less attention in the FSC research agenda. Regarding disruption, food safety scandals remain a popular topic of interest (Septiani *et al.*, 2016; Miranda and Schaffner, 2019), and natural disasters follow. For instance, Kumar and Budin (2006) examine exporters' perspectives and responses to food safety and recall incidents. Lehmann *et al.* (2011) establish the pivotal role of information in the European pork chain in swine fever and dioxin crises. Regan *et al.* (2015) derive a conceptual framework from the 2013 aftermath of the horsemeat adulteration incident in the UK and Ireland. As for natural disaster, Smith *et al.* (2015) examine the resilience of long versus short FSC; Reis (2019) explores the role of government in coping with the 2011 Queensland flood crisis in Australia. To our knowledge, before the COVID-19 outbreak, there was only one discourse on the impacts of the influenza pandemic on the FSC (Ekici *et al.*, 2014).

As an extremely rare disruption, COVID-19 has spurred a growing interest in the FSC during the pandemic. Appendix 1 shows a list of 24 articles examining COVID-19's impacts on the food sector. The list is not exhaustive but introduces various perspectives on the FSC during the COVID-19 outbreak and highlights the literature gap that this paper aims to close. Specifically, extant literature pays attention to the impacts of the COVID-19 pandemic on food security and safety, food hoarding behaviour, food distribution systems (Singh *et al.*, 2020), food waste behaviours and management, blockchain, and Artificial Intelligence. Due to time constraints, most of the papers appear in the form of commentary or short opinion/communication using secondary data, which could induce a certain level of speculative interpretation of findings (Hobbs, 2020). Although other methods, such as survey, literature review, simulation, and life cycle assessment (LCA), occasionally appear, a pressing need to utilise more empirically based evidence to gain further insights into firms' perceptions and responses during this novel crisis exists, and our paper seeks to fill this void.

Unlike operational risk events, a disruption event requires a different mitigation approach. Proactive strategies, such as carrying out excess inventory, proven effective in managing the operational risk, could be costly for coping with disruption risk (Nandi *et al.*, 2020). On the contrary, managing operational risk may not require agility, but agility is crucial in times of deep uncertainty, such as unpredictable disruption and hypercompetitive situations (Teece *et al.*, 2016). Nandi *et al.* (2020) argue that a speedy reactive response is sufficient to tackle the COVID-19 impact. This paper contributes to progress in the study of SCA's role as a disruption-mitigation strategy, by providing empirical evidence for the FSC. Some recent efforts have underlined the suitability of SCA in the FSC. For example, Manning and Soon Jan (2016) propose a resilient model that enhances the agility of the FSC; Bezuidenhout (2016) measures the degree of agility and leanness in the FSC; Hernández and Pedroza (2016) link agility levels with different FSC networks; Nakandala and Lau (2019) explore the implementation of the hybrid of lean and agile strategies in urban FSC. However, the number of studies is fairly limited (Haq and Boddu, 2015). This is partially attributable to the FSC environment, with a high volume and predictable demand where lean and JIT strategies remain dominant (Zarei *et al.*, 2011). As the COVID-19 outbreak escalates globally, the predictable demand on the FSC has changed, requiring firms and their supply chains to develop a reactive response capability with speed or agility. In short, this review highlights a need for empirical investigation of SCA as a disruption-mitigation strategy in the FSC during times of crisis or a rare event.

3. Methodology

The literature review indicates the need for empirical evidence on SCA as a mitigation strategy in FSC during the crisis, and this situation calls for exploratory research that can provide an in-depth understanding of this phenomenon. We adopt a deductive and theoretical elaboration approach, using a multiple-case study to investigate three multi-echelons in the UK food sector. The strength of the case-study approach lies in its ability to grasp deep insights into complex and emerging real-life phenomena that quantitative methods for data collection may not achieve (Barratt *et al.*, 2011; Yin, 2013). The main unit of analysis in this study is the agile practices that these supply chains adopted as the direct result of the ongoing crisis. These practices are embedded in each network and affected by its setting, which means that the boundaries between the context and the phenomenon cannot be clearly defined (Kahkonen, 2014), highlighting the suitability of the case-study design (Yin, 2013).

3.1. Case selection

Cases are recruited using snowball sampling that is intentional and purposive (Noy, 2008). Each case involves multiple companies in different echelons of the FSC that supplies meat (case A), vegetables (case B), and bread (case C). These products represent essential items, demand for which is significantly spurred by consumers’ panic-buying behaviours (Jribi *et al.*, 2020). In addition, before the COVID-19 outbreak, the three cases had adopted the lean strategy that focuses on driving down costs. Details of the cases appear in the Findings section below (Section 4). Sampling from a similar market environment and limiting it to essential food items controlled variation within a population (Eisenhardt, 1989). Each supply chain reflects its fit with the diverse ways of employing agile practices amid the outbreak crisis. Limiting the number of cases to three enabled the required depth of observation and the illumination of contrasting patterns in the data (Eisenhardt, 1989; Voss *et al.*, 2002).

