Data supply chain (DSC): Research synthesis and future directions

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In the digital economy, the volume, variety and availability of data produced in myriad forms from a diversity of sources has become an important resource for competitive advantage, innovation opportunity as well as source of new management challenges. Building on the theoretical and empirical foundations of the traditional manufacturing Supply Chain (SC), which describes the flow of physical artefacts as raw materials through to consumption, we propose the Data Supply Chain (DSC) along which data are the primary artefact flowing. The purpose of this paper is to outline the characteristics and bring conceptual distinctiveness to the context around DSC as well as to explore the associated and emergent management challenges and innovation opportunities. To achieve this, we adopt the systematic review methodology drawing on the operations management and supply chain literature and, in particular, taking a framework synthetic approach which allows us to build the DSC concept from the pre-existing SC template. We conclude the paper by developing a set of propositions and outlining an agenda for future research that the DSC concept implies.

Keywords: data flows, supply chain, innovation, outcome-driven, framework synthesis, systematic review

1 Introduction

The 'explosion of data' (Cukier and Mayer-Schoenberger, 2013), facilitated by technological developments such as sensor and geo-locating devices, smartphones, the Internet of Things (IoT) as well as the associated metadata has wide ranging social, political, environmental educational and economic implications (George *et al.*, 2016; Van Knippenberg *et al.*, 2015; George *et al.*, 2014). The technology industry, managers, consultants and commentators have been quick to point to the potential of these data as a resource to contribute to competitive advantage and innovation opportunities for firms (George *et al.*, 2014; McAfee and Brynjolfsson, 2012). Data constitute new raw materials for product and service development (Manyika *et al.*, 2011); and, needs to be sourced, generated, collected, stored and transformed by firms to lead to new value creation (Chen *et al.*, 2015b; Gupta and George, 2016). In this context, understanding the role and flow of data in establishing competitive advantage becomes critical. Therefore, building on the theoretical and empirical foundations of the manufacturing Supply Chain (SC), we propose Data Supply Chain (DSC) to re-frame the supply chain in the context of the digital and knowledge economy; and, define DSC as a distinct type of supply chain along which data rather than material artefacts are moved, shared, re-configured and aggregated to provide both new opportunities for competitive advantage/business model innovation as well as management challenges (see Figures 4 and 5 in Appendix)[1].

The Supply Chain has become a well-established concept in operations management with strengthening theoretical and empirical foundations (Storey *et al.*, 2006; Mentzer *et al.*, 2001; Lambert *et al.*, 1998) and emergent disciplinary distinctiveness (Ellram and

[1] Please see Figures 4 and 5 in Appendix for a visual comparison of SC vs. DSC as well as an example of DSC respectively.

Cooper, 2014). Mentzer *et al.* (2001: 4) provide a commonly accepted definition of the supply chain as '*a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer'*. The purpose of Supply Chain Management is effectively and efficiently to procure raw materials, transform them and subsequently distribute finished products to end users (Borade and Bansod, 2008). To date, research has focused primarily on the flow of physical materials through the supply chain wherein concern is expressed for raw material flow, inventory management and finished goods distribution (Ballou, Gilbert & Mukherjee, 2000), for example in the context of manufacturing and consumer goods (Burgess *et al.*, 2006); however, little attention has been paid to the procurement, transformation and subsequent distribution of data artefacts within the supply chain context. In the DSC context, 'data' are not about improving process efficiency within the supply chain but are rather intermediate or even final goods within the process itself. Mentzer et al's (2001) definition specifically includes the flow of information within the supply chain: typically, this has been addressed in respect of the question of knowledge management practices for improving information quality and information management processes to facilitate greater supply chain efficiency and effectiveness (e.g. Sarac *et al.*, 2010; Hazen *et al.*, 2014; Cerchione and Esposito, 2016).

The current study distinguishes between data *about* the supply chain, where data are used to improve existing processes or physical artefacts themselves, and data that are the main artefact *moving through* the supply chain. The distinction raises important questions about whether or not and the extent to which the Supply Chain concept may need elaborating to encompass the digital. We develop the concept of Data Supply Chain by means of systematic review (Tranfield *et al.*, 2003), adopting a framework approach to synthesis (Carroll et al., 2011; Dixon-Woods, 2011) enabling us to build the DSC conceptualisation from the existing SC template.

The paper is structured as follows. First, we describe our review methodology that enables us to identify, collate and analyse the evidence relating to the emergent phenomenon DSC. Second, we briefly review the theoretical foundations of SC to provide an initial framework, the scaffolding on which a conceptualisation of DSC can be built (Gough *et al.*, 2012). Third, on the basis of the evidence, we iteratively populate and refine the initial framework to develop our conceptualisation of DSC, teasing out its distinctive characteristics compared to the traditional Supply Chain concept. Fourth, our findings suggest emerging areas of interest and we discuss the implications of these in relation to scholarship and management practice. Finally, we make recommendations for practice and outline a research agenda.

The paper makes three original contributions. First, through the definition and identification of the characteristics of DSC as a distinct type of supply chain, distinguished and distinguishable from supply chains of physical artefacts and hybrid physical artefact/data supply chains. Second, we make a conceptual contribution by framing and drawing a research agenda on DSCs. Finally, the paper makes a methodological contribution by adopting a framework synthetic approach for the literature review, used for the first time, to the best of our knowledge, in the supply chain and operations management fields.

2 Methodology

To develop the concept Data Supply Chain, we adopt a systematic review methodology (Tranfield *et al.*, 2003) to synthesise recent theoretical, conceptual and empirical literature reporting studies in which data are the artefact moving through the supply chain. Additionally, to draw out the distinctiveness of the concept, we contrast the DSC against the literature in which data related to SC process efficiency is the focus. According to Denyer and Tranfield (2009), whose precepts we follow, the systematic review process consists of five stages: Question formulation; Locating and collating primary studies; Study selection/evaluation; Analysis and synthesis, and; the reporting and use of results.

Our analysis and conceptual development are framed in terms of an initial framework of the SC concept upon which we build to identify the distinctive and distinguishing characteristics of DSCs (see sections 3 and 4). Our purpose in this study is to discover whether or not the concept Data Supply Chain is meaningful in the context of the Knowledge Economy (Teece, 1998): by 'meaningful' we mean comprised of distinctive characteristics distinguishing DSC from the traditional SC concept of the material artefact and having consequent specific theoretical and management implications. In this way, our approach is consistent with framework synthesis as described by Barnett-Page and Thomas (2009) and Thomas and Harden (2008).

To achieve this, we explore recent theoretical, conceptual and empirical studies in the Operations, Supply Chain, Manufacturing and, Information Management literature published in English and peer-reviewed journals. Adams et al. (2016) make a case for, under certain conditions, the inclusion of the grey literature in reviews but not where the substantive purpose of the review is bounded by academic conversations as it is in the current study. Consequently, we exclude the grey literature from our review. Our selection criteria are further framed by date limiters 2010-2017 (first quarter only). 2010 was chosen as our departure point following a brief scoping study that failed to identify any relevant studies[2] prior to this date. We searched three databases for relevant studies, ScienceDirect, Scopus and, EBSCO Business Source Complete utilising a set of keywords and search strings[3] designed and tested to identify articles addressing the issue of data moving through supply chains in manufacturing, industrial and service sectors; articles discussing concepts and theories around the notion of DSC, and; those empirical studies which focused on the transformation of traditional manufacturing landscapes through the use of data for innovation and production. The search of electronic databases was supplemented with a hand-search of journals and a citation/snowballing search (Contandriopoulos *et al.*, 2010).

This initial search yielded a total of 5,761 initial articles. Following filtration on the basis of inclusion and exclusion criteria, this number was ultimately reduced to a final total of 71 selected studies (Figure 1). Our selected literature is categorised in terms of their focus on data and supply chain management in Table 3 (Appendix).

