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Blockchain technology for enhancing swift-trust, collaboration and resilience within a humanitarian supply chain setting

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There has been tremendous interest in blockchain technology (BT) (also known as distributed ledger technology) around the globe and across sectors. Following significant success in the financial sector, other sectors, such as humanitarian sector, have started deploying BT at various levels. Although the use of BT in the humanitarian sector is in its infancy, donors and government agencies are increasingly calling for building BT-enabled swift-trust (ST) and more collaborative relationships among various humanitarian actors in order to improve the transparency and traceability of disaster relief materials, information exchanges and flow of funds in disaster relief supply chains. Our study, which is informed by organisational information processing theory and relational view, proposes a theoretical model to understand how BT can influence operational supply chain transparency (OSTC) and ST among actors engaged in disaster relief operations. Our model also shows how BT-enabled ST can further improve collaboration (CO) among actors engaged in disaster relief operations and enhance supply chain resilience (SCR). We formulated and tested six research hypotheses, using data gathered from international non-governmental organisations with the help of the Coordinator for Humanitarian Affairs (OCHA) database. We received 256 usable responses using a pre-tested survey-based instrument designed for key informants. Our results confirm that our six hypotheses were supported. Our study offers significant and valid contributions to the literature on ST, CO and SCR and BT/distributed ledger technology. We have also noted the limitations of our study and have offered future research directions.

Keywords: blockchain technology; distributed ledger technology; humanitarian supply chain management; humanitarian operations management; swift-trust; collaboration; supply chain resilience; operational supply chain transparency

1. Introduction

Disasters and crises are complex and very challenging for organisations involved in disaster relief operations (Gibson and Tarrant 2010; Gunasekaran et al. 2018). Increasingly natural disasters are affecting the lives of the people. For instance, earthquakes and tsunamis accounted for the majority of the 10,373 lives lost in 2018, while extreme weather adversely affected nearly 61.7 million people (UNISDR, 2019). These events suggest that volatility in our natural, economic and social systems appears to be increasing at a faster rate than many organisations and societies can cope with. Hence, in recent years, a majority of developing economies have been either deliberately designed, or have evolved, to operate efficiently and effectively in routine environments characterised by stability and predictability (Gibson and Tarrant 2010; Zhang, Wang, and Zhu 2019; Ivanov and Dolgui 2019). Despite a high level of preparation, one of the most powerful earthquakes and tsunami in 2011, which was triggered by 9.0 Mw (moment magnitude scale) along the northern Pacific coast of Japan (Nakanishi, Black, and Matsuo 2014; Koshimura and Shuto 2015; Aoki 2016), caused potential damage to lives and properties. Similarly, the 2010 Haiti earthquake or 2018 Kerala floods resulted in many lessons to be learned that have led to a paradigm shift in ways post-disaster relief efforts were managed. We contribute to this paradigm shift through two overall objectives: firstly, we seek to understand how blockchain technology (BT) and operational supply chain transparency (OSTC) influence swift-trust (ST) among actors engaged in disaster relief operations; secondly, we seek to understand how ST and collaboration (CO) among these actors influence supply chain resilience (SCR). In the next sections, we introduce these different constructs in the context of humanitarian operations, the theorised relationships between them and then, the research questions for our study.

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Given the high number of humanitarian relief actors engaged in post-disaster relief efforts, the lack of CO (Moshtari 2016; Islam and Walkerden 2017; Dubey et al. 2019a) and high levels of corruption (Islam and Walkerden 2017; Dwivedi et al. 2018) among these humanitarian organisations (HOs), there is often poor distribution of relief materials to the affected areas, particularly in the last mile; causing congestion at local airports and roads. This can even lead to competition among these humanitarian actors over limited resources (e.g. building materials, medicine, labour etc.) raising costs and causing delay (Chang et al. 2011; Moshtari 2016; Awasthy et al. 2019). To address these challenges, the humanitarian actors are increasingly calling for more collaborative relationships and enhanced resilience in disaster relief supply chains via emerging technologies (Ko and Verity 2019; Dubey et al. 2019a; Chen, Das, and Ivanov 2019). Improved CO within a humanitarian setting can yield benefits, such as access to more resources (e.g. donations, equipment, skills and information) (Moshtari 2016; Wagner and Thakur-Weigold 2018) and further enhance resilience (Wieland and Marcus Wallenburg 2013; Dubey et al. 2019b).

CO is one of the areas within the operations management field that has attracted significant attention. It is well understood that CO has a positive impact on organisational performance (Cao and Zhang 2011). It enables organisations to achieve competitive advantage by reducing costs and improving service levels, as well as enabling quick response to any changes in the environment (Stank, Keller, and Daugherty 2001; Tsou 2013). However, successful CO among the actors engaged in disaster relief operations is based on the level of the actor's commitment (Moshtari 2016; Dubey, Altay, and Blome 2017; Dolgui et al. 2019). Ralston, Richey, and Grawe (2017) argue that the factors that impede successful CO are differences in power, financial reasons, conflicting goals or poor alignment in terms of the use of IT. Casey and Wong (2017) further argue that the lack of trust and transparency in information sharing among supply chain partners often leads to poor CO. In humanitarian settings, the lack of trust and visibility are often cited as the main reasons behind poor CO among humanitarian actors (Moshtari 2016; Dubey et al. 2019a). These problems are often due to a large number and variety of actors, a chaotic post-disaster relief environment and the lack of sufficient resources (Balcik et al. 2010; Moshtari 2016). Hence, BT is put forward as a technology that may change organisation cultures, supply chains and industries (Kewell, Adams, and Parry 2017; Min 2019; Zhu et al. 2019; Zhu and Kouhizadeh 2019; Saberi et al. 2019; Queiroz and Wamba 2019; Dolgui et al. 2019; Wang, Han, and Beynon-Davies 2019a, 2019b). Due to increasing interest in bitcoin, the BT application that powers cryptocurrency concept and provides the underlying technology has gained heightened interest among scholars, policymakers and business communities (Min 2019; van Hoek 2019). In general, BT allows for safe financial transactions between two or more actors involved in supply chain networks via a digital decentralised ledger, which cannot be interfered with (Dolgui et al. 2019). In fact, many organisations, like Maersk (Lal and Scott 2018) and Walmart in cooperation with IBM (Yadav and Singh 2020), have implemented BT in their organisations. Moreover, some scholars argue that BT has great potential to shape disaster relief supply chains (see, Thomason et al. 2018; Chen 2018; Ramadurai and Bhatia 2019), though the development and the implementation of BT solutions in humanitarian settings are still at an early stage.