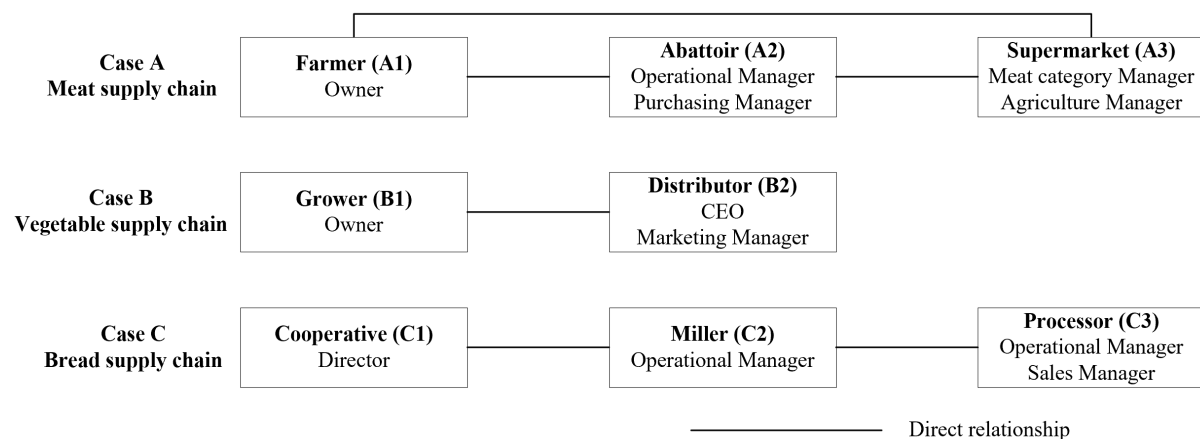


Figure 2: Three case profiles

Note: CEO: Chief Executive Officer

3.2. Data collection

The main source of data is the semi-structured interview, a popular tool for generating knowledge in qualitative studies. Twelve semi-structured interviews (five for case A, three for case B and four for case C) were conducted with each firm’s key stakeholder, either directors or affiliated with the supply chain management department of each firm (see Figure 2). Interviews were conducted by phone from early May to the middle of August 2020, and the interview questions followed an interview protocol

customised to each echelon in each supply chain case. The respondents received the questions in advance to fully inform them of the research objectives and questions before they engaged in the interviews (Voss *et al.*, 2002). The use of an interview protocol (see Table 1) helped in conducting the thematic analysis of qualitative data to draw out emerging themes (Guest *et al.*, 2012; Miles *et al.*, 2018). We posed questions as open requests for information about how the agility initiative was developed and implemented at the supply chain level because we aimed to seek stories about their adopted agility initiative.

Table 1: Interview Protocol

Section	Questions
The company and the interviewee	<ul style="list-style-type: none"> ▪ Please provide a brief overview of your company ▪ Please describe your responsibilities within your company ▪ Please describe the supply chain of your company prior to the COVID-19 crisis. Please describe the relationship between you and your supply chain partner. Is your supply chain vulnerable to risk and disruption? In case of risk or disruption events, how is responsible for risk management in your firm and your supply chain?
COVID-19 sensing	<ul style="list-style-type: none"> ▪ How has the COVID-19 impacted your firms' operation? Are these impacts negative or positive? What are the most pressing impacts? How are these impacts similar or different from the past events that your firm has experienced? ▪ How has the COVID-19 impacted your supply chain? Are these impacts negative or positive? What are the most pressing changes? How are these impacts similar or different from the past events that your supply chain has experienced? ▪ What do you think about the impacts of the COVID-19 on your firm, your supply chains, and the UK FSC business environment in general? What are their unique characteristics?
COVID-19 responding	<ul style="list-style-type: none"> ▪ How were you and your supply chain able to react to these impacts? Who was responsible for devising these responses in your firm and your supply chain? How did you include the supply chain partners in the responding efforts? ▪ How long did it take to implement these responses? How do you perceive the role of quick or agile actions in coping with the impacts? What would be the consequence if you failed to take actions or delayed in taking actions?
Post-COVID-19 transforming	<ul style="list-style-type: none"> ▪ How do these responses influence your firms' operation and your supply chain's operations and relationship when the COVID-19 recedes? Will any of your COVID-19 responses continue in the post-COVID-19 period? If yes, do you expect any major changes in how you and your supply chain operate? ▪ What are your views on the long-term impact of the COVID-19 on your firm and your supply chain?

During the interview, we vigilantly followed where the interviewees led us and adapted the questions to the progress of each interview (Charmaz, 2014). Data collection for each case ended when new, significant insights could no longer be gained (Yin, 2013). The length of each interview varied between 40 and 60 minutes. The transcripts were emailed to interviewees for validation of facts and to check for any anomaly or misinterpretation of data during the transcription process. Permission to record and transcribe interviews was obtained at the beginning of each discourse, and anonymity and confidentiality are fully respected by disguising respondent and company names.

3.3. Data analysis

Case analysis is a process of data reduction that aims to interpret, structure and elucidate available data (Miles *et al.*, 2018), consisting of within-case and cross-case analyses (Eisenhardt, 1989; Yin, 2013). The within-case analysis contributes to isolating patterns and identifying commonalities, gradually establishing the generalisations that were consistent across cases (Kaufmann and Denk,

2011; Miles *et al.*, 2018). Following the within-case analysis, the cross-case analysis detected any commonalities and differences between patterns across the cases, employing a pattern-matching technique and enabling the theory to emerge (Eisenhardt, 1989). We compared the empirically-based patterns of the strategies that the three cases adopted, with each other and with the dynamic capability framework. The answers to two RQs were then aggregated and a set of cross-case conclusions was drawn. The cross-case conclusions enabled intertwining the findings in each case with the selected theory, the DC, and demonstrating a close link between empirical evidence and emergent theory.