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[2] On the basis of title and abstract evaluation.
[3] Available from the corresponding author

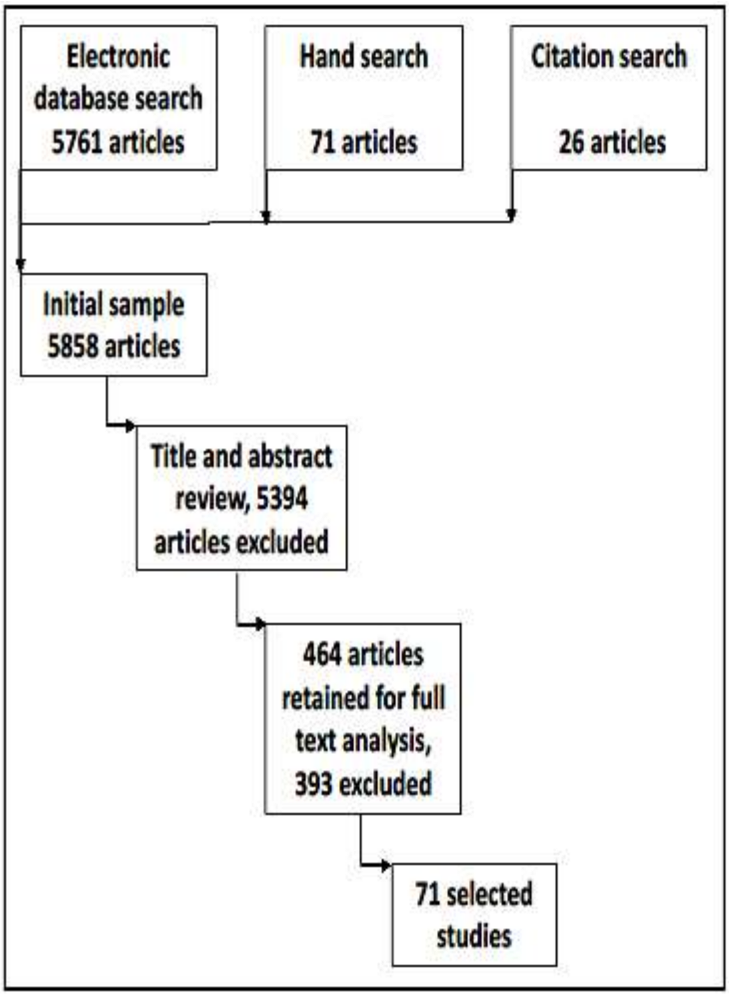

Figure 1: Search strategy

Analysis and synthesis follow the framework synthetic approach (Barnett-Page and Thomas, 2009; Thomas and Harden, 2008): this is similar to framework analysis (Ritchie, Spencer, O'Connor 2003) but applied to the literature (Dixon-Woods, 2011). Following Carroll et al.'s (2011) prescriptions, we begin with a broad conceptualisation of the Supply Chain so as to promote inclusivity in our analysis which, through iteration and augmentation in light of selected studies we develop the DSC concept. By means of this process, we are able to suggest a novel conceptualisation of the DSC which simultaneously reflects its SC origins as well as the evidence of the selected studies.

In total, 71 articles are included in our review and the results of our search indicate a rapidly growing interest in the phenomenon of data as the artefact moving through the supply chain and data intensive supply chains, with a marked acceleration in the years following 2013 (see Figure 2). The cut-off point for inclusion in this study was end of March 2017. In the first 3 months of 2017, we were able to find ten published, relevant studies, compared to 24 in the whole of the previous year. Although the topic remains young, early indications are that it is attracting considerable and growing attention.

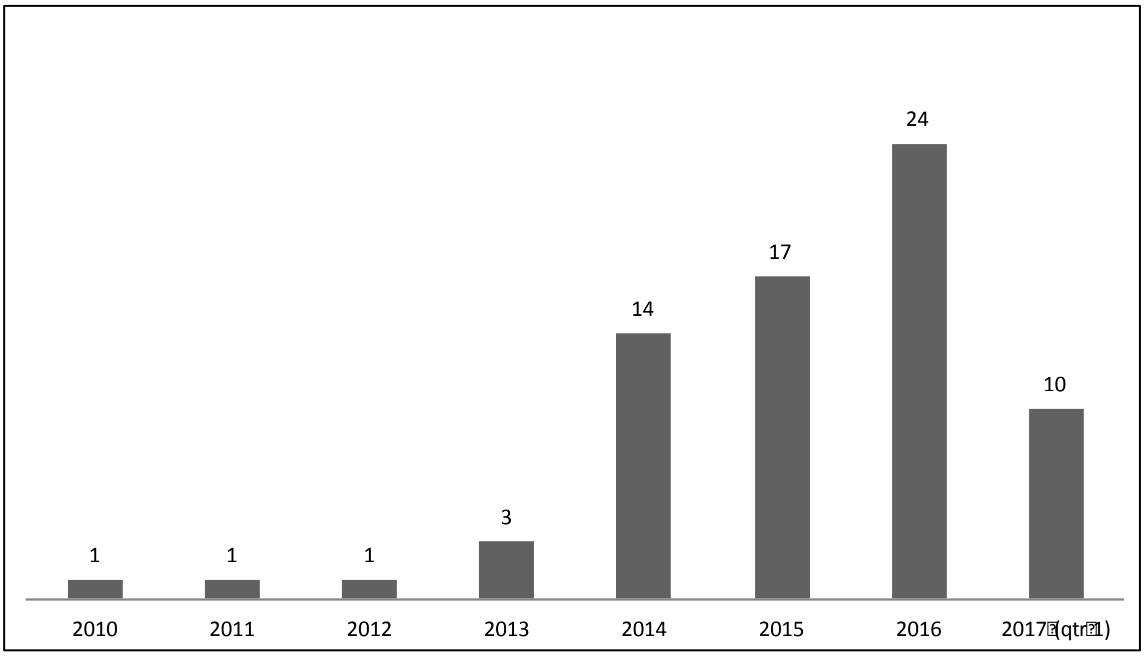

Figure 2: Included studies by year

Selected articles are drawn from 31 different journals, 14 of which provide two or more articles (see Figure 3). Figure three also indicates that the scholarly conversation is taking place in diverse communities, including: operations and technology management; human resource management; management, and; information management.

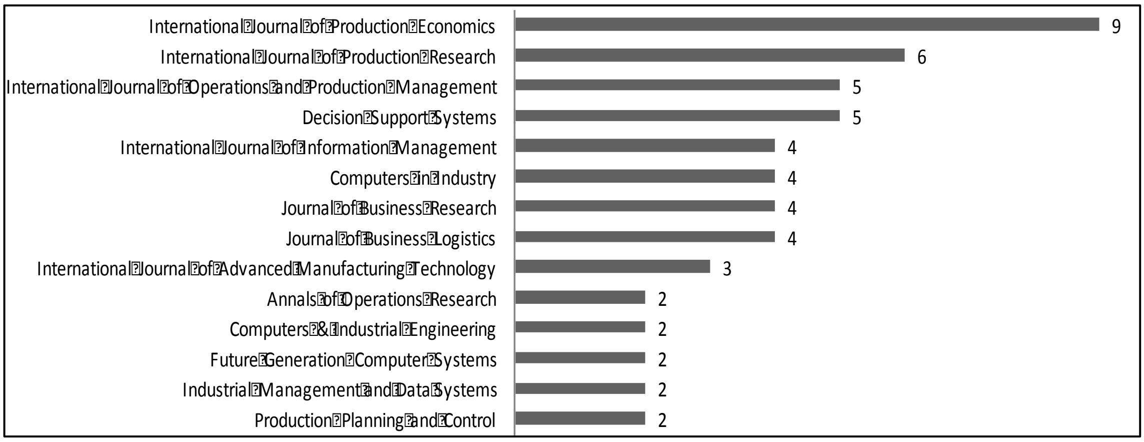

Figure 3: Included studies by journal (>2 publications)

3 From Supply Chain to Data Supply Chain

The concept of the Supply Chain as a phenomenon of scholarly interest has attracted attention since the early 1980s. In this section, we briefly review this literature to provide an initial architecture, the scaffolding on which a conceptualisation of DSC can be built.