In the past, scholars have argued that lack of trust among the partners in supply chain was a major issue because CO requires information sharing of sensitive data and requires visibility in supply chain (Barratt 2004; Ramanathan 2014; Ramanathan and Gunasekaran 2014; Dubey et al. 2018a; Mejia, Urrea, and Pedraza-Martinez 2019). However, except for anecdotal evidences, the existing literature has remained silent on the role of BT, which allows actors to share information in a completely safe and transparent way, with the result of enabling ST among those engaged in disaster relief operations. Scholars in the past have studied the direct relationship between ST and CO among the actors engaged in disaster relief operations (Tatham and Kovács 2010; Lu, Goh, and De Souza 2018; Dubey et al. 2019a). However, research into the mediating role of ST between BT and CO is in its infancy. Finally, understanding of the effects and interrelationships of BT, OSTC and ST remains fragmented and lacks adequate theoretical grounding. Hence, our first research question is: *what are the distinct and combined effects of BT and OSTC on ST?*

Understanding of the concept of SCR is in its infancy stage; it was first defined from an organisational perspective in the case of supply chain management in the early 2000s (Hohenstein et al. 2015; Tabaklar 2017). However, the term resilience has been studied in other fields for considerably longer, such as materials science, ecological sciences and organisational research (Pettit, Croxton, and Fiksel 2013). Despite increasing literature on SCR, there is still no common definition of the concept (Gunasekaran, Subramanian, and Rahman 2015; Tukamuhabwa et al. 2015; Chowdhury and Quaddus 2017; Ivanov, Dolgui, and Sokolov 2018; Ivanov and Sokolov 2019). Following Ponomarov and Holcomb's (2009, 131) definition, we argue that SCR is 'the adaptive capability of the supply chain that prepare it to deal with unexpected events, respond to disruptions and further help to recover from disruptions via maintaining continuity of operations at desired level of connectedness and control over structure and function'. Currently, studies in SCR have emerged that discuss more thoroughly the role of procurement (Pereira, Christopher, and Lago Da Silva 2014; Vanpoucke and Ellis 2019; Kaur and Singh 2019), the role of trust (Soni, Jain, and Kumar 2014; Jain et al. 2017; Dubey et al. 2019b), the role of flexibility (Ivanov, Sokolov, and Dolgui 2014; Kamalahmadi and Parast 2016; Chowdhury and Quaddus 2017; Sreedevi and Saranga 2017; Dubey et al. 2019c), the role of cooperation/CO (Christopher and Peck 2004; Wieland and Marcus Wallenburg 2013; Scholten and Schilder 2015; Dubey et al. 2019b), the role of supply chain visibility (Brandon-Jones et al. 2014) and the role of emerging technologies like big data and predictive analytics (Dubey et al. 2019c; Singh and Singh 2019; Ivanov, Dolgui, and Sokolov 2019) and BT (Min 2019).

To build resilient supply chains, there are diverse capabilities that need to be in place (Tabaklar, 2017; Sá et al. 2019; Hosseini and Ivanov 2019; Elluru et al. 2019). However, humanitarian supply chains involve various actors with different skills coming together from different organisations to achieve a common goal: to help people and alleviate suffering. Despite a common goal, the CO efforts among the actors are often challenging due to barriers resulting from geography, different cultural backgrounds and different organisational policies (Balcik et al. 2010). Moreover, the unpredictability and surges in demand, coupled with scant resources, are the main characteristics of the humanitarian settings (Balcik and Beamon 2008; Kovács and Spens 2009; Altay and Labonte 2014; Altay and Pal 2014; Altay et al. 2018; Ni et al. 2019). Hence, scalability is an important characteristics of humanitarian supply chains, as the design of humanitarian supply chains must be flexible enough to accommodate the sudden change in demand during disaster relief operations (Day 2014; Tabaklar, 2017; Singh and Singh 2019). Moreover, to achieve scalability in humanitarian supply chains, it is important to build ST among actors involved in disaster relief operations (Tatham and Kovács 2010; Dubey et al. 2019a) and CO (Moshtari 2016) via information sharing (Altay and Pal 2014). In this study, we focus on ST and CO as antecedents of SCR. Research has shown that ST and CO may severely impact upon certain humanitarian supply chain management characteristics (i.e. Tatham and Kovács 2010; Dubey, Altay, and Blome 2017; Lu, Goh, and De Souza 2018; Dubey et al. 2018a, 2019a). However, such crucial effects have not been addressed by prior research theoretically or been subjected to empirical testing. For instance, Min (2019) argues that BT can be effectively utilised to reduce supply chain disruptions and may help to enhance SCR. However, in the context of humanitarian settings, evidence of the potential of BT still remains elusive. The extant literature provides anecdotal evidence (Ramadurai and Bhatia 2019), yet empirical study is scant. We note this as a significant research gap and hence we specify our second research question as: *what are the direct and combined effects of ST and CO on SCR?*

We answer our two research questions using data collected from respondents in 256 international non-governmental organisations (NGOs) engaged in disaster relief operations in countries across Asia, Europe, Africa, North America and South America. To provide theoretical arguments to interpret our empirical results, we used an integration of organisational information processing theory (OIPT) (see Gattiker and Goodhue 2004; Haußmann et al. 2012; Srinivasan and Swink 2015, 2018; Dubey et al. 2019a, 2019c) and relational view (RV) (Dyer and Singh 1998), because neither perspective can, on its own, explain the direct or mediating roles of BT, OSTC, ST and CO on SCR. Our paper is organised as follows. In Section 2, we present the underpinning theory of our study, theoretical model and our research hypotheses. In Section 3, we illustrate our research design, including a detailed discussion on the operationalisation of our constructs, sampling design and data collection strategy. In Section 4, we present our data analyses. In Section 5, we provide our discussion of the results and implications to theory and practice, the limitations of our study and future research directions.