3.4. Quality assessment criteria

Research quality was assessed by means of four criteria presented in Yin (2013), which includes construct validity, internal validity, external validity, and reliability. Construct validity was established by collecting data from interviews and relevant grey and academic literature. Internal validity was assured through pattern-matching within and across the cases. External validity was achieved by anchoring our analysis through the lens of an appropriate theory, the DC theory, and by recruiting cases that enable a diverse and coherent sample aligned with the scope of this study. Finally, the reliability of this study was ensured by a clear case study protocol to maintain the rigour of the research process and by a formalised coding that involved at least two researchers to enable consistency in allocating the codes to the raw data.

4. Findings

4.1. Within-case analysis

Case A - Meat supply chain

Case A represents the meat supply chain, consisting of an independently owned farm, a large-scale abattoir and a supermarket. The farmer moves livestock to the abattoirs for slaughter and packing before dispatching meat to the supermarket. Part of one of the largest UK supermarket chains, the supermarket wields significant control in this chain, with many years of relationships with farmers and processors. In normal conditions, the supermarket and the abattoir meet regularly. The supermarket has inspectors that routinely visit the farm, aiming to provide full traceability in the network for the assurance of product quality, safety, animal welfare and environmental concerns. The leanness and the dominant role of the supermarket characterise this supply chain. Since the onset of the COVID-19 outbreak, two significant issues have threatened this chain, namely, the health and safety (H&S) of staff at the abattoir and a shift in consumer demand towards affordable and versatile meat cuts.

The H&S maintenance at the processing plant is the key to keeping this chain functional amid this health crisis. The enclosed working environment at low temperatures inside the meat processing factory, where social distancing is difficult to maintain, make this part of the supply chain particularly vulnerable to the COVID-19 outbreak, with a high infection rate. In this situation, the acquisition of sufficient personal protective equipment (PPE) to safeguard the H&S of staff at the abattoir's plant constitutes the priority action in this case. The manager at the abattoir elaborated:

“When Italy and Spain went into lockdown, we already knew that we were going to be impacted. We took a forward-thinking approach and we’ve bought a lot of PPEs before the UK went into lockdown [. . .] We’ve also used Perspex dividers to allow our employees to work shoulder-to-shoulder and it seems to be working.” (Operational Manager, A2)

PPE scarcity is likely during the crisis, and the ability to build up critical resources in this chain comes from its ability to quickly scan the environment to detect relevant threats. Besides, this is attributable to learning from the past, as the farmer explained:

“We are one of the riskiest industries to work in so you're all the time managing risk. A number of years ago we have a procedure in place if we were unable to move pigs off the farm for a week, two weeks, a month, six months, where to divert the animal to”. (Owner, A1)

This practice has proved effective, since the absenteeism rate in the abattoir remains relatively low, and no shutdown has occurred since the onset of the outbreak.

As for the demand shift, this chain suffered from soaring demand for more versatile and inexpensive meat cuts, such as minced meat, and a disproportionate fall in demand for noble meat cuts, such as sirloins, fillets and ribs. The supermarket attributed this change to the prolonged absence of the service outlet for which noble meat cuts are often destined, and home cooking where the cheaper cut is a staple item. The loss of income for many people who are furloughed or made redundant as the result of COVID-19 has partially caused the preference for the cheaper cut. The supermarket described the issue:

“Everybody wants mince-meat. 70% of our supermarket’s demand were sold as mince. It’s a bad situation because the market for expensive carcass like steaks, hindquarter cuts is hit to a degree that the sales of minced meat cannot compensate [. . .] Steaks are crucial to driving value in primary beef and ensure the carcass balance [. . .] Freezing these cuts is not an option for the processor, not only because it is expensive but also because of unknown demand and stock build-up”. (Meat Category Manager, A3)

Taking no action to alter this trend could cause a ripple effect in the upper part of the supply chain because the fall of noble-cut demand makes it unprofitable for the abattoir to continue processing, lowering the farm-gate price of the livestock where the farmer struggles to sell livestock at a price that covers costs. To address this pressing challenge, the supermarket and the abattoir collaborated to reduce the direct income loss for the abattoir and prevent the trickle-down effect on the farmer. Specifically, the supermarket works with the abattoir to narrow down its product range to a small variety of high demand cuts, run a promotion on the slow-moving noble cuts and absorb the excess volume that had been destined for restaurants. These actions help to limit the sizable economic loss to this chain.

As for the prospect in the post-COVID-19 period, case A expects that the normal working condition will be resumed in the abattoir’s factory while the sale of noble cuts in the supermarket will rise even after the reopening of the service outlets. The abattoir is confident that when consumers realise that they can enjoy restaurant-style dining at home, this consumption trend will be reinforced and steaks can be considered as a staple item for home cooking.

Case B - Vegetable supply chain

This case comprises a vegetable grower and a fresh produce distributor. In normal conditions, the distributor aggregates and transports vegetables that the grower produces, to several independently owned restaurants in the UK. Their relationship is nearly one decade old and has always proceeded on good terms. Great stability in supply and demand characterises this supply chain. As the COVID-19 lockdown took effect, despite being hit hard by the overnight evaporation of its only market outlet and the scarcity of harvesting labour, this chain rapidly sensed the opportunities to provide direct supplies to consumers and find alternative sources of labour.