A search through the EBSCOHost database[4] for the term ‘Supply Chain’ in the titles of

[4] June 2017

papers published in peer-reviewed journals returns over 8,000 articles, the earliest with a 1985 date of publication. Scattered at regular intervals within this corpus are articles that either question or find indications of a cognate supply chain disciplinary distinctiveness (Giannakis & Croom, 2004; Burgess, Singh, & Koroglu, 2006; Harland, Lamming, Walker, et al 2006; Ellram & Cooper, 2014), efforts largely prompted by the diversity of perspectives from which the phenomenon was, and continues to be, approached. As a consequence, we notice a plethora of definitional, framework, conceptual and paradigmatic propositions which indicate a continuing search for the field's disciplinary distinctiveness as well as a structure(s) within which to frame research.

Burgess et al (2006) observe, through an analysis of definitions and constructs relating to the SC concept, that *SCM constructs generally fall into two broad groups: the "soft" people-focused constructs that deal with social relationships; and the "hard" system-dominated constructs that deal with technological and infrastructural issues*, the latter having generally received more attention than the former. However, missing from their analysis, though, is any reflection on the artefact being moved through the supply chain.

Giannakis & Croom (2004), for example propose a 'supply chain paradigm' consisting of three dimensions: the physical structure ("synthesis"), human interaction ("synergy") and the coordination and control of operational processes ("synchronisation") of supply chains. Review papers, of which there are many including Croom, Romano & Giannakis (2000), Burgess, Singh, & Koroglu (2006) and, Borade & Bansod (2008), provide competing lists of definitions of the term.

The idea of data moving through supply chains as the primary artefact of interest (i.e. not material artefacts) has gained a little traction in the scholarly literature, and we believe ours is the first, and timely, attempt formally to synthesise this body of evidence into a coherent conceptualisation of the phenomenon. The conceptualization of the Data Supply Chain can set the basis of our 'initial framework' adopted from the study of Storey et al (2006) which examined the idealized characteristics of traditional/conventional manufacturing supply chains from previous studies of supply chain field (Croom *et al.*, 2000; Lambert and Cooper, 2000; Cooper *et al.*, 1997). Accordingly, we define the DSC as *the upstream and downstream flow of multisource, multiform data artefacts from inbound and outbound activities of the firm; forming innovation opportunities and value outcomes in production/service development as a core business area of the firm* and contend that SCs and DSCs differ in several important respects around four characteristics namely: a) the element of exchange, b) the strategy, c) the integration and d) the tools/methods applied for the DSC context. Each of these is further developed below.

While in SC literature we find studies around information processing, sharing, integration or knowledge management and development (Cerchione and Esposito, 2016; Flynn et al., 2010; Fawcett et al., 2007; Fiala, 2005; Hult et al., 2004; Frohlich and Westbrook, 2001); as well as the role of Electronic Data Interchange (EDI) in facilitating information sharing and increasing competitiveness (Prajogo and Olhager, 2012; Power, 2005; Cachon and Fisher, 1997; Webster, 1995; Benjamin et al., 1990); we believe there is still a distinction to be made between data *about* the supply chain and data that are the artefact *moving through* the supply chain. Additionally, smart supply chains are utilizing technologies such as IoT, smart machines, and intelligent infrastructure, and capabilities such as interconnectivity, fully enabling data collection and real-time communication across all supply chain stages, intelligent decision making, and efficient and responsive processes to better serve customers (Wu et al., 2016)[5]. The context of smart supply chain is close to Data Supply Chains (DSC), as they are interconnected, intelligent, integrated and data-oriented; however, there is a major difference between these two as DSC uses data as raw material while smart supply chains support physical raw material flows and improve these flows through the use of real-time data.

Additionally, the concept of 'Collaborative Supply Chains'[6] (CSCs) is relevant to this study as it focuses mostly on gaining competitive advantage and value from the end-customer and CSCs are categorized as outcome-based supply chains (Melnyk et al., 2010). Outcome-based supply chains, contrary to traditional supply chains (which were strategically decoupled and price driven), are new forms of supply chains strategically coupled and value driven (Melnyk et al., 2010). For Melnyk et al (2010) the supply chain should be designed and managed to deliver specific outcomes. Outcome-based perceptions are forming a new way of data-based decision-making, disrupting the business landscape while moving from the world of 'making things' to a 'world of outcomes' (Ng et al., 2009). The outcome-based approach in the context of supply chains is not only based on collaboration, but also value co-creation (Lusch and Vargo, 2006; Vargo and Lusch, 2004; Normann and Ramirez, 1993), towards this direction the smart supply chain is also an outcome-based supply chain (Wu et al., 2016).

3.1 Element of exchange

Central to many conceptualisations of the supply chain is the notion of an artefact moving through it or along it. Mentzer et al (2001) as well as others (e.g. Lambert *et al.*, 1998; La Londe and Masters, 1994; Cooper and Ellram, 1993) define the supply chain context as that set of firms passing materials forward (Cooper and Ellram, 1993) aligned to bring products or services to market through manufacturing (Lambert *et al.*, 1998) to deliver them into the hands of the end user (La Londe and Masters, 1994). Ahi & Searcy (2013) state specifically that the supply chain contemplates the product from initial processing of raw materials to delivery to the end-user. Croom, Romano & Giannakis (2000) describe this artefact as the element of exchange. This is about the 'what' that is being transacted (the artefact) and the 'how' of its transaction (relationships between actors).

In their review of 569 SCM papers, Soni and Kodali (2011) note that previous research has largely focused on the asset and information dimensions. Assets are typically conceived as artefacts with a material form and that require inventory and transportation management, from warehouse design to forms of shipping. The information dimension relates to the flows between supply-chain partners that facilitate co-ordination, often supported by electronic media (Croom et al 2000).

Xu (2011), for example, focuses on a number of novel technologies, in particular what he calls service-oriented architecture such as RFID, agent, workflow management, and the Internet of Things (IoT), as a means of significantly improve the performance of

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[5] Addo-Tekorang and Helo (2016) discusses the literature on Big Data applications in operations and SCM, in other words the smart supply chain literature.

[6] Following the view of networked, inter-organizational, interconnected relationships among supply chains, Davis and Spekman (2004) and Spekman and Davis (2016) proposed the 'Extended Enterprise' (EE) concept, which was revisited recently providing the context for 'Collaborative Supply Chains'.

supply chain quality management. Promoting the use of these and other technologies for SCM improvement is a common theme in the literature (see, for example, Cerchione and Esposito, 2016; Sanders, 2016; Fawcett et al., 2007; Fiala, 2005).

Here, we re-emphasise the distinction between the current paper and previous studies. Unlike those studies cited in Soni and Kodali's review, our interest is not in information *about* the supply chain, information that supports the operation, management and analysis of supply chain functionality, but in information that is the asset being moved within it. In spite of the rapid growth in importance of data as a raw material for product development and innovation, little attention has been paid to its upstream, downstream and network flows through the supply chain (Tan, Zhan, Ji, et al 2015; Gobble, 2013). That is, as well as distinguishing between information about the supply chain and information as the artefact of exchange, we contend that the distinction between information and physical materials as the artefact of exchange has important implications for the conceptualisation of DSC.