2. Theoretical model and hypotheses development

The foundation of our theoretical model is grounded in two perspectives: OIPT and RV. In recent years, OIPT has emerged as a powerful explanation of how information is used effectively to gain competitive advantage, especially when organisations execute tasks that involve a high degree of uncertainty (Galbraith 1974; Srinivasan and Swink 2015, 2018; Zhu et al. 2018; Dubey et al. 2019a, 2019c). Following Galbraith (1971, 1977), we argue that an organisation can either reduce their needs for information via mechanistic approaches or increase their information processing capability. The first option, i.e. reducing its information processing need via creating slack resources/or by creating self-contained tasks, may prove costly and does not contribute to agility. The second option, i.e. increasing information processing capability of the organisation via investing in both lateral and vertical information systems, is perhaps a better option in uncertain environments (Srinivasan and Swink 2018). Hence, we argue that increasing information visibility may help to enhance ST among the actors engaged in disaster relief operations (Dubey et al. 2019a). In addition, an organisation utilising its strong technological capability will not have much effect on the organisational behaviour without also affecting the behaviour of the humans engaged in the process. Thus, we argue, based on RV, that ST and CO among the actors involved in disaster relief operations play a significant role in enhancing resilience in humanitarian supply chains. The RV suggests that an organisation can derive their competitive edge via relational rents or benefits that are created within collaborative relationships and through the joint effort and contribution of the partners (Dyer and Singh 1998; Wang, Tai, and Grover 2013; Moshtari 2016), which may not be feasible through the effort of a single organisation (Cao and Zhang 2011). Hence, we propose our theoretical model informed by two organisational perspectives: OIPT and RV (Figure 1).

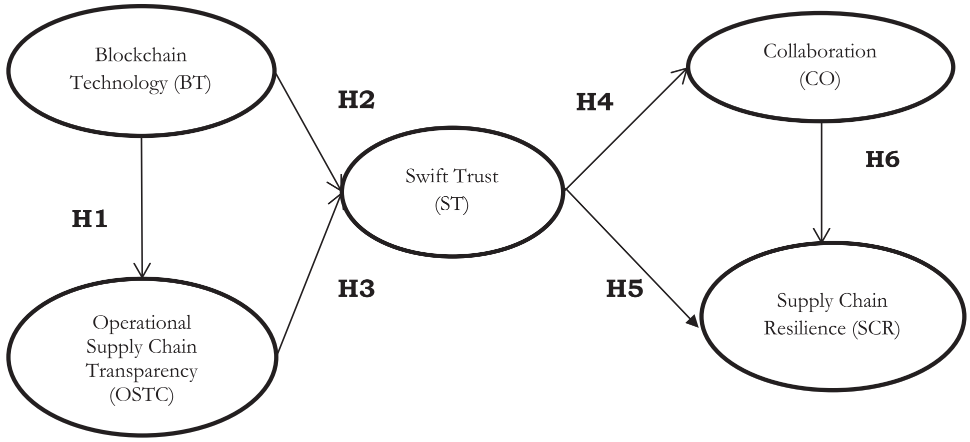

Figure 1. Theoretical model.

2.1. Blockchain technology and operational supply chain transparency

Zhu et al. (2018) argue that a transparent supply chain relies heavily on the flow of materials, fund and related information in entire chain. Morgan, Richey, and Autry (2015) further defined operational supply chain transparency (OSCT as an 'organization's capability to proactively engage in communication with stakeholders to create visibility and traceability into upstream and downstream supply chain operations' (c.f. Zhu et al. 2018, 48). In simple words, we can explain OSCT help the supply chain partners in a supply chain to track current and historical activities of products throughout the entire supply chain. Hence, we can argue that transparency in the supply chain help to reduce the complexity of supply chain processes via improving the visibility of upstream and downstream supply chain operations (Brandon-Jones et al. 2014). Dolgui et al. (2019) argue that BT is a hack-resistant, tamper-proof and immutable due to its distributed ledger and network verification process. Hence, due to this characteristics, BT offers traceability, since append-only distributed databases of previous transaction records can be shared across the entire partners to partner's network and the historical records remain forever with permanent footprints (Min 2019; Martinez et al. 2019; Roeck, Sternberg, and Hofmann 2019). We have further illustrated the use of BT in supply chain management, particularly in the humanitarian sector, based on Ko and Verity (2019) works (see Appendix 1). Thus, we can argue that BT can be successfully utilised for improving OSCT. Hence, we can hypothesise it as:

H1: BT is positively related to OSTC.

2.2. Blockchain technology and swift-trust

Altay and Labonte (2014) argue that unreliable information and information silos among humanitarian actors is often considered as a key barrier in coordination among the humanitarian actors. In the era of big data, information sharing plays a critical role in effective and efficient disaster response (Dubey et al. 2018a). Casey and Wong (2017) further argue that BT can help to overcome barriers that impede data sharing via providing an information that is publicly accessible to all users while preserving the information security. This may further help to reduce the costs and increase transparency with humanitarian data (Solaiman and Verity 2019). Thus, due to blockchain's distributed ledger technology, it is possible for different humanitarian actors engaged in disaster relief operations to collect and share data on the same network. Hence, we can argue that BT offers a permanent, searchable, irrevocable public records repository. Thus, a combination of time-stamped and digitally verified information hosted on an accessible ledger may help to build rapid trust among the various actors involved in disaster relief operations. Thus we can hypothesise it as:

H2: BT is positively related to swift-trust.

2.3. Operational supply chain transparency and swift-trust

Akkermans, Bogerd, and Van Doremalen (2004) argue that transparency in the supply chain has a positive impact on trust. Although this is well studied by organisational scholars (see Anderson and Narus 1990), the empirical study is limited. Anderson and Narus (1990) found that the past information exchange between two companies has played an important role in building trust. Korsgaard, Schweiger, and Sapienza (1995) found that those organisations had more transparency in terms of rules, on procedural justice, it further resulted into a higher degree of trust and commitment. Kwon and Suh (2004) further argue that behavioural uncertainty often arises from the lack of adequate information sharing or transparency among the partners in the supply chain has a large effect on the governance. The behavioural uncertainty created by any supply chain partner will decrease the trust in other partners. Dubey, Altay, and Blome (2017) further examined how information sharing among the actors involved in disaster relief operations further reduces the behavioural uncertainty and build ST. Hence, based on preceding discussions, we can argue that OSTC created via BT can further help to build ST among humanitarian actors. Thus, we hypothesise it as:

H3: OSTC is positively related to swift-trust.

