# Integrating big data analytics into supply chain finance:
# The roles of information processing and data-driven culture

**Abstract**

The role of big data in implementing supply chain finance (SCF) initiatives lacks empirical study. There is little guidance available for managers on developing an integrated SCF process in the era of big data. Using organizational information processing theory, this study develops and empirically tests a theoretical framework that investigates the effect of big data analytics capability (BDAC) on SCF Integration, and the moderating effect of data-driven culture. The hypothesized relationships were tested using structural equation modelling and moderated regression analysis, with primary survey data collected from a sample of 307 manufacturing firms in China. The results indicate that BDAC has a significant positive effect on internal SCF Integration, and internal SCF Integration fully mediates the relationships between BDAC and SCF Integration with customers and suppliers. Data-driven culture significantly moderates the effect of BDAC on internal SCF Integration. These empirical findings provide timely and useful guidance for managers on using big data analytics and data-driven culture to implement integrated SCF practices to survive in today's data-rich and uncertain environment.

**Keywords** Big data analytics capability; Data-driven culture; Integrated supply chain finance; Information processing capability

## 1. Introduction

The 2008 financial crisis, US-China trade war, and coronavirus (COVID-19) outbreak (DHL Resilience360, 2020) have significantly affected cash flows and access to external capital (Jia et al., 2020). Supply chain finance (SCF) involves the use of financial instruments and information technologies to optimise cash flow tied up in a supply chain (Gelsomino et al., 2019). SCF practices, e.g., reverse factoring, dynamic discounting, pre-shipment finance, inventory finance, and receivable finance align a firm's financial flows with material and information flows and benefit all supply chain actors (Wuttke et al., 2013a, b). Recent advances in the SCF literature suggest using information technology mechanisms such as electronic data to improve information processing capacity (Jia et al., 2020). To learn from electronic financial data, firms may adopt big data analytics to improve real-time analysis of financial/trading information and further enhance information processing capability to reduce financial uncertainty (Jia et al., 2020; Zhao et al., 2015). To advance the idea of information technology mechanism (Jia et al., 2020), this study explores whether the use of big data analytics contributes to the development of an integrated SCF process (Chen et al., 2020).

Issues related to the conceptualization and dimensions of SCF are still evolving (Gelsomino et al., 2016, 2019; Jia et al., 2020; Xu et al., 2018), but there is a common thread – coordination of financial flows within the organisation and between supply chain partners (Hofmann and Belin, 2011; Silvestro and Lustrato, 2014). Jia et al. (2020) suggest intra- and inter-organisational collaboration are instrumental for integrating "financial SC". SCF works when financial instruments and trades are integrated across a supply chain through strategic collaboration and information sharing. To extend the framework of financial SC integration (Jia et al., 2020), we define a multidimensional construct called *SCF Integration* that reflects information sharing and strategic collaboration within a supply chain to optimise working capital and corresponding liquidity tied up in supply chain processes. Incorporating the ideas of SCF Integration (Jia et al., 2020) and the needs to distinguish internal from external integration (Flynn et al., 2010), we establish a new instrument to measure internal, supplier and customer SCF Integration. A review of the SCF literature and interviews with senior executives from three manufacturing firms in China reveals that internal SCF Integration refers to the optimisation of working capital through cross-functional collaboration, and external (with customers and suppliers) SCF Integration refers to the coordination of financial flows through inter-organisational collaboration with customers and suppliers.

The concepts and dimensions of SCF are still evolving because the topic is nascent in the supply chain literature. The supply chain finance studies to date have been largely from a corporate finance perspective, e.g., Chen and Kieschnick (2018). This includes topics such as the cash conversion cycle, e.g., Hofmann and Kotzab (2006). There has also been research in the broad area of risk analysis that has taken a theoretical modelling approach. For a full explication of the state of the literature we direct the reader to Chen et al.(2020). Chen et al. (2020) indicate more research is needed to understand SCF collaboration mechanisms, particularly the need to understand expansion of information processing capability.

The lack of theoretical insights can impede the development of SCF research (Gelsomino et al., 2016; Jia et al., 2020). Given such, one area needing study is the role of big data in SCF, although its potential ability to optimise cash flows in supply chains has been mentioned (Jia et al., 2020). A vast amount of transaction and financial data at large volume, variety, velocity, veracity, and value have been generated at an unprecedented speed (Gunasekaran et al., 2017; Yu et al., 2019a) from the use of various information technologies, e.g., enterprise resources planning (ERP) system, internet of things (IoT), mobile banking, and cloud computing. Optimization of financial flows using the data from these technologies requires a significant information processing capability (Srinivasan and Swink, 2018) supported by big data analytic capability (BDAC). BDAC involves the use of advanced analytical techniques to generate critical insights from processing and analysing vast amounts of data to facilitate data-driven decision-making and ultimately enabling competitive advantage (Dubey et al., 2019; Gupta and George, 2016; Mikalef et al., 2019; Srinivasan and Swink, 2018).

The information processing needs of SCF are consistent with organizational information processing theory (OIPT) (Daft and Weick, 1984; Galbraith, 1973) which argues uncertainty (in choosing suitable and outcomes of SCF) drives increasing needs for information sharing or information processing capacity through BDAC. By reducing uncertainty, firms can manage their information, material, and financial flows more effectively (Gunasekaran et al., 2017; Srinivasan and Swink, 2018; Wang et al., 2016). OIPT suggests that data collection, information processing, and strategic action are used to respond to a rapidly changing business environment (Daft and Weick, 1984; Thomas et al., 1993). Jia et al. (2020) apply OIPT to argue information technology mechanisms such as electronic data can improve information processing capacity, which can enable financial SC integration. This study argues the availability of electronic data means BDAC can be built to process, visualize, and analyse data in a structured and logical way and thereby produce insights enabling data-driven operational planning, decision making and execution for integrating SCF among functions internally and externally (Wang et al., 2016; Srinivasan and Swink, 2018; Williams et al., 2013).

Extending the OIPT's notion of using organization design to coordinate information, this study establishes an integrated SCF framework to understand how BDAC enables internal and external SCF Integration. We argue BDAC generates insights about uncertainty in terms of financial implications, which can enhance external SCF integration through internal SCF Integration, given the importance of having internal integration before implementing external SCF Integration (Jia et al., 2020; Randall and Farris II, 2009; Wuttke et al., 2013a). We further explore the moderating role of a big-data-driven culture because reaping the potential benefits of big data initiatives may be difficult without it (Dubey et al., 2019; LaValle et al., 2011; McAfee and Brynjolfsson, 2012). Organizational culture is key to implementing new supply chain management practices (Braunscheidel et al., 2010; Liu et al., 2010) and deserves a careful consideration in the big data context (Dubey et al., 2019). A data-driven decision-making culture ensures that information flows can lead to business success (Gallivan and Srite, 2005; McAfee and Brynjolfsson, 2012; Shamim et al., 2018). Thus, we expect an interaction between BDAC and data-driven culture that influences the implementation of SCF initiatives. By extending the integrated SCF framework of Jia et al. (2020) and providing new evidence, this study provides timely and useful guidance for managers on the use of big data analytics and a data-driven culture to promote the integration of the whole financial supply chain.

This paper is structured as follows. Section 2 defines the main constructs. Section 3 introduces the theoretical framework and the hypotheses of the study. Section 4 details the methodology employed in the study and is followed by the results of the analyses in Section 5. Section 6 is a discussion of the results and Section 7 provides concluding remarks.

## 2. Theoretical lens and constructs

### 2.1. OIPT

OIPT suggests that firms gather, interpret, synthesize, and coordinate information across the organization to address uncertainty (Burns and Wholey, 1993). Uncertainties in SCF arise when there is a lack of information about which suppliers and customers are likely to fail to deliver or default on payment. Uncertainties also arise from changing market conditions facing suppliers and customers which can impact working capital levels. Processing information in a structured and logical way reduces uncertainty and helps decision makers develop a shared interpretation of the information (Daft and Lengel, 1986; Galbraith, 1973). Information processing capabilities are increasingly key to effective supply chain management (Srinivasan and Swink, 2018; Williams et al., 2013; Yu et al., 2019b). Importantly to the present study, a supply chain can be viewed as an information-processing and interpretation system (Hult et al., 2004; Thomas et al., 1993).