3.2 Strategy

Through a focus on upstream supply, network or chain processes and downstream customers, the aim of the supply chain strategic orientation is to satisfy customers and gain competitive advantage in the market (La Londe & Masters, 1994). Notwithstanding the importance attributed to supply chain strategy in the literature it has, for a long period, remained ill-defined and poorly operationalised (Cigolini, Cozzi,. & Perona, 2004).

Addressing this gap through a nine-year action research study, Perez-Franco, Phadnis, Caplice et al (2016) propose a working definition of supply chain strategy as the collection of general and specific objectives set for the supply chain, and the policies and choices put in place to support them, with the purpose of supporting the business strategy, given the (business unit's) context and environment. Scholars have proposed a variety of strategic orientations. For example, Fisher (1997) proposes a 2-by-2 matrix in which four supply chain strategies emerge from the dichotomisation of product type (functional or innovative) and supply chain type (efficient or responsive) which can be used as an aide to evaluate whether or not a firm's product matches or mismatches its underlying supply chain process: such as unresponsive chains trying to deliver innovative products.

Extending Fisher's (1997) typology, and based on in-depth case studies, Qi, Boyer and Zhao (2009) identify three types of supply chain strategy: lean strategy, agile strategy, and lean/agile strategy.

Broadly, studies such as these support the general conclusion that lean strategies are associated more with functional products while agile strategies are more associated with innovative products. Given the novelty of big data and that firms are still working out ways of dealing with it profitably, it is not clear that such observations continue to hold.

3.3 Integration

The integrative perspective, pervades supply chain scholarship and has frequently been associated with performance (Ataseven & Nair, 2017), though the quality of the evidence supporting the relationship has been questioned (Fabbe-Costes, & Jahre, 2007). To implement supply chain management, some level of integration and co-ordination is necessary both within and beyond organisational boundaries (Cooper, Lambert, & Pagh, 1997). Beyond the immediate boundaries of the firm the requirement for integrated processes and practices extend to include upstream suppliers and downstream customers and the extent to which they are beneficially aligned (Stevens, 1989; La Londe & Masters, 1994; Frohlich & Westbrook, 2010; Ataseven & Nair, 2017). However, integration also takes an internal perspective and considers the internal functions relevant to supply chain management (Cooper & Ellram, 1993; Lambert & Cooper, 2000)). As such, Supply Chain Integration can be understood as the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organizational processes (Flynn, Huo, & Zhao, (2010))

Frohlich and Westbrook (2001) identify five different supply chain integration strategies characterised by different 'arcs of integration' representing the direction (towards suppliers and/or customers) and degree of integration activity and note that, consistently, the widest degree of arc of integration with both suppliers and customers had the strongest association with performance improvement. Flynn et al (2010) conceptualise integration in three dimensions, internal, customer and supplier integration, positively relating them from configurational and contingency perspectives to both operational and business performance though indicated that internal and customer integration were more strongly related to improving performance than supplier integration.

Digital technologies and big data have opened new avenues for the design of business models by enabling firms to change fundamentally the way they organize and engage in economic exchanges, both within and across firm and industry boundaries and also with consumers and users (Zott et al., 2011). This has important implications for the management of multiple specialised technological, creative and user inputs to the innovation process and the management of value co-created across multiple platforms. It represents significant opportunities for new value constellations (Normann, 2001), value ecosystems (Van der Borgh et al., 2012), activity systems (Zott and Amit, 2010), and business model innovation (Baden-Fuller and Morgan, 2010), the echoes of which perhaps being reflected in the collaborative supply chain clusters that scholars are now beginning to identify and describe (e.g. Storey et al, 2006; Stevens & Johnson, 2016).

3.4 Tools and methods

Optimizing the flows through the supply chain cannot be accomplished without implementing a process approach (Lambert & Cooper, 2000) and, increasingly, to manage the processes of flow as well as relationships amongst supply chain actors, managers have been making use of a range of tools and techniques (Storey et al, 2006). Historically, the focus has been placed on the "newest concern" (Ballou et al, 2000: 8) of managing product flows, and so it is that Lambert & Cooper (2000) identify eight key supply chain processes, including:

- Customer relationship management
- Customer service management
- Demand management
- Order fulfilment
- Manufacturing flow management
- Procurement
- Product development and commercialization
- Returns

Maintaining a strictly material artefact focus, Cigolini Cozzi, & Perona, (2004) categorise SC techniques according to whether or not they relate either to the configuration of a supply chain (the physical structure of the chain), or to its management (how the chain operates). Consequently, the tools and techniques are selected for their potential to optimise upon the traditional manufacturing-oriented methods such as for product design, transportation fleet design and so forth.

Although companies expect to broaden and deepen the use of new information and communication technologies for improving supply chain operations (Olhager, & Selldin, 2004; Wang, Gunasekaran, Ngai et al., 2016), we speculate that there will be differences between the flow process management for material artefacts compared against data. For example, a critical consideration for many supply chains in the context of material artefacts has been to understand lead times, define where to position inventory and how much to stock at each point (Scott & Westbrook, 1991). Much of Scott and Westbrook's (1991) discussion is framed in terms of competing logics of supply chains: holding inventory versus the Just-in-Time (JiT) approach. The juxtaposition of the two logics forced managers to confront challenging questions about their own SC practices, in particular relating to the combinations of physical and information processing tools, techniques and practices for SC optimisation. As data becomes the 'flowing artefact', so these questions resurface.

For example, lead times and inventory management take on different characteristics in the knowledge economy. Data can be available nearly instantaneously, require comparatively little space to store[7], and follow a different regulatory framework for their storage and access control than physical materials. As a consequence, new sets of tools and techniques are likely to be required by managers who want to realise the business improvement potential and innovation opportunity that the data artefact promises for competitive advantage.

3.5 Data Supply Chain (DSC)

Based on the previous brief review of the literature, we propose to build a conceptualisation of the Data Supply Chain around an initial framework of four dimensions as presented in Table 1.

Dimension	**Supply Chain**
Element of exchange	The 'what' that is being transacted (the artefact) and the 'how' of its transaction (relationships between actors) (after Croom, Romano & Giannakis (2000))
Strategy	The collection of general and specific objectives set for the supply chain, and the policies and choices put in place to support them, with the purpose of supporting the business strategy, given the (business unit's) context and environment (after Perez-Franco, Phadnis, Caplice et al (2016))

[7] Certainly, data warehousing exists but, compared to physical products they require less space, though perhaps greater energy resources, different security management procedures etc.

Integration	The degree to which an organisation strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organizational processes (after Flynn, Huo, & Zhao, (2010))
Tools/methods	The tools and techniques utilised to optimise flows through the supply chain (after Lambert & Cooper, (2000); Storey et al, (2006)

Table 1: An initial framework for the data supply chain concept

4 Data Supply Chain (DSC) Conceptualization

4.1 Element of exchange

Content represents the element of exchange of the DSC which is usually data, but also can be metadata, information, knowledge and depends also in which stage of processing we find the data raw materials. The Information and knowledge extraction from data are a major focus of the new manufacturing approaches. The advent of APIs, cloud technologies, Internet of Things (IoT) and the related advances of technology have transformed and disrupted traditional manufacturing structures and approaches for achieving intelligent and smart ways of production and distribution while using data as the raw material for the development of new products and services.

Data has become more accessible and ubiquitous, and this move necessitates the right approach and tools to convert data into useful, actionable information and knowledge (Lee *et al.*, 2013). Analytics is a very popular technique lately for exploiting insight available from multiple data streams as technology helps capture rich and plentiful data on phenomena in real time while enhancing dynamic/adaptive capabilities (Erevelles *et al.*, 2016). There are also related studies where social media information landscapes are mapped by collecting and collating entire data sets in social media (Ch'ng, 2015) as well as by using web crawling and scraping data sets –sentiment analysis from online data for sales prediction (Chong *et al.*, 2016). The advances in sensor technology, the Internet, wireless communication, and inexpensive memory have all contributed to the explosion of data (Zhong *et al.*, 2016b; Lee *et al.*, 2014). The rapid growth of the data environment imposes new challenges that traditional knowledge discovery and data mining process models are not adequately suited to address (Li *et al.*, 2016b).