The prolonged closure of restaurants pressurised this chain to quickly find new routes to consumers' doorstep. Sensing the renewed interests in local produce, particularly fresh and healthier items, the distributor quickly modified its business model from business-to-business (B2B) to business-to-consumer (B2C). The distributor explained:

“All of our markets closed overnight but our farmers still have food on the ground. We cannot just close our business like what the restaurants did so we decided that we had to produce something quickly using our existing resources [. . .] We turned to home delivery and sold subscriptions for boxes of produce. When COVID was at its peak, everything was going well. We received hundreds of orders per day”. (Sales Manager, B2)

This agile response was fulfilled by leveraging existing resources, including staff, vans and website. Specifically, the distributor used its restaurant delivery trucks to drop off household orders, renovated its website for direct consumer sales with a new pricing structure and redeployed staff to repackage items for household consumption. Although these actions keep the distributor and its supply chain afloat during this prolonged disruption, they are a tentative solution to minimise the loss. When the COVID-19 pandemic recedes, the distributor expects to return to its B2B model and expounded upon its expectation:

“The transition is not as smooth as it sounds because of the order size, packaging requirement and customer service or things like that. If we were packing in bulk, we could pack very quickly. Having to pack for retail customers takes a lot more time. For scattered locations, there is the possibility that our drivers can't find certain locations [. . .] At this moment in time, we have managed to keep the game and continue to offer home delivery. Going forward, I think that with the lifting of lockdown, consumers will go back to the supermarket and the cake for home delivery will be smaller. We do not have sorts of resources to compete in this niche, so the restaurant distribution is still our focus when this virus ends”. (CEO, B2)

The grower needs roughly fifty workers in each harvesting season, and the majority of this workforce is workers returned from Eastern Europe. Not until the COVID-19 crisis did the grower face the staff-availability issue. This problem was a headache for the grower last year and the year before, as the result of Brexit and the weaker value of the British pound. This year, COVID-19 has put the grower in an unprecedented situation. While there is a lack of European workers coming to the UK due to travel restrictions, an increasing number of UK workers on furlough has applied for farm jobs.

“We received lots of applications from all sorts of backgrounds, those are on furlough or students [. . .] Harvesting job is not for everybody so the drop-out rate is high, but those who retain have been helpful”. (Owner, B1)

This illustrates how the farmer could seize the opportunity arising from the outbreak by extending its labour resource, to avoid the worst-case scenario of crops left to rot in the field. In the future, the grower indicated the possibility of recruiting the local people in harvesting season and ruling out the scenario of investing in robotics technology without government funding.

“We attempted to raise the profile of farm works this year. So in the coming season, if it is not COVID-19 we still have local workers wanting to do the jobs [. . .] Because we operate on really thin margins, so when you're talking about the huge capital expenditures in the robotics technology in advance, even for large growers, it's going to be a challenge”. (Owner, B1)

Case C - Bread supply chain

Case C involves the supply chain of a cooperative, a miller and a bread processor. The processor is a large UK-based family business with a recognised brand name, supplying 50 different ranges of bread and baked products to assorted bakery stores and supermarkets in the UK. The miller converts wheat into finished flour using a sophisticated grinding and sifting process, then dispatches flour to the bread processor. The co-operative represents 60 farmers across 8,000 acres who grow wheat and other arable products, such as oil grape seeds, barley and peas. The cooperative takes care of the ordering and delivery activities, as well as quality assurance, according to the miller's standard. This triadic relationship has operated in high-volume low-demand uncertainty and functioned well through its history.

When lockdown occurred, the unprecedented and significant change for this chain rested in the surge in bread demand, requiring an agile response to accommodate it. The bread processor normally supplied a quarter-million loaves of bread per day, and now must roll out an extra 50,000 loaves per day to accommodate a 20% increase in demand. When the production capacity reached its maximum and the baking process could not be altered, the processor quickly modified its process by reducing the full range to focus on the core items. As the processor explained:

“Bread sale is going through the roof, everybody wants bread. This put pressure on our supply chain as we ramp up the production [. . .] This surge in demand is like an extra day's volume per week. When our production lines already run 24/7 and we cannot alter the entire bread-making process to ensure the consistency of the product, the only way to boost production is to cut the full range that we normally offered from fifty to three core products. This also helps to save nearly an hour of hygiene time when changing the production lines”. (Sales Manager, C3)

While the reduction in product variety allowed this chain to absorb the demand surge, the bread processor expects the demand pattern to return to normal. Thus, the post-COVID-19 era will require no changes, such as investment in technological expansion.

The production capacity at the processor is the only constraint on the ability to absorb the surge in demand. Milling capacity and wheat supply are not the constraints, in case C, on coping with this skyrocketing demand, as explained by the cooperative director:

“Because of the time delay between the decision, the cropping plan is often done 12 months, 18 months in advance so you cannot grow more when you see a high demand for wheat. Fortunately, we have a good season this year, so we do not lack wheat supply”. (Director, C1)

4.2. Cross-case analysis

Three cases provide examples of operationalising the FSC's agile responses in the early COVID-19 outbreak, where business-as-usual is no longer valid. This section synthesises these SCA practices (Table 2) and elaborates them through DC theory sensing, seizing and expected transforming capabilities.