Jia et al. (2020) suggest that OIPT provides a basis for a comprehensive understanding of SCF. Information flow is the foundation of effective SCF, which includes order transactions, debt, and liabilities management (e.g., cash-to-cash-cycle) (Gomm, 2010). Such SCF information helps decrease investment risks and costs of financing projects within supply chains, improve financial decisions, and optimise financing (Gomm, 2010; Pfohl and Gomm, 2009). As such, information processing capacity is increasing in criticality. The flow of financial information in electronic forms is an important feature of information technology mechanism that can reduce uncertainty (Jia et al., 2020). To transform electronic financial data into effective decisions, this study argues uncertainties of SCF problems can be reduced using data analytics to increase information processing capability. Big data analytics capabilities can increase the information processing capacity required to analyse and process data gathered from various sources and improve decision-making (Dubey et al., 2019; Gunasekaran et al., 2017; Srinivasan and Swink, 2018; Yu et al., 2021).

## 2.2. BDAC

From the OIPT perspective, BDAC acts as an organizational capability that enables firms to process and analyse SC financial data. Big data characterized in terms of the 5Vs (volume, variety, velocity, veracity, and value) provide the opportunity to draw associations or identify hidden factors (Dubey et al., 2019; Gupta and George, 2016; Srinivasan and Swink, 2018) that may affect the cash flows of a firm or its suppliers/customers. These new insights help reduce uncertainties related to changing financial situations that can lead to payment default. Following Srinivasan and Swink (2018, p.1851), we define BDAC as an "organizational facility with tools, techniques, and processes that enable a firm to process, organize, visualize, and analyse data thereby producing insights that enable data-driven operational planning, decision-making, and execution". BDAC includes the use of data visualization tools (e.g., dashboards) to share and access relevant information quickly and advanced analytical techniques (e.g., statistical methods and optimization) to analyse information from various sources to inform complex decision-making process (Srinivasan and Swink, 2018). Through effectively orchestrating and deploying data, technology, and talent information processing capacity is improved and generates insights into enhancing operational and strategic decision-making processes (Gupta and George, 2016; Mikalef et al., 2019; Shamim et al., 2018).

### 2.3. Data-driven culture

Organizational culture refers to "a collection of shared assumptions, values, and beliefs that is reflected in organizational practices and goals and that helps its members understand organizational functioning" (Liu et al., 2010, p.375). Previous studies show the importance of organizational culture in shaping business strategies (Saffold, 1988) and implementing supply chain management practices (e.g., Braunscheidel et al., 2010; Dubey et al., 2019; Liu et al., 2010). Big data research has suggested that organizational culture is critical for the success of the firm's big data initiatives (Dubey et al., 2019; Ross et al., 2013; Shamim et al., 2018). Gupta and George (2016) suggest that data-driven culture is one of the critical intangible resources for making the best use of data through BDAC. A culture of evidence-based decision making among senior-level executives (rather than using instincts) is more likely to improve business performance (McAfee and Brynjolfsson, 2012; Ross et al., 2013). Following Gupta and George (2016, p.1053), we define data-driven culture as "the extent to which organizational members (including top-level executives, middle managers, and lower-level employees) make decisions based on the insights extracted from data".

### 2.4. SCF Integration

Supply chain management comprises the integration of intra- and inter-organizational processes to achieve effective flows of products, services, information, and cash with the objective of providing maximum value to customers and other stakeholders (Flynn et al., 2010; Yu et al., 2013; Zhao et al., 2011). Unlike information and material flows, supply chain cash flow has been largely overlooked in the supply chain literature (Liebl et al., 2016; Pfohl and Gomm, 2009; Randall and Farris II, 2009; Silvestro and Lustrato, 2014). SCF facilitates intra-organisational optimisation of financing, namely the interaction between finance, operations (Birge, 2015), and logistics/procurement (Wuttke et al., 2013a) through intra-organisational collaboration for financial risk mitigation (Fischer and Himme, 2017; Martin and Hofmann, 2017). It also involves the optimisation of financing, planning and controlling the flow of financial resources on an inter-organisational level (Hofmann, 2005) which in turn requires the integration of financing processes with customers, suppliers, and service providers (Gomm, 2010; Pfohl and Gomm, 2009; Silvestro and Lustrato, 2014). Normally these activities are led by focal firms (Chen et al., 2021). However, our study does not focus or depend on this relationship.

Our conceptualization of SCF Integration is inspired by Jia et al.'s (2020) integrated theoretical framework that investigates how SCF providers cope with various uncertainties, develop capabilities, and achieve integration of the financial supply chain. Emphasize is intra- and inter-organisational collaboration are essential to integrate financial SC, suggesting that collaboration in SCF requires both internal and external supply chain integration. To ascertain better this integrative view, we interviewed senior executives from three Chinese manufacturers. A senior executive from a leading automotive manufacturer stated, "*it is important to manage cash flows from the entire supply chain perspective, especially involving trading partners like customers and suppliers into financial management*." A chief financial officer from a major auto parts manufacturing firm further indicated integration of SCF can be supported by BDAC "*collaboration with trading partners for financial flow management was one of the important supply chain financing practices which we have conducted over the last few years, especially since the China-US trade war. Of course, to better finance our supply chain operations, within our firm our cross-functional teams have begun to introduce big data analysis techniques to analyse data to optimise our financial structure.*"

The above exchanges seem to corroborate the emerging literature on SCF (Jia et al., 2020) and case studies of industries other than automotive (Li and Chen, 2019; Wuttke et al., 2013a) on the importance and nature of collaboration for SCF. We thus define SCF Integration as the inter-functional optimisation of financing as well as the integration of financing processes with supply chain partners to optimize supply chain cash flows. We use a three-dimensional conceptualization of integrated supply chain strategy incorporating SCF: internal SCF Integration, SCF Integration with customers, and SCF Integration with suppliers.

### 2.4.1. Internal SCF Integration

When different functional areas optimize their respective objectives, they may affect the cash flows and working capital of others. For example, sales promotions put pressures on inventory financing. Resulting misalignments of the functional objectives require intra-organisational collaboration to address (Jia et al., 2020; Martin and Hofmann, 2017). Internal SCF Integration entails optimising working capital through effective collaboration across functional departments such as finance, sales, operations, purchasing, logistics, and information technology to ensure a cohesive process to financing supply chain operations (Jia et al., 2020; Martin and Hofmann, 2017; Wuttke et al., 2013a; Zhang, 2015). Prior research emphasizes that internal integration (intra-organisational collaboration) is essential to the implementation of SCF practices (Jia et al., 2020; Randall and Farris II, 2009; Wuttke et al., 2013a; Yu et al., 2019). Wuttke et al. (2013a) state that logistics/procurement-finance alignment strengthens the link between redefining and restructuring, and thus promotes the implementation of SCF initiatives. Internal SCF Integration enables financial accounting, production, and inventory information to be shared between cross-functional teams, and thus decreases investment risks and capital costs to achieve financial SC information integration (Pfohl and Gomm, 2009).

### 2.4.2. SCF Integration with customers and suppliers

SCF Integration with customers and suppliers refers to the inter-organisational optimisation of working capital and financial liquidity and the integration of financing processes with upstream suppliers and downstream customers to maximise the value for all trading partners (Pfohl and Gomm, 2009). Supply chain partners such as customers and suppliers must collaborate to implement SCF practices (Liebl et al., 2016; Hofmann, 2005; Ling-yee and Ogunmokun, 2001). A chief financial officer from a leading auto parts manufacturing firm in China, in emphasizing the importance of financial collaboration with supply chain partners, noted that *"over the last few years, automotive businesses faced significant challenges obtaining external finance from banks, we need to work collaboratively with business partners to better* *manage cash flows. Supporting each other has become increasingly important especially at this difficult time."*

Collaboration between manufacturers, customers, suppliers, and service providers can be beneficial to all supply chain actors (Flynn et al., 2010; Yu et al., 2013). SCF becomes efficient when invoices are digitalized for automatically triggering the use of SCF instruments. Collaboration with suppliers and customers is required to digitalize and automate transactions between suppliers, customers, and financial and logistics service providers (Pfohl and Gomm, 2009). They also need to establish an agreement on the use of specific SCF instrument to address each other's cash flow problems. External SCF Integration optimises working capital and financial liquidity through integrating customers and suppliers for joint value creation through planning, managing, and controlling supply chain cash flows on an inter-organizational level (Hofmann, 2005; Pfohl and Gomm, 2009; Zhao et al., 2015). External SCF Integration can also be a productivity improver as laborious accounts receivables activities are minimized. Yet another potential benefit to external SCF Integration is a reduction in the risk profile of the supply chain. The ready availability of working capital helps ensure the ongoing viability of the firm using the financing instrument.