Emergent areas:

Data heterogeneity: Manufacturing sites generate enormous data on a daily basis, such data are so complex, abstract, and variable so that it is difficult to make full use of the information and knowledge these data flows carry (Zhong *et al.*, 2016a); Gandomi and Haider (2015) specifically refer to the problem of unstructured heterogeneous data, which constitute 95% of the available data and highlight the challenge to extract valuable outcomes.

Data quality: Data quality issue is often highlighted in literature as poor data quality may influence the effectiveness of knowledge discovery processes, thus making the development of the data improvement steps a significant concern (Mezzanzanica *et al.*, 2015). Data quality challenge often depends on the information systems which give business value to the quality of data and information produced and stored (Ji-fan Ren *et al.*, 2016) and the data value chain management through these systems (El Kadiri *et al.*, 2016).

Data privacy and security: Hossain and Dwivedi (2014) explain the privacy concerns in public applications of citizen data; as data collected by a government agency would offer serious threats if are shared among third parties. Ways to prevent data privacy issues could be anonymization of the data sets for privacy preservation (Zhang *et al.*, 2014) or enhancing the trust between actors enabling to secure data sharing, and data sharing control (Rehman *et al.*, 2016). Moreover, data security concerns can influence customer's willingness to share personal data and information (Kache and Seuring 2017).

4.2 Strategy

Strategy for DSC represents the goals and the motivation that formed this specific supply chain. The DSC strategy is shaped around planning, sourcing, making and delivering outputs and therefore value from the data and knowledge by using various processes, tools and methods. Strategy around the DSC seems to be innovation-led, as it is formed through ideas, practices, and business models; value for DSC is not solely created from an information product/service but also through the disruption of the existing business and operational models (Li *et al.*, 2016a; Ng *et al.*, 2015; Opresnik and Taisch, 2015).

Strategic decisions for DSC are formed around internal and external data usage for improvement of the innovative capability of the firms and data analytics capabilities associated with database searching, mining, and analysis for value creation (Kwon *et al.*, 2014). Managers increasingly view data as an important driver of innovation and a significant source of value creation and competitive advantage (Tan *et al.*, 2015). DSC strategy is formed more around the outcome and the value proposition of this outcome; an outcome-driven approach with a value focus. Value creation is presented as the value from the data itself as the raw material or data value-in-use (Merino *et al.*, 2016) or even data value-in-reuse (Alvarez-Rodríguez *et al.*, 2014) more than ever before.

Emergent areas:

Data generation and exploitation: The DSC strategy formulation usually follows goals as how data are generated and how they are exploited so as to provide competitive advantage and therefore creation of new revenue streams through business model innovation (Opresnik and Taisch, 2015) or through closer interactions with consumers (Ng *et al.*, 2015). Customer-centred product development approaches reveal that customer involvement can provide valuable input for developing tailored information products/ services (Zhan *et al.*, 2016) while data generation from smart interconnected objects provides platforms for data sourcing for innovation and product development (Zhong *et al.*, 2016b).

Innovation (business model and product/service development): DSCs enable firms to create new products and services, enhance existing ones, and invent entirely new business models (Opresnik and Taisch, 2015) – for example through data obtained from the use of actual products (Ng *et al.*, 2015), improving the development of the next generation of products (Li *et al.*, 2015b) and creating innovative after-sales service offerings (Boone *et al.*, 2016). DSCs can have an impact by utilizing all the data points and turn them into informed decisions and actions that improve peoples' lives (Dobre and Xhafa, 2014) as well as environmental and social sustainability outcomes (Dubey *et al.*, 2016) following triple-bottom line perspectives (Hazen *et al.*, 2016). The focus of DSCs can be on socioeconomic development (Njuguna and McSharry, 2017), natural hazards management (Belaud *et al.*, 2014), climate change solutions (Schnase *et al.*, 2014), resilience (Papadopoulos *et al.*, 2016), environmental monitoring and emergency response (Yang *et al.*, 2013) or solving urban problems (Li *et al.*, 2016a; Wang and Li, 2016), through the development of information products and services for these challenges.

4.3 Integration

Integration represents the relationships and collaborative pattern each supply chain maintains internally and externally. For Data Supply Chain (DSC) the integration can be observed as the combined datasets of different sources, processed by different organizational entities (Janssen *et al.*, 2017). The data raw material collected from different sources can have various data qualities and is processed by various organizational entities resulting in the creation of the data supply chain (Janssen *et al.*, 2017). Inbound and outbound data sources can result in value creation when the data sources are handled in an integrated collaborative pattern (Rehman *et al.,* 2016).

The use and re-use of information and data across tools and processes (Alvarez-Rodríguez *et al.,* 2014) as well as the data integration, used and re-use via analytics systems and modules demand flexible and agile integration architectures (Chen *et al.*, 2015a). Common problem arising from the integration of DSC is a lack of interoperability among tools, tangled dependencies between processes or difficulties to exploit existing data and information to name a few that are preventing a proper use of the new dynamic and data-based environment (Alvarez-Rodríguez *et al.*, 2014).

Emergent areas:

Multisource data: Distributed manufacturing across supply chains has transcended vast organizational boundaries among webs of supply chain information sharing practices (Radke and Tseng, 2015) and therefore data integration across analytics systems and processes seems as a crucial challenge(Chen *et al.*, 2015a). The same problem of handling multisource data is highlighted in the studies of Zhang et al (2015) with sensor generated manufacturing data and Lee (2017) with diverse data sources for knowledge extraction from shipping industry, where they discuss the problems of huge integrated datasets difficult to handle with traditional methods.

Interconnectivity: DSC is formed through the interconnection of data raw materials, organizational entities and relationships, analytics/tools, processes, systems, products and services (Kang *et al.*, 2016; Wu *et al.*, 2016; Ng *et al.*, 2015). The veracity (manipulation, noise), variety (heterogeneity of data) and velocity (constantly changing data sources) amplified by the size of the data calls for relational and contractual governance mechanisms to ensure the data quality and enable firms to contextualize data while working in a complex interconnected pattern (Janssen *et al.*, 2017).

4.4 Tools/ Methods

Tools and methods refer to the technological context applied for each supply chain. There are various techniques and industrial applications of data in service and manufacturing sectors, and their use is increasing sharply as new technologies are developed for storage, data processing, data visualization and analytics (Zhong *et al.*, 2016b). Data exploitation methods, advanced analytics and in-memory database technology are seen as key enablers for enhanced top management decisions around the use of data (Hahn and Packowski, 2015). With an aggressive push towards "Internet of Things", data has become more accessible and ubiquitous, and this move necessitates the right approach and tools to convert data into useful, actionable information (Lee *et al.*, 2013).

In order to become more competitive, manufacturers need to embrace emerging technologies, such as advanced analytics and cyber-physical system-based approaches (Lee *et al.*, 2013) and enhance their production with new ideas and innovative products/services. To get the most out of the enormous data (in combination with a firm's existing data), a more sophisticated way of handling, managing, analysing and interpreting data is necessary (Tan *et al.*, 2015). Innovative approaches of information and knowledge extraction are presented in various studies about data extraction from smart objects (Zhong *et al.*, 2016b; Zhong *et al.*, 2016a; Zhong *et al.*, 2015b; Zhong *et al.*, 2015a; Ng *et al.*, 2015; Yang *et al.*, 2013; Zhang *et al.*, 2011); this data generated daily in real-time from service and manufacturing sectors is increasing sharply and lifts up a growing enthusiasm for the use of these data streams for value and innovation. In their paper Zhong et al (2016b) investigate representative applications of these data streams from typical services like finance and economics, healthcare, Supply Chain Management (SCM), and manufacturing sector – by introducing new products and services formed through the utilization of these datasets.