2.4. Swift-trust and collaboration

The CO in the context to humanitarian setting has gained immense attention from operations management scholars (Moshtari 2016; Prasanna and Haavisto 2018; Dubey et al. 2019a). However, the theory of humanitarian supply chain CO heavily relies on traditional supply chain CO theory. The supply chain CO in supply chain management literature has been grouped into two categories (Cao and Zhang 2011): relationship-based (Bowersox, Closs, and Stank 2003) and process-driven (Mentzer et al. 2001). Relationship-based CO is often seen as a long-term partnership in which partners actively share information and strategic resources to achieve a common goal. On the other hand, process-driven CO occurs when two or more organisations engage to achieve common goals (Moshtari 2016; Prasanna and Haavisto 2018; Dubey et al. 2019a). Based on Morgan and Hunt (1994), we extend the underlying proposition (i.e. trust and commitment) leads to CO. One aspect of the Morgan and Hunt (1994) argument is the amount of trust among partners. According to Morgan and Hunt (1994, 23), trust is defined as 'confidence *in an exchange partner's reliability and integrity*'. Moshtari (2016, 1545) argues that in a humanitarian context, 'humanitarian organisation's trust in its partner can be observed via openness between partners/or greater appreciations of partners' contributions towards building collaborative relationship'. Hence, due to high level of competition among organisations for limited resources in the humanitarian context, the mutual trust helps to minimise the opportunistic behaviours, and encourages partners' to exchange information, knowledge and other resources with each other (Moshtari 2016; Dubey, Altay, and Blome 2017; Salem et al. 2019). Dubey, Altay, and Blome (2017) have found a positive association between ST among humanitarian actors engaged in disaster relief operations and level of coordination. Hence, relying on previous findings, we hypothesise it as:

H4: Swift-trust is positively related to collaboration.

2.5. Swift-trust and supply chain resilience

Blackhurst, Dunn, and Craighead (2011) argue that relationship competencies such as communication, relationship management and monitoring systems are positively related to resilience. Relying on previous arguments that RV offers a useful explanation to SCR theory (see Wieland and Marcus Wallenburg 2013; Johnson, Elliott, and Drake 2013; Papadopoulos et al. 2017; Dubey et al. 2019b). Dubey et al. (2019b) have found a positive association between trust and SCR. Hence, relying on previous arguments, we argue that ST among the actors engaged in disaster relief operations will have a positive influence on SCR. Hence, we hypothesise it as:

H5: Swift-trust is positively related to supply chain resilience.

2.6. Collaboration and supply chain resilience

Scholten and Schilder (2015) have found in their study that CO is one of those essential capabilities which have a positive influence on building SCR. The CO between supply chain partners enables the bonding among partners, facilitates joint planning and encourages real-time information exchange (Jüttner and Maklan 2011), needed for quick recovery from disasters while reducing their negative impacts (Altay et al. 2018). Barratt (2004) further argues that mutual respect and sharing of benefits, rewards and risk coupled with effective and efficient information exchange between partners are the founding pillars of the CO. Hence, it well understood based on the literature review that CO among partners bring several benefits such as higher visibility, flexibility and further reduces lead times (Cao and Zhang 2011; Scholten and Schilder 2015). Relying on these essential characteristics of CO, we can argue that CO among disaster relief actors may help to enhance SCR. Thus, we can hypothesise it as:

H6: Collaboration is positively related to supply chain resilience.

We include several control variables in our statistical analyses, which may affect the mediating factors in our theoretical model. Following Moshtari (2016) arguments, we have controlled the interdependency perception. Hibbard et al. (2001) argue that interdependence enhances the desire to maintain the relationship. Moreover, we control for the temporal orientation. CO requires long-term investment in terms of human resources and information. Hence, long-term orientation has a significant positive impact on successful CO (Morgan and Hunt 1994), particularly when the degree of uncertainty is high. Moreover, long-term orientation helps to enhance mutual trust among partners.

3. Research design

3.1. *Survey instrument development*

To test our six research hypotheses, we first defined our constructs and generated our items via a critical review of the literature published in organisational studies and operations management. Secondly, we adapted them to fit clearly in context to humanitarian operations management (Moshtari 2016; Dubey et al. 2019a; Salem et al. 2019). To further assess the clarity of items used in survey-based instrument and their proper adaptation in context to humanitarian settings, we requested seven humanitarian or disaster relief operations practitioners to fill out the questionnaire in front of the researcher who attended 4th French National Humanitarian Conference (Paris 22 March 2018) and to raise any concerns found within. For instance, we asked these experts to have their view on the clarity and appropriateness of the measures purporting to tap the constructs. We adopted a seven-point Likert scales with end points 'strongly disagree' and 'strongly agree' to measure the items of all latent variables and capture responses for all items. Based on this, we examined the content validity of constructs and their related measuring items (see Appendix 2).

3.2. *Sampling design*

Since the empirical context of our study is based on international NGO's engaged in disaster relief operations in various countries across Asia, Europe, Africa, North America and South America, the constructs which we used in our study are grounded to examine the relationship between organisations, viewed from the focal organisation's perspective. Informed by Lambe, Spekman, and Hunt (2002) and Moshtari (2016) works, our measures were based on perceptions of one key informant. We identified the key informants with the help of the Coordinator for Humanitarian Affairs (OCHA) database. The contact information of all these international NGOs were gathered with the help of OCHA leadership team. We ensured that the respondents were knowledgeable about the applications of emerging technologies in disaster relief operations with the help of the OCHA team. The guidance of the OCHA team in this context was highly appreciable as they provided us database about those NGOs who are using BT, big data analytics and artificial intelligence in disaster relief operations or are planning to adopt.

3.3. *Data collection*

We undertook data collection following Dillman's (2011) tailored design method. In recent years, scholars have adopted this method to improve the response rate (see Rothaermel and Alexandre 2009; Cao and Zhang 2011; Eckstein et al. 2015; Moshtari 2016; Dubey et al. 2019a, 2019b, 2019c). We started our data collection in September 2018 and completed it in February 2019. We contacted 1713 respondents via e-mail with a package consisting of invitation letter, which clearly explained the purpose of our study, and with assurance to each participant that strict anonymity and confidentially about their information would be maintained. After three e-mail reminders, we received 256 usable responses, giving an effective response rate of 14.94%. This response rate is low, though it is in line with similar studies, e.g. 13% Moshtari (2016) or 23% Saberi et al. (2019), which is likely due to the fact that our respondents were NGOs and most are yet to fully understand the role of BT in their context. The participants involved in our study were senior managers in their organisations (logistics/supply chain/procurement head or Director or CEO). Their profiles are shown in Appendix 2. Our respondents were broken down as follows: 23.44% from NGOs managing health services, 30.47 from NGOs managing logistics services, 21.88% from NGOs managing food security, 16.02% from NGOs managing water, sanitation and hygiene and 8.2% from NGOs managing camp coordination. They worked in NGOs from 26 counties across five continents (see Appendix 3).