Uncertain cash flows can increase customers and/or suppliers' default risk and therefore raise the probability of supply chain disruptions and even customer/supplier bankruptcies (Liebl et al., 2016). For example, long payment terms may improve a buying firm's liquidity, but they increase the needs for supplier to finance its receivables (Hofmann and Kotzab, 2010; Seifert et al., 2013). Managing financial flows collaboratively with customers and suppliers can reduce default risks in the supply chain by optimising working capital and improving financial liquidity (Liebl et al., 2016; Ling-yee and Ogunmokun, 2001; Wuttke et al., 2013a,b). Reverse factoring as a financial instrument can ease buyers' and suppliers' working capital by accelerating the in-payment for the supplier and increase the payment term for the buyer (Liebl et al., 2016; Martin and Hofmann, 2019). While suppliers and customers may independently access to the SCF instruments via a financial service provider, reverse factoring and other SCF instruments require strategic collaboration between suppliers and customers to jointly select a suitable finance service provider, agree to share transaction data with the service providers, and agree to help each other's cash flow problems. In other SCF arrangements such as pre-shipment finance, inventory finance and receivable finance, large buyers or sellers can arbitrage credit by providing suppliers and/or buyers with access to capital at lower rates (Dyckman, 2009; Xu et al., 2018). All these require collaboration between suppliers and customers.

## 3. Theoretical framework and hypothesis development

### 3.1. Theoretical framework

This study integrates the OIPT (Daft and Lengel, 1986; Galbraith, 1973) and organizational culture literature (Saffold, 1988) to conceptually develop the framework in Figure 1. OIPT suggests that a firm increases information processing capacity to fit with information needs. To address cash flow and working capital problems, a firm may benefit from using SCF instruments. It is important to understand financial problems, but there are many uncertainties given financial strains may arise anywhere in a supply chain. Thus, a firm gains benefit from SCF when it can integrate information flows with financial flows. Internal and external SCF Integration serve as coordination mechanisms to facilitate information gathering and sharing. The availability of information does not improve decision making if there is a lack of capacity to analyse information. Thus, building BDAC could be helpful to implement SCF Integration. Moreover, the lack of a strong data-drive culture could reduce the efficacy of BDAC.

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### 3.2. Research hypotheses

Following previous research (e.g., Narasimhan et al., 2013), in addition to the review of the literature and the theoretical lens provided by the OIPT, we integrate interviews with senior executives to complement hypothesis development.

#### 3.2.1. Effect of BDAC on SCF Integration

The importance of information and data management in implementing SCF practices has been acknowledged (e.g., Hofmann and Johnson, 2016; Zhao et al., 2015), but few studies offer theoretical explanations (cf. Jia et al., 2020). To date there is only one study (Zhao et al., 2015) investigating how financial institutions utilize big data from external sources to improve the predictability of SCF clients' business failure. Using OIPT as a theoretical lens, Jia et al. (2020) argue information technology (use of financial electronic data) can increase information processing capacity. As an extension from having more electronic data to having more analytical insight, we argue that building BDAC increases information processing capacity thus facilitating the integration of the financial supply chain. A chief financial officer from a leading auto parts manufacturer stated that "*big data has been a very hot topic in recent years, actually over the last few years we have adopted relevant information systems including ERP system to gather and analyse data for better financial management. Analysing real-time data from various sources did help us manage and forecast cash flow more effectively in order to finance our supply chain operations.*"

SCF improves working capital levels and financial liquidity by aligning cash flows with product and information flows to efficiently manage assets of multiple members in a supply chain network (Pfohl and Gomm, 2009; Wuttke et al., 2013a, b). This increases the demand for network-level financial information and analytics capability. Consistent with OIPT, building BDAC helps firms process, visualize, and analyse data in a structured and logical way (using e.g., advanced statistical techniques, quantitative methodologies, and sensitivity analysis) thereby producing insights that enable data-driven operational planning, decision making, execution, and achievement when SCF integration is present (Srinivasan and Swink, 2018; Wang et al., 2016; Williams et al., 2013). Through processing and analysing demand, sales, and operations planning data BDAC helps functional departments (such as marketing, production, and purchasing) build cross-functional collaboration to exchange financial accounting information regularly for the optimisation of working capital (Gunasekaran et al., 2017; Wang et al., 2016).

As an example of external integration, Nike shares information about the nature of the shoe market with suppliers to help suppliers deliver the right materials in a timely manner. Further, Nike can offer its superior credit rating to secure financing for suppliers. Nike needs BADC to continuously assess and ensure SCF instruments used benefit them and the suppliers since BADC can predict a supplier's future cash flows given changing market conditions. Thus, BDAC can enhance flexibility and response times to customers and changing market conditions, the visibility and transparency of customer information, perception of customer behaviour (customer intimacy and visibility), and intensifying customer engagement (Gunasekaran et al., 2017; Kache and Seuring, 2017) which enables firms to work closely with customers on optimise working capital and financial liquidity. Building BDAC helps firms quickly evaluate and analyse supplier performance (such as quality, delivery guarantee and timeliness, purchasing spend analytics, and payment term spend analysis), identify the sources of supply uncertainties, and manage collaborative relationship with suppliers (Srinivasan and Swink, 201; Wang et al., 2016) thereby improving cash flow management with suppliers. Therefore, we hypothesise that greater data analytics capability yields greater SCF Integration:

*H1: BDAC has a significant positive effect on (a) internal SCF Integration, (b) SCF Integration with customers, and (c) SCF Integration with suppliers.*

### 3.2.2. Effect of internal SCF Integration

According to OIPT, cross-functional processes and systems represent different information processing infrastructures that absorb, utilize, and interpret information (Williams et al., 2013). Information processing at an organizational level is weak without cross-functional coordination, or internal integration to enable the joint formation of a strategic plan especially in uncertain environments (Wong et al., 2011; Yu et al., 2013). For example, such coordination is critical to Gallo wine as it navigates the vagaries of consumer taste in conjunction with uncertain supply quantity and quality. SCF integration with external partners requires access to and exchange of information across multiple functions within an organization (Yu et al., 2013; Zhao at al., 2011). For example, the establishing of an annual sales plan with a key customer requires information from production, quality, sales, finance, and other functions. The continuous monitoring of sales, production and inventory is required to understand cash flows implications to suppliers and customers, suggesting the importance of internal SCF Integration in shaping external SCF Integration.

In the SCF context, we draw upon OIPT to argue that internal SCF Integration enhances external SCF Integration (with customers and suppliers), because integration of internal financial flows is a prerequisite for integrating external financial flows with customers and suppliers (Jacobs et al., 2016). Inter-functional coordination facilitates functional goal alignment, highlights inter-organizational interdependencies, and enables the utilization of each functional area’s capabilities to optimise working capital to finance supply chain operations (Jia et al., 2020; Schoenherr and Swink, 2012; Zhao et al., 2011). As such, internal SCF Integration may function as a coordination mechanism enabling financial integration with customers and suppliers (Zhao et al., 2011). An understanding of internal financial problems could identify causes from outside. For instance, cash flow problems can arise from customers who have greater potential to default or delay payment or those who have complex invoice approval process. This can lead to initiatives to integrate financial processes with customers, e.g., simplifying financial processes, or coordinating invoicing and payment cycles. Coordination of a payables schedule with procurement functions could identify suppliers who might have tight cash flows. A firm with strong finances might strengthen its supply base by offering receivables financing. The meeting of partners' needs will strengthen the financial health of the entire supply chain.

The roles of internal SCF Integration in shaping external SCF is alluded to in an interview of a chief financial officer from a leading auto parts manufacturer we conducted, who stated *"There is a Chinese proverb that says: "deal first the internal problems before resolving external problems." This is also true for our supply chain financial flows management, before talking anything about financial collaboration with trading partners, we must first ensure greater teamwork and communication between different functional departments for boosting working capital, otherwise I think it is difficult to integrate with either customers or suppliers."* We therefore argue that firms must develop internal SCF Integration before they can improve their working capital and unlock the liquidity tied up with supply chain partners.