Emergent areas:

Data collection, processing, storage methods/ tools and provenance: Current challenges, opportunities, and future perspectives such as data collection methods, data transmission, data storage, processing technologies, data-enabled decision-making models, as well as data interpretation and application are highlighted as major concerns (Zhong *et al.*, 2016b). Nowadays, data analytics, which require managing an immense amount of data rapidly, present challenges and difficulties for information processing related to the large amounts of data, high dimensionality, and dynamical change of this data (Chong *et al.*, 2016). Efficiency in SC is about process; whereas, in the DSC context efficiency concept relates to access and storage of data.

Data Analytics: Analytics are the tools used for extracting information, building a knowledge base using the derived data, and developing optimization, visualization and forecasting models around this data (Tannahill and Jamshidi, 2014). To get the most out of multiple data sets (in combination with a firm's existing data), a more sophisticated way of handling, managing, analysing and interpreting data is necessary for their competitive advantage by enhancing their innovation capabilities (Tan *et al.*, 2015; Chae *et al.*, 2014) . For example, data visualisation techniques enhance data interpretation and increase trust in data completeness and validity (Bendoly 2016).

5 Discussion

The review presented the concept of Data Supply Chain (DSC) through its characteristics, focusing on distinguishing the flow of data artefacts as a supply chain of its own with specific a) element of exchange, b) strategy, c) integration and d) tools/methods. The purpose was to unfold the conceptual distinctiveness of DSC and identify the emerging areas of interest arising within the context of Knowledge Economy. Within this context we argue that data can be ‘raw materials’ triggering processes and creating value through their flows across organizational boundaries, while developing new information products/services as well as disrupting existing business models to facilitate such a change. The literature could not allow us to find a conceptualization of this emergent phenomenon, although there is a progressively increasing number of studies focusing on data artefacts, the ways firms can create value from them and how the strategies should be formed around these ‘raw materials’.

The framework synthesis approach allows us to depict the differences of DSC compared to conventional manufacturing SC around four respects: their element of exchange, strategy, integration and tools/methods. The comparison (as it appears also in Table 2) shows that a unique characteristic of DSC is the content. The element of exchange of DSC is usually data, but can also be information and knowledge (processed data raw materials). Data artefacts flowing from inbound and outbound activities of the firm (and not solely from internal databases) integrated and combined in ways that can provide value for the focal firm (through information product/service development), introduce innovative business and operational models.

SC	**Characteristics**	**DSC**	**Emergent areas**
Flow of physical artefacts (materials, products, services) from initial source(s) to final customer.	**Content**	Flow of multisource, multiform data artefacts (or even processed data, information or knowledge) from inbound and outbound activities of the firm	Data heterogeneity Data quality Data privacy and security
Demand-led supply chain (only produce what is pulled through), targeting in production maximisation, revenue and value creation, quality, service, safety, etc. Price-driven (strategically decoupled and price driven)	**Strategy**	Innovation-led (through ideas, practices, and business models; value for DSC is not solely created from an information product/ service but also through the disruption of the existing business and operational models). Outcome-driven (strategically coupled and value driven)	Data generation and exploitation Innovation (business model and product/service development)
Shared information across the whole chain (end to end pipeline visibility).	**Integration**	Integration of multiple data sources (internal and external to the focal firm). Collaboration,	Multisource data Interconnectivity

Collaboration and partnership (mutual gains and added value for all)		interconnection and value co-creation (value through business model innovation)	
IT enabled; Physical manufacturing systems; agile and lean; mass customization methods	**Tools/ Methods**	Analytics-enabled; Cyber-physical manufacturing systems; agile, lean and real-time; tailored customization methods	Data collection, processing, storage methods/ tools and provenance Data Analytics

Table 2: DSC Characteristics and Emergent areas

The strategy formed around DSC is innovation-led and outcome-driven, meaning that contrary to the traditional SC where demand is triggering the production, for DSC innovative ideas and practices can create value for the development of products and services. Traditional approaches of SC are usually decoupled and price driven, focusing on profit increase while for DSC the driver of the production is the outcome of this process which focuses on the value through coupled value co-creation. The integration of multiple sources (data, information, processes, practices etc.) across the immediate boundaries of the firm can be observed in SC in general, however in DSC, the integration is mostly focusing on the combination of the data from internal and external sources (along with the integration as it is perceived in traditional SCs). The methods and tools used for DSC seems as the fourth distinct characteristic which warrants further investigation; data-oriented methods for information product/service development, introduce new patterns of work which rely on analytical skills as well as the reliability mostly on cyber-physical, IoT, and cloud-based systems - for the collection, processing, storage and utilization of data through the supply chain.

Future research towards this direction could focus in understanding further the emergent areas around the DSC context as these were identified through the framework synthesis (Table 2). Previous studies have indicated that indeed data as ‘raw materials’ can be multiform and multisource; therefore, new approaches are required for value extraction and creative industrial use and processing of this heterogeneous data. Data processing and manufacturing approaches should be investigated for the path to better data quality, along with new frameworks to describe and track data manufacturing processes in different industrial applications. In addition to data quality, data privacy is an emerging concern around DSC, as often serious threats arise when these datasets are shared among third parties. Ways to prevent such issues open a new research agenda around trust and shared responsibility among the DSC actors and entities. Furthermore, data collection, processing, storage techniques and methods and data provenance is a research area which is worth expanding. Data generation and exploitation strategies can also focus on the organizational aspects as well as the capabilities and skills the firms should acquire for building innovative DSCs. The outcome-driven approaches DSCs follow can set a strategic way of coupling multisource data in different innovative ways, producing outcomes and value for the firms through products/services or business model innovation.

With this paper, we introduced the concept of Data Supply Chains (DSC) presenting an interesting yet challenging field of research within the notion of data evolution and knowledge economy. Without neglecting the important role of data in supply chains, which has been a more widely explored research area, we draw specific attention to supply chains of data. A field's development is shaped by the clarity of its constructs and underlying assumptions (Bansal and Song, 2016); therefore, we provide a conceptual framework for DSC and believe there is still a big research gap in this highly emergent area. Such research highlights the value and new research directions in exploring beyond the immediate boundaries of a firm to a collaborating pattern of using data and creating value opportunities while disrupting the already existing business and operational models.

Additionally, our methodological contribution is adopting a framework approach for the literature review synthesis, used first time for the supply chain and operations management fields. However, Dixon-Woods (2011) describes as a limitation of framework-based synthesis its tendency to generate results about which there may be some ambiguity, not least because the a priori framework may restrict reviewers' scope of vision. We attempt to address this limitation by using a broadly specified conceptualisation of SC as our starting point but recognise that facets of the DSC phenomenon may, nevertheless, have been missed. We recommend that future research empirically test the validity of our proposal.

6 Conclusion

Data Supply Chains have emerged relatively recently[8] as data evolution expands business scope, disrupts existing operating models, change industries and provide opportunities to work solely on data as the main 'raw material'. Evolution of data and its processing, exchange and reselling transforms the organizational and operational landscape and renders the conceptualization of DSC highly relevant.

Waller and Fawcett (2013) proposed the use of data in supply chain management for improvement and expansion of the production (through the use of analytical skills for optimization and visualisation of the supply chains of their core business). Although data can be used along with the core business processes in different industries where we find data about the supply chains, we put our specific focus on data around the supply chains; and, we emphasize the difference between data utilised to improve supply chain processes vs. data used as the main artefact. We find that the literature that considers data as the main artefact focuses on technical solutions and challenges around data and supply chain management but lacks discussion on the organisational, operational and industrial consequences of DSC (see Appendix).