We tested response bias following the Armstrong and Overton (1977) arguments. We compared the responses of each measurement item between early responses (first 30%) to late responses (last 30%). This test assumes that the late respondents are equivalent to non-respondents (Armstrong and Overton 1977). We found no statistically significant differences (for every measurement item we observed $p > 0.25$), between early and late respondents in responses for all measurement items. Hence, we can argue that non-response bias do not pose a major concern in our study.

Table 1. Measurement scales.

Items	Lambda	Variance	Error	Alphas	SCR	AVE
BT1	0.89	0.79	0.21	0.93	0.94	0.77
BT2	0.89	0.80	0.20			
BT3	0.89	0.79	0.21			
BT4	0.86	0.73	0.27			
BT5	0.87	0.75	0.25			
OSTC1	0.89	0.79	0.21	0.90	0.93	0.77
OSTC2	0.88	0.77	0.23			
OSTC3	0.84	0.70	0.30			
OSTC4	0.90	0.81	0.19			
ST1	0.91	0.82	0.18	0.87	0.92	0.80
ST2	0.91	0.82	0.18			
ST3	0.87	0.75	0.25			
CO1	0.89	0.78	0.22	0.87	0.92	0.80
CO2	0.89	0.79	0.21			
CO3	0.91	0.83	0.17			
SCR1	0.86	0.74	0.26	0.88	0.92	0.74
SCR2	0.88	0.78	0.22			
SCR3	0.84	0.70	0.30			
SCR4	0.85	0.73	0.27			
I1	0.93	0.87	0.13	0.80	0.93	0.87
I2	0.93	0.87	0.13			
LTO1	0.91	0.83	0.17	0.91	0.94	0.84
LTO2	0.93	0.87	0.13			
LTO3	0.90	0.82	0.18			

Notes: BT, blockchain technology; OSTC, operational supply chain transparency; ST, swift-trust; CO, collaboration; SCR, supply chain resilience; I, interdependence; LTO, long-term orientation

4. Data analysis

We first tested our measurement items for the assumption of constant variance, existence of outliers and normality. Further, to ensure that multi-collinearity is not a major problem, we calculated variance inflation factors (VIF). In our case, all VIF were < 3.0, and therefore significantly below the recommended threshold of 10.0 (Hair et al. 2006). Hence, we can argue that multi-collinearity is not a major issue in our study.

4.1. Measurement properties of constructs

Table 1 reports coefficient alphas (α), scale composite reliabilities (SCR) and average variance extracted (AVE) for the study's first-order, multi-item constructs. The values derived indicate reliable and valid measures of the individual constructs. After examining the construct validity individually, we performed a confirmatory factor analysis (CFA) with the help of AMOS 22.0 (Liang and Yang 2018) and the maximum likelihood procedures (Hair et al. 2006). The measures of goodness of fit had satisfactory results (χ^2/df = 1.74; CFI = 0.97; GFI = 0.92; TLI = 0.93; RMSEA = 0.03).

Next, we have examined the discriminant validity of the constructs used in our study (Table 2). Following, Fornell and Larcker (1981) arguments, we compared the square root of AVE of each construct with the absolute value of the correlation of that factor's measure with all measures of other factors in the model, as reported in Table 2.

4.2. Common method bias

The use of key informants is in common in organisational research (see Schilke 2014; Moshtari 2016; Srinivasan and Swink 2018; Fosso Wamba et al. 2019), common method bias might create problem in some studies (see Podsakoff et al. 2003; Ketokivi and Schroeder 2004). Hence, to avoid such possibility, we followed several steps. Firstly, and most importantly, we gathered CO and SCR response in a separate survey. This technique is known as split survey method. Eckstein et al. (2015) argue that split survey method reduces the likelihood of common method bias. Secondly, we performed Harman's one-factor test via loading all the measurement items of our study into an exploratory factor analysis. The maximum variance explained by a single factor is 42.78%, suggesting that common method bias was unlikely to contaminate our study. Thirdly, we applied the marker variable test (Lindell and Whitney 2001) which attempts to control for common method variance (CMV) via including a variable to the measurement model that is theoretically unrelated to the main constructs used in our

Table 2. Descriptive statistics and discriminant validity.

	Scale range	Mean	SD	BT	OSTC	ST	CO	SCR	I	LTO
BT	1–7	5.26	0.94	*0.88*						
OSTC	1–7	4.91	0.87	0.28	*0.88*					
ST	1–7	5.72	1.08	– 0.07	– 0.22	*0.89*				
CO	1–7	5.65	1.06	– 0.08	– 0.06	0.29	*0.89*			
SCR	1–7	5.63	1.04	– 0.04	0.04	– 0.22	– 0.12	*0.86*		
I	1–7	3.42	0.88	0.39	0.18	– 0.13	– 0.20	0.09	*0.93*	
LTO	1–7	3.21	0.58	– 0.06	– 0.15	0.09	0.09	0.03	– 0.12	*0.92*

Italic values represent square root of AVEs of the constructs.
Notes: BT, blockchain technology; OSTC, operational supply chain transparency; ST, swift-trust; CO, collaboration; SCR, supply chain resilience; I, interdependence; LTO, long-term orientation

Table 3. Hierarchical regression results ($n = 256$).

Variables	Model 1 (DV = ST)	Model 2 (DV = SCR)
Controls		
I		– 0.017 ($p = 0.643$)
LTO		– 0.053 ($p = 3.320$)
Paths		
BT → OSTC	0.69 ($p = 0.000$)	
OSTC → ST	0.63 ($p = 0.000$)	
BT → ST	0.98 ($p = 0.000$)	
ST → CO		0.86 ($p = 0.000$)
ST → SCR		0.862 ($p = 0.000$)
CO → SCR		0.41 ($p = 0.000$)
R^2	0.575	0.797

Notes: BT, blockchain technology; OSTC, operational supply chain transparency; ST, swift-trust; CO, collaboration; SCR, supply chain resilience; I, interdependence; LTO, long-term orientation

model. By performing this test, we have not noted any potential effects that would indicate a significant amount of CMV. These findings in total indicated that common method bias is not a serious issue in our study.