*H2: Internal SCF Integration has a significant positive effect on (a) SCF Integration with customers and (b) SCF Integration with suppliers.*

### 3.2.3. Mediating role of internal SCF Integration

Information needs for financial integration with customers and suppliers can be informed by big data analytics, but it also depends on information gathering from and coordination of information flows across multiple internal functions (Galbraith, 1973; Swink and Schoenherr, 2015). While analysing information collected from suppliers and customers can reduce financial uncertainty (Kahn et al., 2006; Swink and Schoenherr, 2015), coordination across different functions (e.g., procurement, quality, marketing, and finance) is required to assess different scenarios and solutions. This requires internal SCF Integration. For example, United Dairy Farmers must make daily decisions about what products to produce from the milk it receives. These decisions are dependent upon the quality and price of raw milk from the supply market that changes daily, as well as the changing consumer demand across various distribution channels. Collectively, the understanding of the financial implications of these factors can reduce uncertainties and therefore help maximize financial returns. Thus, insights produced by BDAC inform different functions to aid operations planning and subsequently coordinate financial and cash flows with suppliers and customers.

Past studies argue firms build internal information processing capabilities first to interpret information gathered from customers and suppliers (Schoenherr and Swink 2012; Swink and Schoenherr, 2015; Yu et al., 2013). New insights about suppliers and customers generated by BDAC are used for inter-functional coordination. This argument is corroborated by a chief financial officer from the auto parts manufacturing firm in China, who stated, *"Analysing and processing financial and non-financial data from various sources is extremely important for us to improve inter-functional coordination and manage cash flows more effectively but working collaboratively with customers or suppliers for the optimisation of financial liquidity is a complicated process."* As noted above, the chief financial officer also stated, "*deal first the internal problems before resolving external problems*". Thus, it is suggested that internal SCF Integration mediates the relationships between BDAC and SCF Integration with customers and SCF Integration with suppliers.

*H3: Internal SCF Integration significantly mediates the relationships (a) between BDAC and SCF Integration with customers and (b) between BDAC and SCF Integration with suppliers.*

#### 3.2.4. Moderating effect of data-driven culture

Previous research has suggested that organizational culture influences a firm's ability to process information, rationalize, and exercise discretion in the decision-making processes (Liu et al., 2010; Shamim et al., 2018). So, the benefits of big data analytics may depend on elements of organizational culture. Effective information flows require high levels of congruence between organizational culture and strategic supply chain practices (Gallivan and Srite, 2005). Gupta and George (2016) argued that a data-driven culture is a critical intangible resource for the development of BDAC. Dubey et al. (2019) find that a big data culture has significant and positive moderating effects on the relationships between tangible resources and human skills and big data predictive analytics. A culture of evidence-based decision making is required to enhance potential benefits of big data analytics (Dubey et al., 2019; McAfee and Brynjolfsson, 2012).

Researchers suggest that firms with a culture of evidence-based decision making ensure that all decision makers have performance data at their fingertips every day (McAfee and

Brynjolfsson, 2012; Ross et al., 2013). Such data-driven cultures can enhance the use of big data analytics to drive internal SCF Integration and better manage their financial flows. In other words, neither BDAC nor data-driven culture alone is sufficient to implement internally focused SCF practices. Instead, they supplement and reinforce each other. Similar arguments were also noted by a chief financial officer at a leading auto parts manufacturing firm: "*although we have adopted ERP and share the results of data analysis with all functional departments, we were aware that some functional managers still preferred to plan and organise functional activities based on experience or even intuition. We have made efforts to develop a culture of evidence-based decision making to ensure all managers have performance data at their fingertips every day.*" Another senior production executive from a motorcycle manufacturing firm in China also stated that: "*in addition to the adoption of advanced data analysis techniques, building a data-driven decision-making culture is also important for us to manage day-to-day operations. When our production department complains something to CEO, he always says, "let us look at the data and listen to the data". We are encouraged to make a decision based on data rather than intuition.*" Therefore, to take advantage of new insights obtained from BDAC, firms need a data-driven, analytical culture. It is the interaction between BDAC and a data-driven culture that creates interest in promoting internal integration. So, we view data-driven culture as complementary to BDAC, in that the presence of data-driven culture makes data analytics capability more valuable and impactful on internal SCF Integration.

*H4: Data-driven culture significantly moderates the relationship between BDAC and internal SCF Integration.*

### 3.3. Statistical controls

To account for the differences between firms, firm age, firm size, industry type and geographical region (see Table 1) were employed as control variables in the conceptual model. Firm size (measured by the number of employees) and firm age (measured by the number of years since the firm was established) were controlled because larger or older firms may be more likely to build BDAC to develop integrated SCF than small or young firms (Yu et al., 2019a). A dummy variable was used for industry type. The dummy variable Industry1 refers to automobile, Industry2 refers to fabricated metal product, and Industry3 refers to electronics and electrical. The base group is other industries. The type of industry was controlled because firms in the different sectors may build different BDAC to facilitate SCF (Yu et al., 2019a). Compared with other manufacturing industries (such as chemicals and petrochemicals, food, beverage and alcohol, and textiles and apparel), many large automobile manufacturing firms (such as Maruti Suzuki and General Motors) have adopted advanced and state-of-the-art technologies, such as artificial intelligence, IoT, machine learning, and robotics on their manufacturing floors. With the adoption of new and sophisticated technologies, automotive manufacturers are more like to collect, analyse and process a large amount data to optimize their supply chain cash flows. A dummy variable was also employed for geographical region. Region1 refers to Southwest China, Region2 refers to Yangtze River Delta, and Region3 refers to Central China. The base group is other regions. As noted above, the survey data was gathered from different geographical locations that represent diversity of regional economic growth in China. Manufacturing firms in Yangtze River Delta or Pearl River Delta (the most developed regions) are more likely to develop higher levels of BDAC and SCF Integration than those in Northwest or Central China (underdeveloped regions) (Yu et al., 2019a).

## 4. Research methodology

### 4.1. Data collection

To test the research model (see Figure 1), we conducted a cross-sectional study using primary survey data gathered from manufacturing firms in China during July–October 2019. We randomly selected 1,500 manufacturing firms from the databases provided by Contemporary Service Alliance for Integration of Informatization and Industrialization. With the help of the Alliance, we sent the survey questionnaires along with a cover letter explaining the main purpose of the research, guidance for completion of the questionnaire, and maintenance of respondent confidentiality. After several reminders via phone, WeChat text, or email, a total of 317 questionnaires were returned. Due to missing data, ten returned questionnaires were discarded, which leads to 307 useable questionnaires, reflecting an effective response rate of 20.47%. Table 1 summarizes the respondents and responding firms, indicating that our sample reflects a wide range of industry types, geographical regions, firm sizes and job roles. The responding firms come from several main geographical regions representing different stages of economic development in China, including Southwest China, Yangtze River Delta, Central China, Pearl River Delta, Bohai Sea Economic Area, Northeast China, and Northwest China (Zhao et al., 2006). Most respondents were middle or top managers (such as CEO/president, vice president, director, or general manager) and had been in their positions for more than six years, which suggests that they were knowledgeable about the survey questions.

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**4.2. Measures**

The measurement items used in this study (see Table 2) were developed through close collaborations between researchers and practitioners to ensure theoretical grounding in research and practical relevance in industry, thus enhancing the content validity of the instrument (Dillman et al., 2008; Srinivasan and Swink, 2018). All the items pertaining to BDAC, data-driven culture and SCF Integration were operationalized on seven-point scales, namely from 1 "strongly disagree" to 7 "strongly agree". Since no measurement instrument for SCF Integration exists, a number of new items were developed using case studies of three manufacturing firms in China. Empirical insights were drawn from in-depth semi-structured interviews with senior executives and our observations during site visits. In addition, knowledgeable academic experts were employed to develop the SCF Integration scales (e.g., Ling-yee and Ogunmokun, 2001; Randall and Farris II, 2009; Zhang, 2015). Furthermore, a series of analyses were also conducted to evaluate the reliability and validity of the newly developed SCF Integration scales.