The three cases operationalised SCA practices by sensing changes in the form of opportunity and threats. These changes emanated from two sources: labour and market demand. Unsurprisingly, COVID-19—a health crisis—has caused significant impacts on the labour-intensive areas of the supply chain, including the H&S of staff working in the FSC at the abattoir's factory (case A) and the availability of seasonal harvesters (case B). However, labour-related issues are not mentioned as a significant concern in case C, which involves an automated process from farm to factory. Although all actors in the supply chains from farms to supermarket have adopted formal social-distancing measures in their operations and acquired additional PPEs, the level of PPE stock and the subsequent impacts of shortages are far more substantial for the abattoir, due to its working environment and position in the

network. As for the demand-related changes, the three cases experienced variations in normal demand patterns, including a shift towards affordable items (case A), a preference towards local foods and online delivery (case B) and a surge in demand (case C). These distortions arise from panic buying and the prolonged closure of restaurants, of uncertain duration.

Upon sensing these opportunities and threats, the three cases enacted various SCA initiatives to mitigate threats and embrace opportunities, by acquiring, combining and modifying resources. Case A acquired PPE stock to safeguard its workforce in a highly contagious environment, which, in turn, ensured business continuity at the abattoir and avoided potential disruption in the chain. Case A also used a relational resource to solve the carcass problem and leveraged the supermarket's positional resource, by which the supermarket acted as a conduit to the market. Case B extended its resources by hiring the furloughed people who were out of jobs as the result of COVID-19 impacts and modified its existing tangible resources, including staff, website and vehicles, to convert a B2B business model to B2C. Finally, case C modified its production process to maximise the output production of the core items, responding to the demand surge. This exemplifies how different types of tangible and intangible resources can be extended, combined and modified to derive agile responses amid abrupt changes.

Finally, though all SCA practices adopted in the three cases are intrinsically reactive, in response to the threats and opportunities emerging from the COVID-19 event, some of them are expected to translate to the supply chain transformation in the post-COVID-19 period. Case A anticipated the enduring trends of steak cooking in the British family outlasting the crisis. By raising the firm's job profile, case B expected to attract the local workforce in the future. Although the home delivery of fresh produce is an opportunity for case B to expand its business, it requires the establishment of an effective business model to continue attracting online retail demand. This is not a feasible option in case B, so no transformation in this chain is expected. The threats related to the PPE acquisition (case A) and bread demand surge (case C) are expected to vanish at the end of this health crisis, so no transformation or change is anticipated.

Table 2: Summary of three cases' agility initiatives during the COVID-19 crisis

Concepts	Case A	Case B	Case C
RQ1 - How have the SCA practices been operationalised by the FSC to cope with changes engendered by the COVID-19 crisis?			
<i>(a) Through sensing capability</i>			
Sensing threat/opportunities	Labour - H&S maintenance (Threat)	Labour (returned) shortage (Threat); Labour (alternative) availability (Opportunity)	Demand surge (Threat)
	Demand shift worsens carcass balance (Threat)	Demand evaporation (Threat) and demand surge—home delivery (Opportunity)	
<i>(b) Through seizing capability</i>			
Extend/combine/modify tangible and intangible resources	Acquire resource: acquiring sufficient PPE stocks to protect the workforce against contagion risks	Acquire resource: hiring furloughed workers filling the void of not having returned immigrant labour	Modify resources: reduce the product range to supply only the core products.
	Combine resources: abattoir leverages the relational resource with supermarket who possess positional resource to mitigate the carcass balance issue	Modify resources: staffs, vehicles, websites to quickly find new routes to market.	
RQ2 - How are these SCA practices expected to transform the FSC in the post-COVID-19 period?			
Expected transformation (if any)	No expected change in the working environment at the abattoir	Raise firms' profile to attract local workers next year	No expected change in this supply chain environment

	The steak sale at the supermarket continues to grow	No expected change in its business model	
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5. Discussion and implications

In this section, we first discussed key findings with respect to two RQs and compared these findings with the evidence found in extant COVID-19-related literature to derive three practical implications for the FSC. Second, we introduced the refined DC framework in the crisis by augmenting the sustaining capability to support the desirable changes outlasting the crisis.

5.1. Practical implications for the food supply chain during the COVID-19 outbreak

Answering RQ1 about how the SCA practices have been operationalised to cope with changes engendered by the COVID-19 crisis, Section 4 provided empirical evidence for the SCA operationalisation via sensing and seizing capabilities in the DC lens.