In recent years, operations management scholars have shown increasing interest in performing an endogeneity test (see Dong, Ju, and Fang 2016; Liu et al. 2016; Dubey et al. 2018b) to address causality problems that are often found in studies when researchers use non-experimental data to test their research hypotheses; as is the case in operations management research where empirical researchers often use non-experimental data collected over a period (i.e. cross-sectional data). Following Guide and Ketokivi (2015)'s arguments, we tested for endogeneity by conducting the Durbin–Wu–Hausman test (see Davidson and MacKinnon 1993). For this, we first regressed BT and OSTC on ST, then used the residual of this regression output as an additional regressor in our hypothesised equations. We found that the parameter estimate for the residual was not significant. Similarly, we regressed ST over CO and SCR, and then used the residual of the regression output as an additional regressor. Again we found the parameter estimate for the residual was not significant. Hence, we concluded that BT and OSTC were not endogenous in our setting. Similarly, we also concluded that ST was not endogenous to CO and SCR. Next, we performed our hypotheses tests, detailed in the next section.

4.3. Hypotheses tests

We examined our research hypotheses via hierarchical regression analysis. Two models, each for ST (M1), and SCR (M2), were tested. In M1, we tested the direct impacts of BT and OSTC on ST. In M2, we tested the direct effects of the ST on CO and SCR. We controlled the effects of control variables of our study. Table 3 summarises the regression analyses results for M1 and M2, respectively.

As we discussed in the beginning of our Section 4, we noted highest VIF = 3.0. This clearly suggests that multicollinearity is not an issue in our study (Hair et al. 2006). In the case of Model 1, we have found support for H1 (BT → OSTC) ($\beta = 0.69$, $p = 0.000$). We can argue that BT has a positive and significant effect on OSTC. H2 (BT → ST) ($\beta = 0.98$, $p = 0.000$) indicates that our initial assumption informed via review of academic literature and practitioner reports found support. We can argue based on our regression results that BT has a significant effect on building ST. However, extant literature and reports have clearly advocated this argument. However, to our understanding, based on a review of literature, it was not clear that how the use of BT can help to build ST among the actors involved in disaster relief operations. For H3 (OSTC → ST) ($\beta = 0.63$, $p = 0.000$), we found support. Hence, we can argue that OSTC has a positive and significant effect on ST. Overall, the predictors BT and OSTC explain nearly 57.5% ($R^2 = 0.575$) of the total variance in ST. This indicates that BT and OSTC are strong predictors of ST.

Similarly, in the case of model M2, we have found support for hypotheses H4 (ST → CO) ($\beta = 0.86$, $p = 0.000$), H5 (ST → SCR) ($\beta = 0.862$, $p = 0.000$) and H6 (CO → SCR) ($\beta = 0.41$, $p = 0.000$). These results clearly suggest that ST developed among the humanitarian actors has positive significant effects on CO and SCR. Moreover, CO among the humanitarian actors has a significant positive effect on SCR. Overall, the ST and CO together explain nearly 79.7% of the total variance in SCR ($R^2 = 0.797$). Thus, we can argue that ST and CO are the strong predictors of the SCR in the humanitarian relief supply chain.

5. Discussion of results and implications to theory and practice

The operations management literature broadly conceptualises distributed ledger technology as a technologically enabled ability that allows anyone to transfer assets – including intangible assets – without the risk of hacking and building silos that limit interactions among trading partners. In addition to the security benefit, the distributed ledger technology further reduces transaction cost, improves visibility across the supply chain and further enhances coordination among the partners (Min 2019; Roeck, Sternberg, and Hofmann 2019; Dolgui et al. 2019), thereby enabling organisations to gain competitive advantage (Hughes et al. 2019). We further expand the definition to include the inter-organisation and process elements of distributed ledger technology, positioning from an OIPT and RV perspective, ensuring safe transaction in the entire supply chain is both a challenge and an opportunity. In the humanitarian context, the data sharing, donor financing, cash programmes and crowdfunding always remained a serious challenge (Mejia, Urrea, and Pedraza-Martinez 2019). Rarely, humanitarian NGOs rely on the 'mechanistic' approach to take decisions via rules, hierarchy, targets and goals (Dubey et al. 2019a). Instead, humanitarian NGOs need to process large data of quality information stored in data warehouse to take quick decisions (Altay and Labonte 2014; Altay and Pal 2014). To reduce the distortion of information and create transparency in the entire humanitarian supply chain, organisations need infrastructure and processes that may enable to exchange information without any distortion among all the key partners involved in disaster relief operations. Hence, the information exchanged via increased information processing ability without fear of distortion of information can reduce behavioural uncertainty, especially when disaster relief teams are hastily formed and the scenario in which the hastily formed teams are highly volatile and operational tasks are highly complex (i.e. highly interdependent). These basic characteristics of disaster relief operations have renewed relevance, considering the large number of humanitarian actors coming from different cultural background and beliefs. Hence, informed via literature and reports, we view BT as a kind of distributed ledger technology as belonging to the specific case of information processing capabilities, made possible by recent growth in technologies, which are embedded in organisational and processes. Hence, in this study, we have examined the associations between BT and operational supply chain transparency and their effects on building ST among the actors engaged in disaster relief operations. Hence, to address this, we have posited our first research question. The empirical results of our study have confirmed the validity of existing strands of theory regarding trust and transparency (Akkermans, Bogerd, and Van Doremalen 2004). This in itself may be seen a significant contribution to the literature, as previous research efforts have clearly called for empirical validation of trust created via distributed ledger technology (Min 2019; Roeck, Sternberg, and Hofmann 2019; Dolgui et al. 2019). Moreover, our results further support the need for technology-enabled ST among the disaster relief actors (Dubey et al. 2019a) and to further improve transparency and traceability of funds in disaster relief chains (Mejia, Urrea, and Pedraza-Martinez 2019).