This study conceptualises SCF Integration as a multidimensional construct: internal SCF Integration, SCF Integration with customers, and SCF Integration with suppliers. A total of 12 items were used to measure SCF Integration. The measures for *internal SCF Integration* included developing open-and-honest information sharing environment to optimise financial structure, having working capital needed to finance supply chain operations, financial accounting information exchange between cross-functional teams, and obtaining funds from a variety of formal sources to finance supply chain operations. The scales for *SCF Integration with customers* included working together with customers to compare financial strengths to identify/gain synergistic opportunities, focusing on inventory shift from key customers, offering discount terms as a means of encouraging customers to pay earlier, and offering competitive credit terms to customers. The measures for *SCF Integration with suppliers* included working closely with suppliers in improving cooperative cash flow management, lowering inventory levels without additional demand for terms from vendors, extending accounts payable by taking longer to pay suppliers, and meeting competitive prices from suppliers. Section 4.4 and Table 2 confirm the reliability and validity of the SCF Integration scale.

The measures for *BDAC* were adapted from Srinivasan and Swink (2018), which focused on integrating information from various data sources for decision making, using data visualization techniques (e.g., dashboards) to assist decision-maker in understanding complex information, decomposing information and help root cause analysis and continuous improvement, and deploying dashboard applications/information to managers' communication devices (e.g., smart phones, computers). The measures for *data-driven culture* were adapted from Gupta and George (2016), which included data being considered a tangible asset, decisions made based on data rather than instinct, overriding intuition when data contradict viewpoints, business rules in response to insights are extracted from data, and employees are trained to make decisions based on data.

------------------------------ Insert Table 2 -------------------------------

To assess the content validity of the measurement scales (especially the newly developed SCF Integration scales), four academic experts in the fields of supply chain and operations management were invited to review and provide feedback on the survey items. Pilot tests of the survey were performed with executives who helped review the survey for item content, understandability, and reasonableness regarding expectations for respondent knowledge. Following feedback from both the executives and academics, redundant and ambiguous measurement items in the survey instrument were eliminated or modified (Yu et al., 2019a, b; Zhao et al., 2006).

### 4.3. Non-response bias and common method bias

Researchers suggest several approaches to evaluating non-response bias, for example, testing if there are significant differences between respondents and non-respondents (Hair et al., 2010). However, demographic characteristics of the non-respondents are not available in this study. Thus, the potential non-response bias was assessed by comparing annual sales and firm age of early and late responding firms (Hair et al., 2010; Lessler and Kalsbeek, 1992). The results indicate that all t-statistics are non-significant at the 0.05 level, which suggests absence of non-response bias.

There is potential for common method bias (CMB) when collecting self-reported data from a single source at one point in time. In this study, we used the ex-ante and ex-post approaches to dampen the potential for CMB. When designing the questionnaire, the adjacent variables in the theoretical framework (i.e., BDAC, data-driven culture and three SCF Integration dimensions) were put in distinct sections (Zhao et al., 2011). When sending the questionnaires to the randomly chosen firms, in the cover letter we assured the respondents that all information they provided would remain completely anonymous and confidential, and that any data analysis would be conducted on an aggregate level for research purposes solely. The respondents were advised that different sections of the questionnaire should be consulted or completed by the relevant senior functional managers across the firm, for example, chief technology officers who are responsible for overseeing technical aspects and technological resources of the firm were recommended to complete the BDAC and data-driven culture sections. Previous empirical research has suggested that this approach helps to obtain an overall perspective from the top executives and an expert perspective from the relevant functional departments of the firm (Li et al., 2008; Yu et al., 2019a). Furthermore, selecting right and knowledgeable key informants is also critical in minimising the potential CMB (Miller and Roth, 1994). As noted above, the respondents in this study were directly involved in managing day-to-day supply chain operations and thus had explicit knowledge of information, material and financial flows within the supply chain.

After the data collection (ex-post), we tested for CMB in multiple ways. A confirmatory factor analysis (CFA)-based Harman's single-factor test was conducted as Harman's single-factor test alone does not eliminate the possibility of CMB (Podsakoff et al., 2012). Indicators including the chi-square divided by the degrees of freedom ($\chi^2$/df < 5), comparative fit index (CFI > 0.90), incremental fit index (IFI > 0.90), standardized root mean square residual (SRMR < 0.10), and the root-mean-square error of approximation (RMSEA < 0.10) were used to assess the fit of the model (Hair et al., 2010; Hu and Bentler, 1999). The results indicate that the model fit indices ($\chi^2$/df = 8.480, CFI = 0.643, IFI = 0.645, RMSEA = 0.156 and SRMR = 0.109) were unacceptable and significantly worse than that of the measurement model, suggesting that a single factor model is not acceptable. To further evaluate CMB, two latent variable models (one included only the traits and the other included both the traits and a method factor) were tested and compared (Podsakoff et al., 2012). The results suggest that the method factor only marginally improved the model fit indices (both CFI and IFI by 0.016), and the item loadings were still significant. In summary, considering the findings of the tests conducted and the other procedural remedies aforementioned, we conclude that CMB is unlikely to confound the interpretation of the research results.

## 4.4. Measurement validation

As noted above, since we developed the new scales for SCF Integration based on the existing literature and empirical insights, we conducted an EFA for internal, supplier and customer SCF Integration. The EFA result shows three factor model with 66.357% variance explained. We then used the same scales to establish a CFA model that includes SCF Integration, BDAC and data-driven culture. The CFA results presented in Table 2 indicate that the measurement model has good fit across most model fit indices ($\chi^2$/df = 3.009, CFI = 0.909, IFI = 0.910, RMSEA = 0.081 and SRMR = 0.051), suggesting all the constructs (i.e., BDAC, data-driven culture and SCF Integration) are unidimensional (Hair et al., 2010; Hu and Bentler, 1999).

The values of Cronbach's alpha and composite reliability (CR) were calculated to examine construct validity. As shown in Table 2, the Cronbach alpha (ranging from 0.787 to 0.910) and CR (ranging from 0.793 to 0.912) values of all constructs were higher than the generally recommended threshold of 0.70 (Hair et al., 2010). In addition, a corrected item-total correlation (CITC) score for each measurement item was also computed to evaluate item reliability (Kerlinger, 1986). Table 2 shows that all CITC values are larger than the minimum acceptable value of 0.30. Therefore, these results suggest sufficient reliability of the measurement scales.

The results of CFA (see Table 2) also reveal that all factor loadings for each theoretical construct were statistically significant ($p < 0.001$) and higher than 0.50, indicating convergent validity of the constructs (Hair et al., 2010; O'Leary-Kelly and Vokurka, 1998). In addition, the average variance extracted (AVE) values exceeded the recommended threshold value of 0.50 (Fornell and Larcker, 1981), except that SCF Integration with suppliers (AVE = 0.492) had AVE scores marginally below 0.50. Based on these results, we concluded that our theoretical constructs and scales had convergent validity.

In this study discriminant validity was evaluated by comparing the correlation between theoretical construct and square root of AVE (Fornell and Larcker, 1981). As indicated in Table

3, the square root of AVE of all the constructs was larger than the correlation between any pair of them, which provides evidence for discriminant validity (Fornell and Larcker, 1981).

------------------------------ Insert Table 3 ------------------------------

## 5. Hypothesis testing and results

### 5.1. Main effect analysis and results

Structural equation modelling (SEM) with AMOS 25 was used to test the hypotheses proposed in the theoretical framework (see Figure 1). Table 4 reports the outcomes of the hypothesis testing, and indicates that the structural model was found to be statistically adequate with good fits ($\chi^2$/df = 2.505, CFI = 0.905, IFI = 0.907, RMSEA = 0.070, and SRMR = 0.052) (Hair et al., 2010; Hu and Bentler, 1999). Although four control variables were included in the research model, no statistically significant positive effect of firm size and industry type on SCF Integration with customers and suppliers was found, and firm age and Region3 (Central China) have a significant negative effect on SCF Integration with customers. Including control variables in the model lends credibility to the findings given that, after controlling for firm size, firm age, industry type and geographical region, the significant positive relationships between the theoretical constructs were still observed (Hair et al., 2010).

------------------------------ Insert Table 4 ------------------------------

Table 4 indicates that BDAC had a significant positive effect on internal SCF Integration ($\beta$ = 0.452, $p$ < 0.001), but no statistically significant effect on either SCF Integration with customer ($\beta$ = 0.093, *n.s.*) or SCF Integration with suppliers ($\beta$ = -0.028, *n.s.*). Hence, H1a is supported, while H1b and H1c are rejected. The structural model also reveals that internal SCF Integration is significantly and positively associated with SCF Integration with customers ($\beta$ = 0.868, $p$ < 0.001) and suppliers ($\beta$ = 0.892, $p$ < 0.001), which provide strong support for H2a and H2b.