With the sensing capability, the FSC actors in each case were able to quickly identify the list of relevant changes ignited by the COVID-19 pandemic (see Table 2). We found two characteristics in the analysis of these changes. First, the COVID-19-related changes are specific to each case setting. The sudden eruption of COVID-19 has brought in systemic conditions to induce changes, including high contagion, consumer behaviour shifts and the abrupt introduction of control measures with prolonged and uncertain durations. Nevertheless, each affected case experienced changes differently, depending on its setting, such as whether the case has labour-intensive operations or involves selling to a service outlet. Second, the COVID-19-derived changes are abrupt and can be in the forms of opportunities and threats. This was substantiated in the academic literature. Ibn-Mohammed *et al.* (2021) provide a critical review of how the COVID-19 pandemic has caused negative and positive impacts and offer perspectives on how these impacts can be leveraged to steer towards a better and more resilient economy. Although only four threats and two opportunities deriving from labour and demand sources are identified in this paper (Table 2), they represent the significant issues that aligned with the discourse in the extant literature. Hobbs (2020) discusses how the COVID-19 pandemic has inflicted various shocks on FSCs, such as panic buying, the sudden shift from the foodservice outlet to home consumption, labour shortages and transportation disruption. Richards and Rickard (2020) describe the constraint that immigrant labour became on the vegetable supply chain. Interestingly, price spikes, often associated with the epidemic outbreak, were not found in three FSC cases, similar to the finding by Deaton and Deaton (2020). On the positive side, the literature reveals how COVID-19 has spurred novel opportunities in the market, predominantly the triumph of online grocery shopping and local products in the short FSC (Cappelli and Cini, 2020; Gray, 2020; Hobbs, 2020; Richards and Rickard, 2020). Arguably, social media proliferation and novel e-commerce platforms facilitate these trends (Fei *et al.*, 2020). Apart from labour and demand-related changes, other types of threats, i.e. supply shortage due to restricted food trade policies, or financial pressures in FSC (Aday and Aday, 2020) and opportunity trends, i.e. robotic harvesting (Mitaritonna and Ragot, 2020) can be realised in the literature. In summary, our first practical implication is that as the COVID-19 engenders abrupt opportunities and threats that are specific to each case setting, the first crucial step in operationalising the SCA is to sharpen the sensing capability by sifting and assessing relevant changes in the environment.

With seizing capability, three cases operationalised the SCA practices by acquiring, combining and modifying tangible and intangible resources to mitigate threats and capitalise on opportunities that had been identified with the sensing capability. Acquiring resources, particularly scarce ones, might be challenging, due to the lack of supply alternatives during crisis times (Natarajarathinam *et al.*, 2009), so the crisis literature rarely discusses this option. Conversely, there are abundant stories of how the actors in FSCs have pivoted their business models by modifying and combining resources. Since the

rise of the COVID-19 outbreak, newspapers have reported many anecdotes on how the FSCs, regardless of size, have effectively pivoted their business models: A fast-food chain turned dozens of its restaurants into mini supermarkets (Jack, 2020); big wholesalers have pivoted to direct online sales (Eley, 2020); small-scale farmers and butcher shops eliminated the middle-man, directly supplying consumers by leveraging B2C online platforms, such as the novel Farm2Fridge platform. Similarly, the combination of resources across firms and supply chains has been well-captured during this emergent crisis. The establishment of temporary networks illustrates this, not only at the supply chain level but also at the cross-chain level, such as the trial partnership between delivery platforms and supermarkets (Butler, 2020). The literature widely acclaims the combination of resources or collaboration during the crisis, the ‘glue that holds supply chain organisations in a crisis together’ (Richey, 2009, p. 623). As argued by Piriyaawattana (2020), firms mostly possess valuable resources that are entrenched within inter-organisational ties, and such resources should be activated against adversities, such as in this COVID-19 situation. Several academic papers have established the role of collaboration in meeting this COVID-19 event. Hobbs (2020) calls for robust buyer-seller partnerships to build trust and weather the impacts of demand shifts and supply risk, both within and after the crisis. Fei *et al.* (2020) argue no one-size-fits-all strategy for the complicated COVID-19 situation can balance the trade-offs between health and economics. Hence, the mere commonality is to bind together, sharing ideas and experiences, making assessments and attempts, transforming a global crisis into opportunities for more sustainable and resilient food systems and a better food environment for mankind. In summary, our second practical implication is that after sensing the relevant opportunities and threats caused by the COVID-19, the second step to operationalise the SCA practice is to hone its seizing capability by acquiring, combining, and modifying tangible and intangible resources. Combining sensing and seizing capability, we support Nandi *et al.* (2020), who argued SCA as a suitably resilient management approach in an event with a rare probability of occurrence.

Answering RQ2 about how these SCA practices are expected to transform the FSC in the post-COVID-19 period, Section 4 provided the anticipation of the three cases regarding their transformation. We observed that not all SCA practices are expected to engender the supply chain transformation that outlasts the impact of the crisis (Table 2). The literature (see Hobbs (2020)) also raises some doubts about the ‘outlasting effect’ of some trends. For example, the novel condition—social distancing with supermarket queuing hassles imposed by the COVID-19 crisis—drove the spur of online grocery shopping. However, this trend might not reach the same pulse when the crisis subsides. Similarly, interests in fresh local produce that healthier orientation during this health crisis renewed might fade away with the return of the abundance of cheap alternatives from the global complex supermarket chain. The heavy reliance on immigrating workers might not ease if the farm work profile remains unattractive to the local workforce. For transformation to occur, firms and their supply chains must continue offering competitive benefits to the market when normality resumes. Only when the locally sourced supply chain can expand its scale to drive down the costs and offer a more convenient shopping experience than mainstream supermarket chains will the triumph of local food demand continue. Thus, our third implication is that the FSC needs to build up the capability to reinforce and extend the favourable changes for the transformation to occur when the COVID-19 has subsided. RQ2 also enables us to establish a missing link between sensing and seizing capability and transformation capability during the crisis.