Next, we further examined the relational orientation (technology-enabled ST and CO) as an informal governance between humanitarian actors engaged in disaster relief operations. To address this concern, we posited our second research question. The results obtained via data analyses confirm that there is a significant association between ST and CO. This finding of our study further supports Moshtari (2016) findings. Moreover, our study further empirically validate the claim of previous studies (see Roeck, Sternberg, and Hofmann 2019; Dolgui et al. 2019; Hughes et al. 2019). Our results are quite consistent with previous trust–commitment theory (Morgan and Hunt 1994). Further, informed by previous research (see Wieland and Marcus Wallenburg 2013; Dubey et al. 2019b), we examined the influence of relational competencies on SCR. Informed by Dyer and Singh (1998) RV, we examined the effects of technology-enabled ST and CO on SCR. Scholten and Schilder (2015) argue that the literature focusing on CO and SCR is rich. However, it is little known that how CO influences SCR. Moreover, to our knowledge, the literature have remained silent on the combined effects of ST and resilience. Hence, our results based on data, we confirm that CO and ST are significant predictors of SCR. Thus, we can argue that these results

Table 4. Summary of hypotheses tests.

Hypothesis	Expected relationship	Supported?
H1	BT is positively associated with OSTC	Yes
H2	BT is positively associate with ST	Yes
H3	OSTC is positively associated with ST	Yes
H4	ST is positively associated with CO	Yes
H5	ST is positively associated with SCR	Yes
H6	CO is positively associated with SCR	Yes

Notes: BT, blockchain technology; OSTC, operational supply chain transparency; ST, swift-trust; CO, collaboration; SCR, supply chain resilience; I, interdependence; LTO, long-term orientation

offer a unique contribution to literature which have either studied the relationship between trust and resilience or CO and resilience. Moreover, previous theoretical propositions empirical validation was a clear research gap. Hence, via this study, we confirm that ST and CO have a significant influence on SCR. Hence, our results are consistent with the relation view of Dyer and Singh (1998) and Wieland and Marcus Wallenburg (2013). Table 4 provides a summary of the evidence of our data provides in support or non-support of the research hypotheses generated in our study. Collectively, these findings have implications for theory and practice in this emerging field.

5.1. Contributions to theory

Based on our results, we can argue that our study offers some useful contributions to theory. Firstly, there is an agreement in the literature that ST is one of the formative elements of the CO, to date, little is known that how ST can be developed. Tatham and Kovács (2010) argue that ST is essential for bringing temporary teams formed with a clear purpose and common task with a finite life span. Dubey et al. (2019a) found a strong and positive association between big data analytics capability and ST. Hence, informed by this study, we further examined the role of distributed ledger technology in building ST. Altay and Labonte (2014) argue that humanitarian supply chains are extremely dynamic. As a result, supply chain visibility and data tracing can often be challenging (Altay and Pal 2014; Mejia, Urrea, and Pedraza-Martinez 2019). Hence, increasing transparency can greatly enhance trust – among the actors engaged in disaster relief operations. Thus, our empirical results clearly suggest that BT offers a way to improve transparency in humanitarian supply chains and further build ST. These findings clearly support OIPT. Secondly, our results further widen our conceptual understanding of SCR; on the other hand, it further expands our knowledge about the technology-enabled relational competences recommended for supply chains designed for post-disaster relief operations. Our work further empirically tested the points raised by previous scholars (see Min 2019) in humanitarian settings. Our findings suggest that BT is an organisational capability, which has positive effects on transparency, ST and CO; which in their totality have a significant and positive effect on humanitarian SCR. Thus, our efforts further refine the previous understanding of the role of emerging technologies in improving humanitarian supply chains design, in order to improve the efficiency and effectiveness of post-disaster relief efforts. These findings of our study further confirm Wang, Tai, and Grover (2013) arguments related to the integration of information processing view and RV.

5.2. Contributions to practice

Our study echoes the points raised by Fisher, Olivares, and Staats (2019) relating to how empirical research enhances operations management. Specifically, such research provides prescriptions to improve operational decisions and/or identifies evidence of the existence of a phenomenon. A practical aim of our study is to provide directions to managers engaged in disaster relief efforts who either are using emerging technologies, such as BT, or contemplating their use in disaster relief efforts. In an attempt to provide this direction, we have grounded our study in theory and used survey data to test our research hypotheses. Hence, we have attempted to answer some questions that often confuse managers engaged in disaster relief efforts, such as: When should I use BT? How does BT help to improve the disaster relief efforts? In the past, most of the prior work in this area have been limited in some way, offered either anecdotal evidence, lacking theory or having an absence of data-driven studies. By undertaking a data-driven survey, which is strongly grounded in theory, our results offer some robust findings that provide interesting directions to the policymakers or the managers engaged in disaster relief operations. As we understand that logistics efforts nearly account 80% of disaster relief operations (see Jahre et al. 2007). Hence, visibility, accountability and traceability remain a major concern in these disaster relief supply chains. Moreover, HOs are increasingly handling volumes of sensitive information related to their donors. Moreover, there is a dilemma among the stakeholders that to what extent, these new technologies help to preserve the information. Thus, our empirical results offer immense guidance that investment in BT not only offer security to the information exchange, it further improves ST and CO among the actors engaged in disaster relief operations. Moreover, distributer ledger technology may help to improve donor financing and crowdfunding capabilities. Thus, we can argue that BT could enable humanitarian actors to better control the distribution aid, and ensure that funds reach the right victims, in right time via lowering transaction cost and publicly monitoring the flow of disaster relief materials, information and fund, the resilience of humanitarian supply chains can be improved.

5.3. Limitations of our study and further research directions

Informed by Barratt and Oke (2007) arguments, we submit that the competitive advantages stem from the ways in which such technologies are used, rather from the technologies themselves. Hence, as with any study, the results of our study should be cautiously evaluated in the light of its limitations. Based on the legal structure of our organisations in our sample and related confidentiality requirements concerning information about their partners and donors, we did not have the ability to collect sufficient amount of data, which would have been desirable, especially in context to the role of the organisational culture on the effects of BT and OSTC on ST. However, our limitation can offer an opportunity to further extend our theory. Hence, in future, the interaction effect of the organisational culture can be examined on the paths connecting BT, OSTC and ST. Moreover, we have collected data which are based on the perception of an individual. Although previous studies have shown a strong association between perceptual-based study and actual study (Dess and Robinson 1984), however, in future the objective measures can provide better insights. Moreover, the subjective measures often suffer from common method bias. Despite several measures we undertook to minimise the effects of common method bias, we argue that the data gathered from multiple respondents may be useful (see Ketokivi and Schroeder 2004). Further research may examine the nonlinear effects of BT on OSTC/ST. Since our study is informed by previous assumptions, the linear assumption may not hold good in a dynamic environment (Fosso Wamba et al. 2019). Finally, it is worth noting that the use of a single method may not provide complete insights (Craighead and Meredith 2008). Hence, we argue that there is need for mixed-methods research (Boyer and Swink 2008) or alternative methods (e.g. cross-sectional or longitudinal studies, well-structured single or multiple case studies, field studies or lab experiment) to further explore the linkages between BT and OSTC/ST/CO/SCR among disaster relief organisations.