An important distinction is to be made when data are the main artefact: data are not consumed nor do they perish in the process of production, nor do data necessarily depreciate. Moreover, data have atypical characteristics compared to physical raw materials in a supply chain: data can be inputs, intermediate goods as well as end products themselves. Therefore, DSC can be an iterative process where data leads to expansive value creation. As El Kadiri et al. (2016) suggests, data product cycle is not a closed loop system and more data iteratively feedbacks into different decision-making phases. These characteristics of data in the DSC lead to several consequences for the industrial and organisational setting. Collaboration, coordination and transparency within industries become more prevalent (Li et al. 2016a; Janssen et al. 2017) compared

[8] with the advent of Open APIs and the Web 2.0 paradigm.

to persistence of competition and secrecy in supply chains around physical goods. Sharing data is generally beneficial and creates positive externalities for processes and organisations (Kwon et al. 2014; Li et al. 2016a; Janssen et al. 2017). Moreover, we find that data transforms supply chain management into demand chain management by decreasing the need for excessive inventories and increasing customer response (Christopher and Ryals 2014). Finally, we also find that DSC should allow for flexibility and adaptability since data lead to a more inductive logic in processing rather than a deductive one (Erevelles et al. 2016).

These highlighted facts emphasize that DSC needs to be tackled with a fundamentally different approach to data used about a physical supply chain. There are, however, several ways in which the DSC approach can learn and benefit from the physical supply chain literature. Models utilized in SC can be transformed to create the foundational framework for the operation of DSC. Such research would help scholars to advance DSC models and inform practitioners in such contexts.

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APPENDIX

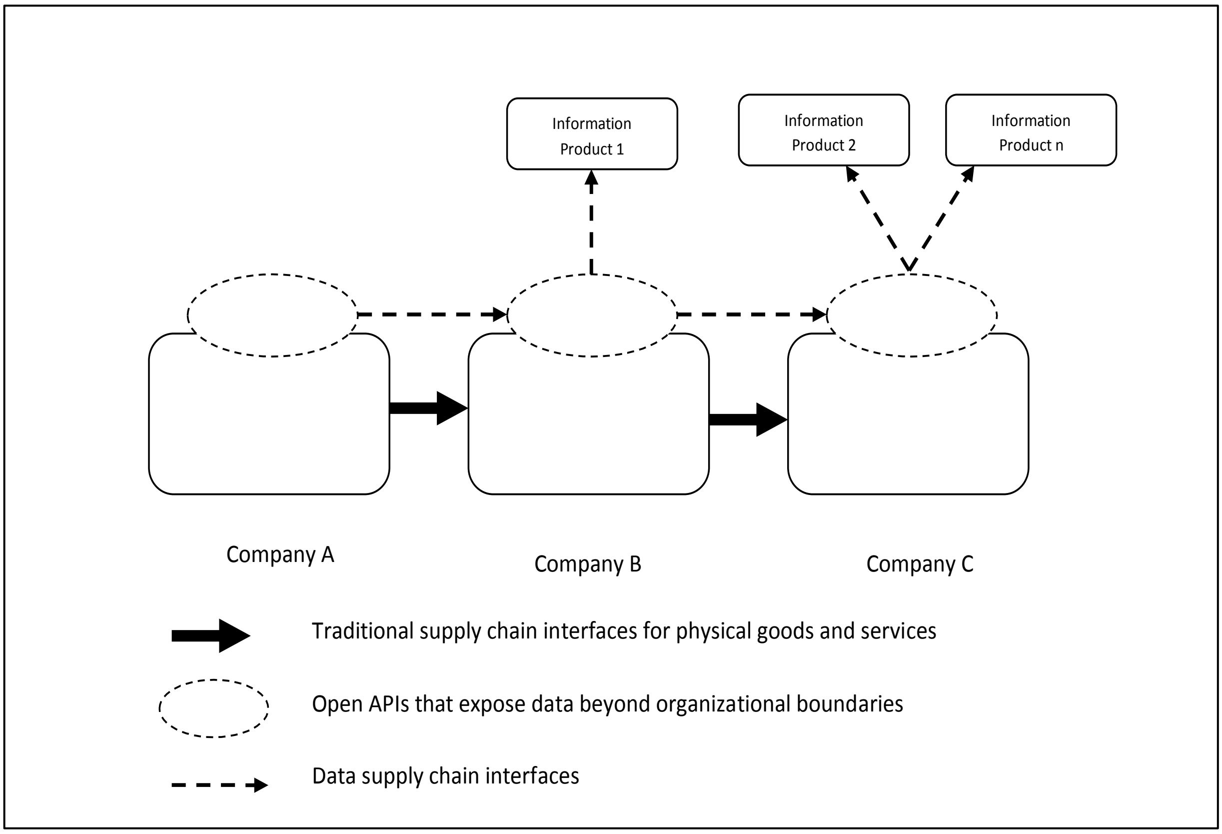

Figure 4: DSC vs. SC (Spanaki et al. 2016)

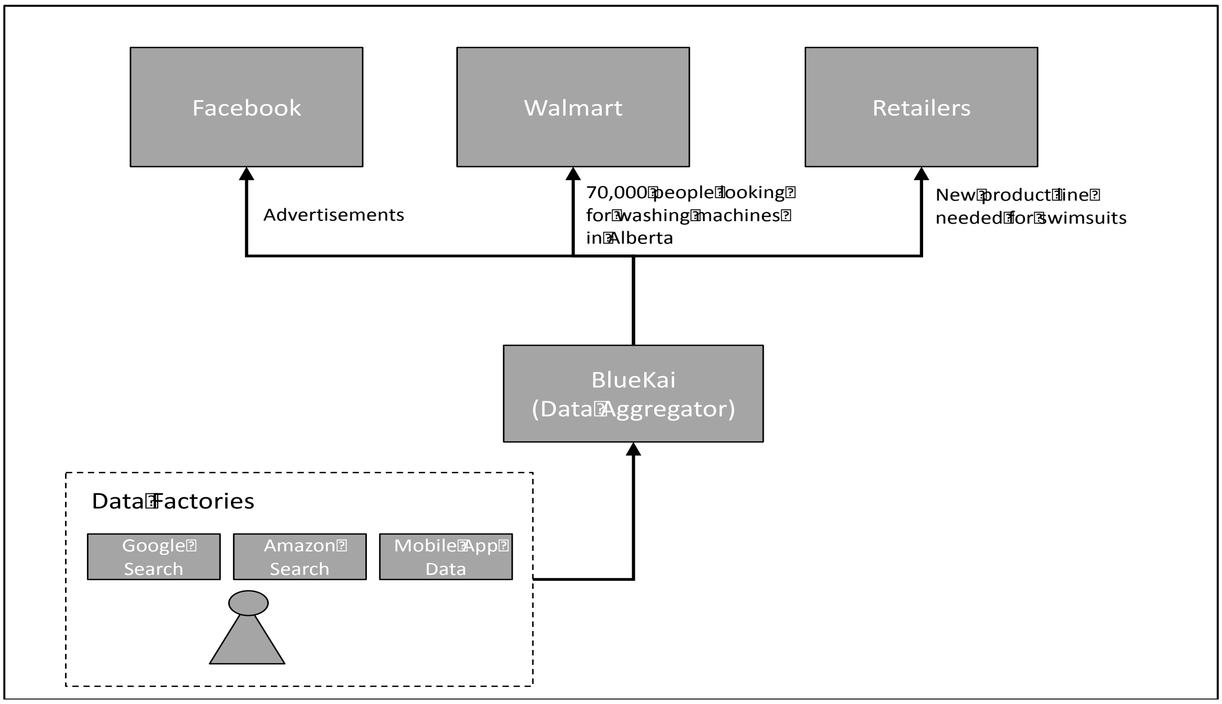

Figure 5: An Example of DSC (Mulligan, 2013)