5.2. Theoretical implication

We offer a refined dynamic capability framework for the operationalisation and advancement of SCA in times of crisis (Figure 3) and give a detailed description of the proposed framework.

First, the crisis initiates sudden conditions for systemic opportunities and threats to occur, which require the supply chain to provide agile responses by leveraging and sharpening the sensing and seizing capability. Sensing involves activities to identify and assess the relevant opportunities and

threats specific to the supply chain context. This definition is consistent with the sensing definition in the conceptual models of Teece (2007) and Wilhelm *et al.* (2015). The seizing capability involves acquiring, combining and modifying tangible and intangible resources, to mitigate threats and optimise opportunities. This definition supplements the threat mitigation in the seizing definition of Teece (2007) and specifies the process for the development of this capability, including acquiring, combining or modifying the resources.

When the crisis subsides, a sustaining capability is augmented for the transformation to occur in the post-crisis period. The favourable conditions that stimulate changes normally vanish once the crisis ends. While a crisis may be serendipitous for systemic and subtle changes in the supply chain, supply chain actors can sustain the changes that are conducive to long-lasting benefits. We argue that to recognise transformation in the DCV's framework, these supply chains must develop the capability to sustain the positive changes, defining the sustaining capability as the activities directed towards the desirable changes in the market and business environment enduring once the crisis has subsided.

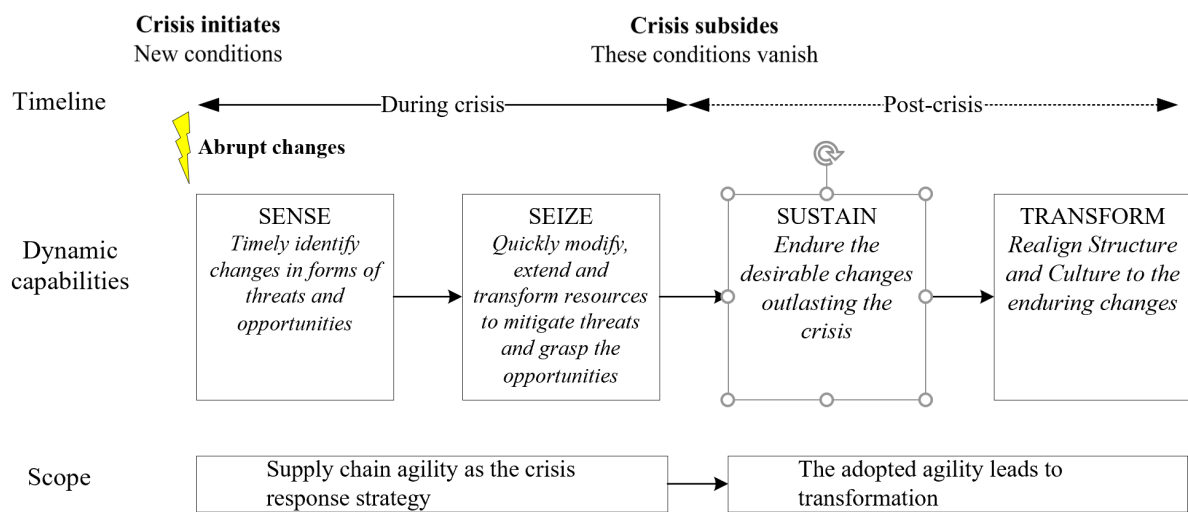


Figure 3: The dynamic capability framework during crisis considering supply chain agilities

The DC theory is often criticised for lacking clarity about its core concepts (Ambrosini and Bowman, 2009), the difficulties of determining the virtues of the theoretical outcomes (Zahra *et al.*, 2006) and the lack of empirical practices that link with its core concepts (Wang and Ahmed, 2007). The empirically-based framework this study proposes benefits overcoming these weaknesses and advancing the explanatory power of the dynamic capability in the crisis context. Further, this framework stimulates deeper insights into the theoretical discourse of SCA. We continue to support Eckstein *et al.* (2015) and Dubey *et al.* (2018) in positioning SCA as sensing and seizing capabilities in the DC framework. Meanwhile, we endorse Teece *et al.* (2016), establishing the crucial role of agility and the DC framework in deep uncertainty or crisis. Finally, we believe that the framework can be generalised in other supply chain contexts, in a crisis event that induces systemic and widespread shocks.

6. Conclusions

We set out to explore how the FSC manifests itself in providing timely responses to the abrupt changes engendered by the COVID-19 outbreak. Drawing on the DC theory, we investigated a multi-case study that looked at three cases of UK food supply chains to illustrate operationalisation of agile

responses through leveraging the sensing and seizing capabilities and the expectation that these responses would engender transformation in a post-COVID-19 period. This exploratory study is among the few that discuss the role of SCA as a crisis- mitigation strategy.

We find that the COVID-19 crisis inflicted abrupt changes, representing not only threats but also opportunities in the FSC network. Sensing capability allows three supply chains to quickly locate and assess the changes deriving from the COVID-19 crisis, including (i) operational challenge for a labour-intensive process (processing factory, farm harvesting), (ii) demand distortion in three different patterns (shift towards affordable items, local fresh foods and home delivery, a surge in demand). Seizing capability enabled the three cases to build, combine, modify resources to seize the opportunities and mitigate the threats. Resources in the three cases include tangible (vehicles, employees, IT-existing website) and intangible (relational and positional resources) forms. The cases utilised unique forms of sensing and seizing capabilities. Although these practices align with evidence from the literature, one interesting finding from the case studies, which differs from the existing theoretical framework, is that not all agile practices can translate into the transforming capability. Thus, augmenting the sustaining capability in the dynamic capability framework could allow a genuine translation of agile practices into the transforming capability.