### 5.2. Mediation analysis and results

A bias-corrected bootstrapping approach (with n = 10,000 bootstrap resamples) was used to test for the mediating effect of internal SCF Integration on the relationships between BDAC and SCF Integration with customers and SCF Integration with suppliers (Zhao et al., 2010). The bootstrapping analysis results are reported in Table 5, which reveals that the direct effect of

BDAC on SCF Integration with customers was not significant ($\beta$ = 0.107, *n.s.*), and the indirect effect of BDA on SCF Integration with customers via internal SCF Integration was positive and significant ($\beta$ = 0.448, $p$ < 0.001 and 95% CI = 0.303–0.802). The results indicate that internal SCF Integration fully mediates the effect of BDAC on SCF Integration with customers. In addition, the Sobel test was also performed, and the results further indicate that internal SCF Integration (z = 6.196, $p$ < 0.001) acts as a full mediator on the relationship between BDAC and SCF Integration with customers. Hence, both the bootstrapping analysis and Sobel test offer strong support for H3a. Similarly, the same holds for the BDAC → internal SCF Integration → SCF Integration with suppliers paths; the results of bootstrapping analysis and Sobel test reveal that BDAC indirectly affects SCF Integration with suppliers through the implementation of internal SCF Integration. Thus, H3b is supported.

------------------------------ Insert Table 5 -------------------------------

### 5.3. Moderation effect analysis and results

To test for the moderating effect of data-driven culture, the moderated regression method was used (Hair et al., 2010). The moderating role of data-driven culture in the relationship between BDAC and internal SCF Integration was assessed using a three-stage regression (Hair et al., 2010), namely (1) control variables (firm size, age, industry type and geographical region), (2) main effect variable (BDAC), and (3) moderating variable (data-driven culture). As shown in Table 6, variance inflation factors (VIF) values were less than 3 in all three models indicating that multicollinearity is not a concern in this study (Mason and Perreault, 1991). The interaction term between BDAC and data-driven culture had a significant positive effect on internal SCF Integration ($\beta$ = 0.102, $p$ < 0.05), which suggests that data-driven culture moderates the relationship between BDAC and internal SCF Integration. Thus, H4 is supported. We follow the standard procedures suggested by Aiken and West (1991) to calculate regression slopes and plots. Figure 2 indicates that the positive relationship between BDAC and internal SCF Integration is strengthened when data-driven culture is high.

------------------------------- Insert Table 6 -------------------------------

------------------------------ Insert Figure 2 -------------------------------

## 6. Discussion and implications

This study is an early attempt to develop an understanding of SCF Integration and how big data and a data-driven culture facilitate SCF Integration. The theoretical lens of OIPT, recently applied in the supply chain management literature (Srinivasan and Swink, 2018; Swink and Schoenherr, 2015; Yu et al., 2019b, 2021), has been used to establish an integrated SCF model. From an information technology mechanism perspective, this study explains how big data analytics increases the information processing capacity required to achieve SCF Integration and the importance of data-driven culture in enhancing such effects.

### 6.1. Implications for researchers

This study makes an important contribution to the SCF literature by not only extending the integrated SCF framework of Jia et al. (2020) in terms of information technology mechanisms, consisting of three key dimensions from the upstream, internal, and downstream perspectives of the supply chain, but also integrating big data research with the SCF literature. An important contribution of this study is that it establishes the theoretical construct of SCF Integration and empirically verifies the measurements of the three dimensions of SCF Integration through a psychometrically sound survey instrument. The SCF Integration construct and its measures enable researchers to further extend the framework of SCF developed by Jia et al. (2020). While this paper deepens the understanding of information technology mechanisms (big data analytics), future studies can use our SCF Integration construct to empirically explore other mechanisms that address organizational structure design, coordination and control, and the needs to match information processing needs with information processing capacity (Daft and Lengel, 1986).

This study reveals an association between internal and external SCF Integration. Consistent with OIPT, this study shows the importance of establishing internal SCF Integration before implementing SCF Integration with customers and suppliers. According to OIPT, sharing of financial data and collaboration across different functional areas to address financial issues within the firm facilitates effective information sharing among supply chain partners (Yu et al., 2013; Zhao et al., 2011). External SCF Integration facilitated by insights from both internal and external financial flows helps manage and optimize financial liquidity and working capital in a supply chain (Silvestro and Lustrato, 2014). Thus, internal SCF Integration is a construct that reflects cross-functional coordination that facilitates internal information and financial flows to customers and suppliers for optimising working capital throughout the entire supply chain

(Silvestro and Lustrato, 2014). These arguments corroborate our interviews with senior executives who highlighted that inter-organisational collaboration with customers and suppliers can help optimise financial flows along the supply chain, but first firms must fully understand and manage their internal financial flows. While SCF reflects financial instruments used to address SC financial problems, the conceptualization of SCF Integration from an integration perspective reflects a theoretical construct that emphasizes collaboration and information sharing across functions and suppliers/customers to advance the SCF field (Jia et al., 2020).

Another important contribution to the SCF literature and the broader literature on big data is that our study empirically validates the use and effect of BDAC on the implementation of SCF practices. The results suggest SCF is not just a solution for the accounting functions to address cash flows problems independently. Treating SCF from a supply chain integration perspective can have profound implications for understanding how financial flows and other operational and strategic information flows are integrated. SCF involves the use of electronic data and platforms, giving rise to the opportunity to use big data analytics (BDAC) to facilitate SCF Integration in a smarter manner. Even though big data analytics are shown anecdotally to be useful for SCF in both the big data and SCF literature (e.g., Dubey et al., 2019; Hofmann and Johnson, 2016; Zhao et al., 2015), this study provides important initial evidence which demonstrates big data analytics are crucial for internal SCF Integration. Extending the information technology mechanisms of OIPT (Jia et al., 2020), our results indicate that BDAC increases information processing capacity to inform internal SCF Integration; and, more importantly, it serves a crucial information gathering and coordination "bridge" that integrates insights generated by BDAC with customers and suppliers to implement SCF instruments.

This study provides new evidence to illustrate how emerging technologies may shape the management of SCF. Although the existing literature on SCF argues for the important role of big data technologies (such as blockchain and smart contract) and big data facilitating the implementation of SCF initiatives (Hofmann and Johnson, 2016; Zhao et al., 2015), empirical evidence of such links are still scarce (Jia et al., 2020). The interviews with senior executives in China also reveal the use of big data technologies and analytics is becoming increasingly important for manufactures to collaborate with customers and suppliers to manage and optimise liquidity and working capital of all the supply chain participants. In addition, this finding also makes an important contribution to the big data literature by revealing the applications of big data analytics are not limited to forecast market demand and improve operational processes (Dubey et al., 2019; Mikalef et al., 2019; Srinivasan and Swink, 2018), but also to optimize financial flows through integrating SCF.

Finally, this study deepens the application of OIPT to the SCF literature, from the information technology mechanism and organizational culture perspectives. While OIPT has been used to explain information processing capacity increases by using electronic data (Jia et al. 2020) to reduce uncertainty, this study contributes by delineating the role of a data-driven culture in enhancing the benefits of big data analytics. Our results reveal that a data-driven culture enhances the ability of BDAC to facilitate internal SCF Integration. This is an important finding as it provides an initial step for researchers to investigate how organizational culture can help to seize the full value of big data, especially in the SCF context. Our interviews with senior executives also suggest that a data-driven culture and BDAC supplement and reinforce each other to enable firms to optimise working capital along the supply chain. Previous research has demonstrated the importance of organizational culture in the adoption of innovative information systems (Liu et al., 2010) and positioned a culture of evidence-based decision making as one of the critical resources enabling firms to extract value from big data (McAfee and Brynjolfsson, 2012; Ross et al., 2013). However, it is not clear how a data-driven culture could play such a role. Our finding extends Dubey et al.'s (2019) work that suggests a big data culture can enhance the relationships between tangible resources and human skills and big data predictive analytics, in that a data-driven culture is also important for firms that invest in big data analytics to support SCF.