6. Conclusion

BT (which is also known as distributed ledger technology) is considered as a transformative technology with the potential to increase transparency and building trust in the supply chain across various industries. The technology has the potential to play a critical role in enhancing CO via building ST among various actors engaged in disaster relief operations. Our study aimed at providing an initial understanding of the application of this distributed ledger technology in the humanitarian supply chain via addressing two research questions: *what are the distinct and combined effects of BT and OSTC on ST?*; and *what are the direct and combined effects of ST and CO on SCR?*. The purpose of this study was accomplished by developing a conceptual model based on OIPT and RV, which was empirically tested using data gathered from 256 respondents from international NGOs engaged in disaster relief operations. The findings provide evidence in support of the proposed conceptual model, which demonstrates that BT exerts positive and significant influence on operational supply chain transparency and they both together significantly influences building ST that in turn has a significant and positive influence on both CO and SCR. Given the critical role of trust, CO and SCR in handling global challenges such as disaster relief operations, this study has made significant useful contributions by establishing the role of BT in facilitating them. Hope, this paper provides enough food of thought.

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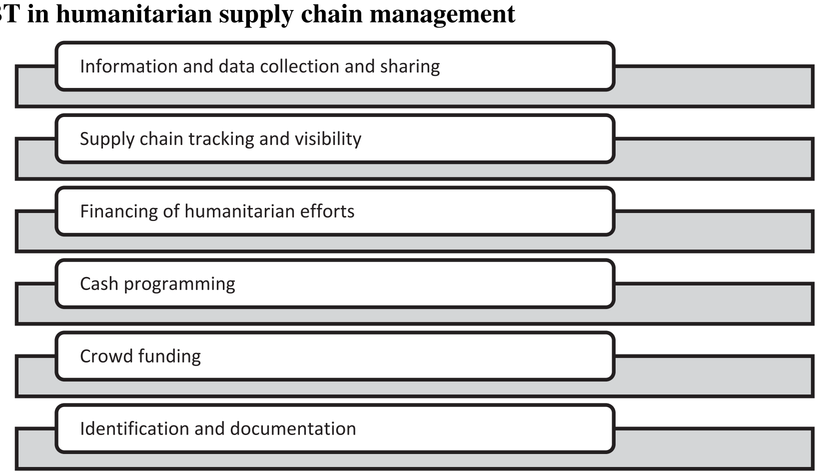
Appendix 1: Use of BT in humanitarian supply chain management



Adapted from Ko and Verity (2019).

Appendix 2: Construct operationalisation

Construct	Types	Relevant literature	Survey items
Blockchain technology (BT)	Reflective	Hughes et al. (2019)	1. We use distributed ledger technology to share information during disaster relief operations (BT1) 2. We use distributed ledger technology as it help to maintain confidentiality, integrity and availability of the data (BT2) 3. We use distributed ledger technology to improve transparency in disaster relief supply chain (BT3) 4. We routinely use distributed ledger technology as a data platform that traces the origins, use and destination of humanitarian supplies (BT4) 5. We routinely use distributed ledger technology to avoid unreliable information to avoid confusion among partners engaged in disaster relief operations (BT5)
Operational supply chain transparency (OSTC)	Reflective	Zhu et al. (2018)	1. We routinely share our operational plans (i.e. distribution and storage plans) (OSTC1) 2. Our partners routinely gather strategic information related to disaster-affected areas (OSTC2) 3. Our partners routinely share strategic information (OSTC3) 4. Our local partners share their strategic information related to local culture, government regulations and other useful information (OSTC4)
Swift-trust (ST)	Reflective	Robert, Denis, and Hung (2009); Dubey, Altay, and Blome (2017; Dolgui et al. 2019)	1. Our partners are trustworthy (ST1) 2. We have no reason to doubt each other's competence and preparation for task (ST2) 3. While working together on specific task, I believe I can rely on them not to cause trouble by careless work (ST3)
Collaboration (CO)	Reflective	Hemingway and Gunawan (2018)	1. We routinely share our resources (i.e. information, expertise and infrastructure) among our partners (CO1) 2. We work closely to design and implement our operations in response to disasters (CO2) 3. We share our risks and benefits (CO3)
Supply chain resilience (SCR)	Reflective	Altay et al. (2018)	1. Our organisation can easily restore material flow (SCR1) 2. Our organisation would not take long to recover normal operating performance (SCR2) 3. The supply chain would quickly recover to its original state (SCR3) 4. Our organisation can quickly deal with disruptions (SCR4)
Interdependency (I)	Reflective	Moshtari (2016)	1. It would be costly for our organisation to lose its collaboration with the partner (I1) 2. This partner would find it costly to lose the collaboration with our organisation (I2)
Temporal orientation (TO)	Reflective	Moshtari (2016)	1. Long-term goals in their relationship (TO1) 2. Partners expect to work together for a long time (TO2) 3. Participating organisations concentrate their attention on issues that will affect targets beyond the next (TO3)

Appendix 3: Profiles of the respondents

Organisations main service	Frequency	Percentage
Health	60	23.44
Logistics	78	30.47
Food security	56	21.88
Water, sanitation and hygiene	41	16.02
Camp coordination	21	8.20
Nationality	Frequency	Percentage
Asia		
China	27	10.55
DPR Korea	3	1.17
India	22	8.59
Indonesia	3	1.17
Japan	18	7.03
Thailand	3	1.17
Europe		
Belgium	6	2.34
Denmark	4	1.56
France	19	7.42
Finland	7	2.73
Ireland	5	1.95
Netherlands	13	5.08
UK	11	4.30
Africa		
Cameroon	17	6.64
Egypt	5	1.95
Niger	4	1.56
Nigeria	4	1.56
Somalia	2	0.78
South Africa	11	4.30
North America		
Canada	17	6.64
USA	52	20.31
Mexico	3	1.17
South America		
Argentina	6	2.34
Brazil	19	7.42
Chile	8	3.13
Peru	11	4.30