		Focus			
	Selected Literature	**Smart supply chains** Data are used to create process efficiency for physical flows	**Technical** Necessary technical advances for DSC and data challenges	**Hybrid forms** Physical artefact/data supply chains, servitization	**Data as artefact** Data are the main artefact moving through the supply chain
1	Alvarez-Rodríguez, J.M., Labra-Gayo, J.E. & De Pablos, P.O. (2014)	X	X		
2	Belaud, J., Negny, S., Dupros, F., Michéa, D. & Vautrin, B. (2014)		X		X
3	Bendoly, E. (2016)	X	X		
4	Boone, C.A., Hazen, B.T., Skipper, J.B. & Overstreet, R.E. (2016)	X			
5	Cenamor, J., Sjödin, D. R., & Parida, V. (2017)		X	X	X
6	Chae, B., Yang, C., Olson, D. & Sheu, C. (2014)	X			
7	Chen, K., Li, X. & Wang, H. (2015)		X		X
8	Ch'ng, E. (2015)		X		X
9	Chong, A.Y.L., Li, B., Ngai, E.W.T., Ch'ng, E. & Lee, F. (2016)	X	X	X	
10	Christopher, M. & Ryals, L. J. (2014)	X		X	X
11	De Oliveira, M.P.V., McCormack, K. & Trkman, P. (2012)	X		X	
12	Dobre, C. & Xhafa, F. (2014)		X		X
13	Dubey, R., Gunasekaran, A., Childe, S.J., Wamba, S.F. & Papadopoulos, T. (2016)	X	X	X	X
14	El Kadiri, S., Grabot, B., Thoben, K., Hribernik, K., Emmanouilidis, C., Von Cieminski, G. & Kiritsis, D. (2016)		X		X
15	Ellram, L. M. & Tate, W. L. (2016)	X	X	X	
16	Erevelles, S., Fukawa, N. & Swayne, L. (2016)	X	X	X	X
17	G&omi, A. & Haider, M. (2015)		X		X
18	Giannakis, M. & Louis, M. (2016)	X	X	X	X
19	Groves, W., Collins, J., Gini, M. & Ketter, W. (2014)	X	X		
20	Gunasekaran, A., Papadopoulos, T., Dubey, R., Wamba, S. F., Childe, S. J., Hazen, B. & Akter, S. (2017)	X		X	
21	Hahn, G.J. & Packowski, J. (2015)	X	X	X	
22	Hazen, B. T., Boone, C. A., Ezell,	X	X		

	J. D. & Jones-Farmer, L. A. (2014)				
23	Hazen, B.T., Skipper, J.B., Ezell, J.D. & Boone, C.A. (2016)	X	X	X	X
24	Hofmann, E. (2015)	X	X	X	
25	Hossain, M.A. & Dwivedi, Y.K. (2014)		X		X
26	Janssen, M., van der Voort, H. & Wahyudi, A. (2017)		X		X
27	Ji-fan Ren, S., Fosso Wamba, S., Akter, S., Dubey, R. & Childe, S.J. (2016)	X	X		
28	Kache, F., & Seuring, S. (2017)	X	X	X	
29	Kang, H.S., Lee, J.Y., Choi, S., Kim, H., Park, J.H., Son, J.Y., Kim, B.H. & Noh, S.D. (2016)	X			
30	Kumar, M., Graham, G., Hennelly, P. & Srai, J. (2016)	X		X	X
31	Kwon, O., Lee, N. & Shin, B. (2014)		X		X
32	Lee, C.K.H. (2017)	X	X	X	
33	Lee, J., Kao, H. & Yang, S. (2014)	X	X	X	X
34	Lee, J., Lapira, E., Bagheri, B. & Kao, H. (2013)	X	X	X	
35	Li, Q., Luo, H., Xie, P., Feng, X. & Du, R. (2015a)	X	X	X	
36	Li, F., Nucciarelli, A., Roden, S. & Graham, G. (2016a)	X	X	X	X
37	Li, J., Tao, F., Cheng, Y. & Zhao, L. (2015b)	X	X		
38	Li, Y., Thomas, M.A. & Osei-Bryson, K.-. (2016b)		X		
39	Matthias, O., Fouweather, I., Gregory, I. & Vernon, A. (2017)	X		X	X
40	Mehmood, R., Meriton, R., Graham, G., & Kumar, M. (2017)		X	X	X
41	Merino, J., Caballero, I., Rivas, B., Serrano, M. & Piattini, M. (2016)		X		X
42	Mezzanzanica, M., Boselli, R., Cesarini, M. & Mercorio, F. (2015)		X		X
43	Ng, I., Scharf, K., Pogrebna, G. & Maull, R. (2015)	X	X	X	X
44	Njuguna, C. & McSharry, P. (2017)		X		X
45	Öberg, C. & Graham, G. (2016)	X	X	X	X
46	Opresnik, D. & Taisch, M. (2015)	X	X	X	X
47	Papadopoulos, T., Gunasekaran, A., Dubey, R., Altay, N., Childe, S.J. & Fosso-Wamba, S. (2016)		X	X	X
48	Radke, A.M. & Tseng, M.M. (2015)		X		X
49	Ramanathan, U., Subramanian, N., & Parrott, G. (2017)			X	X
50	Rehman, M.H.U., Chang, V., Batool, A. & Wah, T.Y. (2016)		X		X
51	Rymaszewska, A., Helo, P., & Gunasekaran, A. (2017)			X	X

52	Schnase, J.L., Duffy, D.Q., Tamkin, G.S., Nadeau, D., Thompson, J.H., Grieg, C.M., McInerney, M.A. & Webster, W.P. (2014)		X		X
53	Schoenherr, T. & Speier-Pero, C. (2015)		X		
54	Souza, G. C. (2014)	X		X	X
55	Tachizawa, E. M., Alvarez-Gil, M. J. & Montes-Sancho, M. J. (2015)	X		X	X
56	Tan, K.H., Zhan, Y., Ji, G., Ye, F. & Chang, C. (2015)		X		X
57	Tannahill, B.K. & Jamshidi, M. (2014)		X		
58	Trkman, P., McCormack, K., de Oliveira, M. P. V. & Ladeira, M. B. (2010)	X	X	X	X
59	Waller, M. A. & Fawcett, S. E. (2013)	X	X	X	X
60	Wang, G., Gunasekaran, A., Ngai, E. W. T. & Papadopoulos, T. (2016)	X			
61	Wang, X. & Li, Z. (2016)		X		X
62	Wu, L., Yue, X., Jin, A. & Yen, D.C. (2016)	X	X	X	
63	Yang, L., Yang, S.H. & Plotnick, L. (2013)			X	X
64	Zhan, Y., Tan, K.H., Li, Y. & Tse, Y.K. (2016)	X		X	
65	Zhang, X., Liu, C., Nepal, S., Yang, C., Dou, W. & Chen, J. (2014)		X		
66	Zhang, Y., Qu, T., Ho, O.K. & Huang, G.Q. (2011)	X	X	X	
67	Zhang, Y., Zhang, G., Du, W., Wang, J., Ali, E. & Sun, S. (2015)	X	X	X	
68	Zhong, R.Y., Huang, G.Q., Lan, S., Dai, Q.Y., Chen, X. & Zhang, T. (2015a)	X	X	X	
69	Zhong, R.Y., Lan, S., Xu, C., Dai, Q. & Huang, G.Q. (2016a)	X	X		
70	Zhong, R.Y., Xu, C., Chen, C. & Huang, G.Q. (2015b)	X	X	X	
71	Zhong, R.Y., Newman, S.T., Huang, G.Q. & Lan, S. (2016b)	X	X	X	

Table 3: Focus of Selected Literature