### 6.2. Implications for managers

Our research findings yield several valuable insights and timely guidance for practitioners, particularly regarding the threat of financial crisis caused by the current volatile environment (from the ongoing US-China trade war to the current COVID-19 outbreak). The trade war has made financing increasingly difficulty for many firms to obtain. This is being exacerbated by the COVID-19 outbreak. Financing now presents a significant challenge ahead for global supply chains. The magnitude of the challenge is exemplified by a potential doubling of loans at risk for Chinese banks. As such, many firms, especially small and medium sized enterprises, might face greater pressure in capital adequacy (Asian Banking & Finance, 2020).

The first insight our study offers is timely and important for managers facing such uncertain financial situations.  The optimisation of the financial flows along the supply chain in an uncertain environment requires big data analytics, data-driven culture, and integration of internal and external financial flows and processes. Our interviews with senior executives in automotive, motorcycle, and auto parts manufacturing firms indicate liquidity pressure was addressed by building up SCF Integration capabilities.

Second, while supply chain managers focus on managing flows of material and information within the supply chain, they often put less attention on the management of financial flows. In the current uncertain environment, this is not sustainable. The integrated SCF framework developed in this study suggests that mangers should implement integrated SCF practices, including internal SCF Integration through intra-organisational coordination of financial flows and external SCF Integration through inter-organisational collaboration with upstream suppliers and downstream customers, to manage and optimise liquidity and working capital for all supply chain partners. We suggest managers should first gather, coordinate, analyse, and understand information about financial and cash flows across key functions before integrating such flows with external supply chain partners. The time might be right for supply chain managers to integrating SCF into operational decisions. They should do so by first reaching out to accounting, marketing, and other functions to develop integrated SCF solutions, and to remember it is big data analytics that creates new insights for optimizing financial flows and that it is SCF Integration with customers and suppliers that reduces unnecessary financial burdens in a supply chain. We believe that our findings and integrated framework offer managers a new perspective to bring together data analytics, supply chain, and finance functions for developing integrated financial supply chains.

Third, our empirical findings suggest the application of big data analytics is not only for predicting demand or improving operational efficiency, but also improving financial flows. Many firms lack the data analytics that can help predict future financial flows, let alone implementing SCF instruments to proactively optimize cash flows. To cope with the current environmental uncertainties that threaten financial stability of the supply chains, managers should improve information processing (building data analytics capability) by leveraging electronic finance data rather than rely upon financial service providers to offer factoring solutions. Managers need to adopt analytical tools, dashboards, and related decision support systems to analyse and integrate demand, sales, financial accounting, and operations planning data to create financial-flow predictions that can be regularly exchanged between cross-functional teams for the optimisation of working capital throughout the entire supply chain. However, supply chain managers should not simply purchase big data analytics software or hire data scientists and expect them to create insights for addressing financial problems. They should build a big data analytics team within the supply chain functions and integrate the team with other functions and prioritize the allocation of resources to the development of BDAC because BDAC is a “bridge” that ties insights from big data analytics to strategic actions for enabling financial integration with customer and suppliers.

Finally, many firms are unsure of the importance of a data-driven culture. We show that a data-driven culture can contribute to the optimisation of financial flows by changing how executives make decisions, from intuition to a reliance on data. Our findings suggest that hiring data scientists to perform analytics alone is not sufficient for optimising internal financial integration. A data-driven culture means all functions and levels of management must learn to use data and understand how to use analytics to efficiently optimise financial supply chains process. Managers should note that building data analytics capability can help to optimise internal financial integration, but the firm must adopt a culture of evidence-based decision making e.g., through empowering and coaching all employees at all levels to make data-driven decisions.

## 7. Conclusions and directions for future research

Although the role of big data in implementing SCF initiatives has been mentioned, empirical studies in the SCF context are still scarce. Also, little guidance is offered to managers for developing integrated financial supply chain processes in the big data era. This study suggests that SCF Integration can be implemented effectively when information processing capacity is increased though collaboration and data analytics. This study develops an integrated SCF framework that shows internal SCF Integration and external SCF Integration can be enhanced by developing big data analytics capabilities and such benefits rely heavily on a data-driven culture. Our hypotheses are supported by case studies and survey data from China. The findings provide useful guidance to mangers for developing integrated SCF through a data analytics capability in the current uncertain and data-rich environment.

We recognise the following limitations of our study. First, researchers suggest various firm resources and assets that are not examined in the present study but equally important to reap the benefits of big data, for example physical resources, employees' knowledge and skills, and organizational learning (Gupta and George, 2016). Future researchers might investigate how these assets and organizational capabilities affect the implementation of SCF practices. One particular aspect might be to study whether there is a difference between focal and non-focal firms as broached by Chen et al. (2021). Second, previous research has suggested some factors that may influence SCF Integration practices, such as a competitive and uncertain environment, relationship commitment, and trust (Jia et al., 2020). Future researchers might investigate the role of environmental factors in different SCF practices. Third, there is always a risk that the findings are an artifact of the sample. However, given the breadth of responses we believe this concern to be minimal, but highlight it as an opportunity for future study. Specifically, replication with a different set of industries. Finally, the performance consequences of the implementation of SCF Integration are not examined in this study, future researchers are encouraged to examine the effect of SCF Integration on firm (such as finance and market) and operational performance (such as flexibility, delivery, quality and cost).

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**Table 1: Profile of respondents and responding firms (n=307)**

| | Percent (%) | | Percent (%) |
|---|---|---|---|
| **Industries** | | **Respondent location (geographical regions)** | |
| Automobile | 35.8 | Pearl River Delta | 4.6 |
| Chemicals and petrochemicals | 5.9 | Yangtze River Delta | 11.7 |
| Electronics and electrical | 10.4 | Bohai Sea Economic Area | 3.6 |
| Fabricated metal product | 17.3 | Northeast China | 3.3 |
| Food, beverage and alcohol | 3.3 | Central China | 9.4 |
| Rubber and plastics | 2.6 | Southwest China | 65.5 |
| Textiles and apparel | 2.0 | Northwest China | 2.0 |
| Others | 22.8 | **Job titles** | |
| **Number of employees** | | President / Chief executive officer (CEO) | 5.9 |
| 1 – 100 | 6.2 | Vice President | 7.5 |
| 101 – 200 | 11.1 | Director | 15.0 |
| 201 – 500 | 17.6 | Manager | 45.3 |
| 501 – 1000 | 10.4 | Other senior executive | 26.4 |
| 1001 – 3000 | 28.7 | **Years in current position** | |
| > 3000 | 26.1 | ≤ 5 | 30.9 |
| **Annual sales (in million Yuan)** | | 6 – 10 | 29.0 |
| Below 10 | 2.0 | > 10 | 40.1 |
| 10 – 50 | 7.5 | **Firm age** | |
| 50 – 100 | 11.4 | ≤ 10 | 16.6 |
| 100 – 500 | 18.9 | 11 – 20 | 30.6 |
| 500 – 1000 | 14.7 | 21 – 30 | 22.5 |
| Above 1000 | 45.6 | > 30 | 30.3 |