This study comes with limitations that offer opportunities for future investigations. First, our scope is confined to a limited sample size in the context of the FSC in the UK, a developed country. Although it fits the exploratory nature to query a nascent and complex phenomenon, some of our findings, such as the shortage of labour, might not apply to other regions, particularly a developing country. The COVID-19 pandemic is a global health crisis but bears the regional nuances that offer an interesting research avenue for cross-case analysis. Second, the study was conducted from early May to the middle of August 2020, when the lockdown was lifted but vaccines were not yet available. There is little certainty of what the future might hold, even for near-term impact. The temporal characteristics of the trend open an opportunity for longitudinal analysis, particularly in the post-COVID-19 era. Therefore, we invite researchers to explore the trends of online grocery shopping and consumers' preferences for local and short supply chains. This contributes to advancing how the novel sustaining capability is operationalised to allow the SCA practices to engender the supply chain transformation. Finally, this paper approaches SCA from the disruption of the mitigation and opportunity-seeking angles of a notorious lean food system, in the face of crisis. While we strongly believe that our proposed taxonomy holds value for the SCA discourse, future studies that shed light on the performance of a supply chain designed with agility amid COVID-19 threats further inform the academic discourse.

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Appendix 1: The food supply chain literature under the COVID-19 pandemic

Academic references	Issue date	Research type	Central themes
Cappelli and Cini (2020)	31/03/2020	Commentary	The role of short FSC in international crisis
Gray (2020)	14/04/2020	Commentary	Canadian food transports: bulk freight, rail, trucks.
Ivanov and Dolgui (2020)	15/04/2020	Conceptual model	Proposal of an intertwined supply network (ISN) using viability and trophic chain modelling
Weersink et al. (2020)	17/04/2020	Commentary	COVID-19 implications on Canadian dairy and poultry chain from retail, distribution network, processor to farm
Kerr (2020)	18/04/2020	Commentary	Impacts of COVID-19 on international food trade
Deaton and Deaton (2020)	18/04/2020	Commentary	Canadian food security issues
Long and Khoi (2020)	19/04/2020	SEM	Hoarding effect during COVID-19 using expanded Planned Behaviour Model (PBM)
Jribi et al. (2020)	19/04/2020	Survey	Changes in food waste behaviour during the COVID-19 period from 284 respondents
Hobbs (2020)	21/04/2020	Commentary	Canadian food challenges & implications
Larue (2020)	21/04/2020	Commentary	Labour issues during COVID-19 in Canadian agriculture
Hailu (2020)	23/04/2020	Commentary	COVID-19 impacts on Canadian food processors
Di Vaio et al. (2020)	27/04/2020	Review	Artificial Intelligence in the Agri-Food system in the COVID-19 scenario
Power et al. (2020)	13/05/2020	Commentary	Inequality in the UK food system (food banks, food insecurity, poverty, Universal Credit)
Garnett et al. (2020)	01/06/2020	Commentary	Vulnerability analysis in the UK food system
Rizou et al. (2020)	08/06/2020	Commentary	Food safety and the need for respective bioanalytical protocols in the post lockdown period
de Paulo Farias and de Araújo (2020)	19/06/2020	Survey	Food price and distribution in infected areas in Brazil
Zhu and Krikke (2020)	16/06/2020	System Dynamic	Simulate a three-tier cheese supply chain under three disruption scenarios
Pulighe and Lupia (2020)	17/06/2020	Commentary	Role of urban agriculture in lockdown
Fan et al. (2020)	23/06/2020	Review	Global food and nutrition security
Aldaco et al. (2020)	26/06/2020	LCA & MFA	Food waste management in Spain under lockdown
Singh et al. (2020)	29/06/2020	Simulation	Design a resilient and responsive food distribution system incorporating truck-drone delivery under strict lockdown
Veselovská (2020)	7/07/2020	Survey	Cross-country and cross-sector survey (including food) in 211 Central Europe firms under COVID-19 disruption
Sharma et al. (2020)	15/07/2020	Case analysis	Solid waste management including food, biomedical and plastic wastes during COVID-19
Laborde et al. (2020)	31/07/2020	Commentary	Global food security (availability, access, utilisation, price stability) under COVID-19

Note: The retrieval of the list of 24 articles on the topic of the FSC in the COVID-19 pandemic utilised a process of applying relevant keywords and search strings to the Web of Science and Scopus, two main scientific databases for literature discovery. The keywords relate to two topics, food supply chain ((food OR agriculture) AND “supply chain”) and epidemic outbreak (epidemic OR pandemic

OR COVID-19 OR coronavirus). We limited the scope of the search to peer-reviewed articles and the timeframe up to 31/07/2020. Two criteria for assessing relevance were: (i) the article is written in English (ii) FSC defines the main topic of the study. A process of applying these inclusion and exclusion criteria yielded a list of 24 relevant articles. The entire process aligned with the systematic literature review framework proposed in Tranfield *et al.* (2003).