Table 2: Reliability and validity of measurement model

| Measurement Items | Factor loadings | Cronbach's alpha | Composite reliability | AVE | CITC range |
|---|---|---|---|---|---|
| **1. Big data analytics capability** | | 0.910 | 0.912 | 0.723 | 0.767–0.847 |
| We easily combine and integrate information from many data sources for use in our decision making | 0.832 | | | | |
| We routinely use data visualization techniques (e.g., dashboards) to assist users or decision-maker in understanding complex information | 0.910 | | | | |
| Our dashboards give us the ability to decompose information to help root cause analysis and continuous improvement | 0.853 | | | | |
| We deploy dashboard applications/information to our managers' communication devices (e.g., smart phones, computers) | 0.803 | | | | |
| **2. Internal SCF Integration** | | 0.798 | 0.816 | 0.529 | 0.475–0.702 |
| We develop open-and-honest information sharing environment to optimise the financial structure | 0.739 | | | | |
| We have working capital needed to finance supply chain operations | 0.812 | | | | |
| Financial accounting information is regularly exchanged between cross-functional teams (e.g., finance, operations, purchasing, logistics, information technology) | 0.768 | | | | |
| We draw funds from a variety of formal sources (such as banks, finance companies, or credit unions) to finance supply chain operations | 0.568 | | | | |
| **3. SCF Integration with customers** | | 0.833 | 0.834 | 0.557 | 0.644–0.676 |
| Customers and us compare financial strengths to identify/gain synergistic opportunities | 0.757 | | | | |
| We focus on inventory shift from key customers | 0.787 | | | | |
| We give discount terms as a means of encouraging customers to pay earlier | 0.721 | | | | |
| We offer competitive credit terms to customers | 0.719 | | | | |
| **4. SCF Integration with suppliers** | | 0.787 | 0.793 | 0.492 | 0.545–0.670 |
| We work closely with suppliers in improving cooperative cash flow management | 0.708 | | | | |
| We focus on lowering inventory levels without additional demand for terms from vendors | 0.693 | | | | |
| We focus on extending accounts payable by taking longer to pay suppliers | 0.597 | | | | |
| We meet competitive prices from suppliers | 0.794 | | | | |
| **5. Big data-driven culture** | | 0.894 | 0.898 | 0.639 | 0.649–0.795 |
| We consider data a tangible asset | 0.694 | | | | |
| We base our decisions on data rather than on instinct | 0.819 | | | | |
| We are willing to override our own intuition when data contradict our viewpoints | 0.793 | | | | |
| We continuously assess and improve the business rules in response to insights extracted from data | 0.865 | | | | |
| We continuously coach our employees to make decisions based on data | 0.817 | | | | |
| Goodness-of-fit indices: $\chi^2$ = 538.595; df = 179; $\chi^2$ / df = 3.009; CFI = 0.909; IFI = 0.910; RMSEA = 0.081; SRMR = 0.051 | | | | | |

Table 3: Mean, standard deviation (SD) and correlations of constructs

| | Mean | SD | BDAC | ISCFI | SCFIC | SCFIS | DDC |
|---|---|---|---|---|---|---|---|
| **Big data analytics capability (BDAC)** | 4.456 | 1.271 | 0.850[a] | | | | |
| **Internal SCF Integration (ISCFI)** | 5.213 | 0.977 | 0.519** | 0.728 | | | |
| **SCF Integration with customers (SCFIC)** | 4.675 | 1.143 | 0.481** | 0.559** | 0.747 | | |
| **SCF Integration with suppliers (SCFIS)** | 4.950 | 1.033 | 0.400** | 0.617** | 0.686** | 0.701 | |
| **Data-driven culture (DDC)** | 5.188 | 1.099 | 0.651** | 0.590** | 0.398** | 0.444** | 0.800 |

Note: [a] **Square root of AVE is on the diagonal.**

** **Correlation is significant at the 0.01 level (2-tailed).**

Table 4: Results of hypothesis test

| Linkages in the model | Unstandardized coefficient | Standardised coefficient | t-value | Hypothesis testing outcome |
|---|---|---|---|---|
| BDAC → Internal SCF Integration | 0.452*** | 0.617*** | 8.992 | H1a: Supported |
| BDAC → SCF Integration with customers | 0.093 | 0.107 | 1.551 | H1b: Not supported |
| BDAC → SCF Integration with suppliers | -0.028 | -0.037 | -0.520 | H1c: Not supported |
| Internal SCF Integration → SCF Integration with customers | 0.868*** | 0.726*** | 8.484 | H2a: Supported |
| Internal SCF Integration → SCF Integration with suppliers | 0.892*** | 0.858*** | 8.730 | H2b: Supported |
| **Control variables** | | | | |
| Firm size → SCF Integration with customers | 0.007 | 0.011 | 0.207 | |
| Firm age → SCF Integration with customers | -0.154** | -0.160** | -2.887 | |
| Industry1 → SCF Integration with customers | -0.040 | -0.018 | -0.354 | |
| Industry2 → SCF Integration with customers | -0.116 | -0.042 | -0.830 | |
| Industry3 → SCF Integration with customers | -0.017 | -0.005 | -0.099 | |
| Region1 → SCF Integration with customers | -0.112 | -0.051 | -0.791 | |
| Region2 → SCF Integration with customers | -0.291 | -0.091 | -1.516 | |
| Region3 → SCF Integration with customers | -0.519* | -0.147* | -2.522 | |
| Firm size → SCF Integration with suppliers | -0.003 | -0.005 | -0.098 | |
| Firm age → SCF Integration with suppliers | -0.054 | -0.064 | -1.137 | |
| Industry1 → SCF Integration with suppliers | -0.023 | -0.012 | -0.234 | |
| Industry2 → SCF Integration with suppliers | -0.046 | -0.019 | -0.370 | |
| Industry3 → SCF Integration with suppliers | 0.105 | 0.035 | 0.700 | |
| Region1 → SCF Integration with suppliers | 0.132 | 0.070 | 1.048 | |
| Region2 → SCF Integration with suppliers | -0.099 | -0.035 | -0.580 | |
| Region3 → SCF Integration with suppliers | 0.007 | 0.002 | 0.038 | |
| **Variance explained** | $R^2$ | | | |
| Internal SCF Integration | 0.381 | | | |

| | |
|---|---|
| SCF Integration with customers | 0.663 |
| SCF Integration with suppliers | 0.707 |
| Goodness-of-fit indices: $\chi^2$ = 508.573; df = 203; $\chi^2$ / df = 2.505; CFI = 0.905; IFI = 0.907; RMSEA = 0.070; SRMR = 0.052 | |

**$^{***}$ $p < 0.001$; $^{**}$ $p < 0.01$; $^{*}$ $p < 0.05$.**

**Table 5: Results of mediation test**

| Structural paths | Direct effect | Indirect effect | SE of indirect effect | 95% CI for indirect effect | Sobel test | Hypothesis testing outcome |
|---|---|---|---|---|---|---|
| BDAC→ISCFI→SCFIC | 0.107 | 0.448*** | 0.119 | 0.303–0.802 | z = 6.196*** | H3a: Full mediation |
| BDAC→ISCFI→SCFIS | -0.037 | 0.530*** | 0.125 | 0.375–0.892 | z = 6.285*** | H3b: Full mediation |

Note: BDAC = Big data analytics capability; ISCFI = internal SCF Integration; SCFIC = SCF Integration with customers; SCFIS = SCF Integration with suppliers; SE = bootstrap standard error; CI = bootstrap confidence interval; Standardized effects; 10,000 bootstrap samples.

**$^{***}$ $p < 0.001$.**

**Table 6: Results of moderation test**

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| **Control variables** | | | |
| Firm size | 0.070 (1.062[a], 1.350[b]) | -0.087 (-1.607, 1.426) | -0.105 (-1.935, 1.459)† |
| Firm age | 0.056 (0.812, 1.483) | 0.125 (2.264, 1.501)* | 0.135 (2.458, 1.511)* |
| Industry1 | -0.010 (-.155, 1.334) | -0.002 (-0.044, 1.344) | 0.004 (0.070, 1.347) |
| Industry2 | -0.132 (-2.062, 1.265)* | -0.015 (-0.292, 1.303) | -0.014 (-0.278, 1.303) |
| Industry3 | 0.012 (0.192, 1.206) | -0.024 (-0.494, 1.209) | -0.016 (-0.334, 1.216) |
| Region1 | 0.096 (1.172, 2.076) | 0.045 (0.692, 2.092) | 0.044 (0.674, 2.092) |
| Region2 | 0.164 (2.189, 1.738)* | 0.110 (1.841, 1.753)† | 0.113 (1.913, 1.754)† |
| Region3 | 0.086 (1.204, 1.600) | 0.007 (0.114, 1.647) | 0.001 (0.025, 1.649) |
| **Independent variables** | | | |
| Big data analytics capability (BDAC) | | 0.249 (3.990, 1.918)*** | 0.252 (4.061, 1.919)*** |
| Data-driven culture (DDC) | | 0.439 (7.203, 1.829)*** | 0.439 (7.260, 1.829)*** |
| **Interaction effect** | | | |
| BDAC × DDC | | | 0.102 (2.241, 1.033)* |
| $R^2$ | 0.039 | 0.399 | 0.409 |
| *Adjust* $R^2$ | 0.013 | 0.379 | 0.387 |
| *F-value* | 1.503 | 19.655*** | 18.567*** |

**$^{***}$ $p < 0.001$; $^{*}$ $p < 0.05$; † $p < 0.10$.**

**Note: The numbers in parentheses are: [a] t values and [b] variance inflation factor (VIF); Dependent variable is internal SCF Integration.**

**Figure 1: Proposed research model**

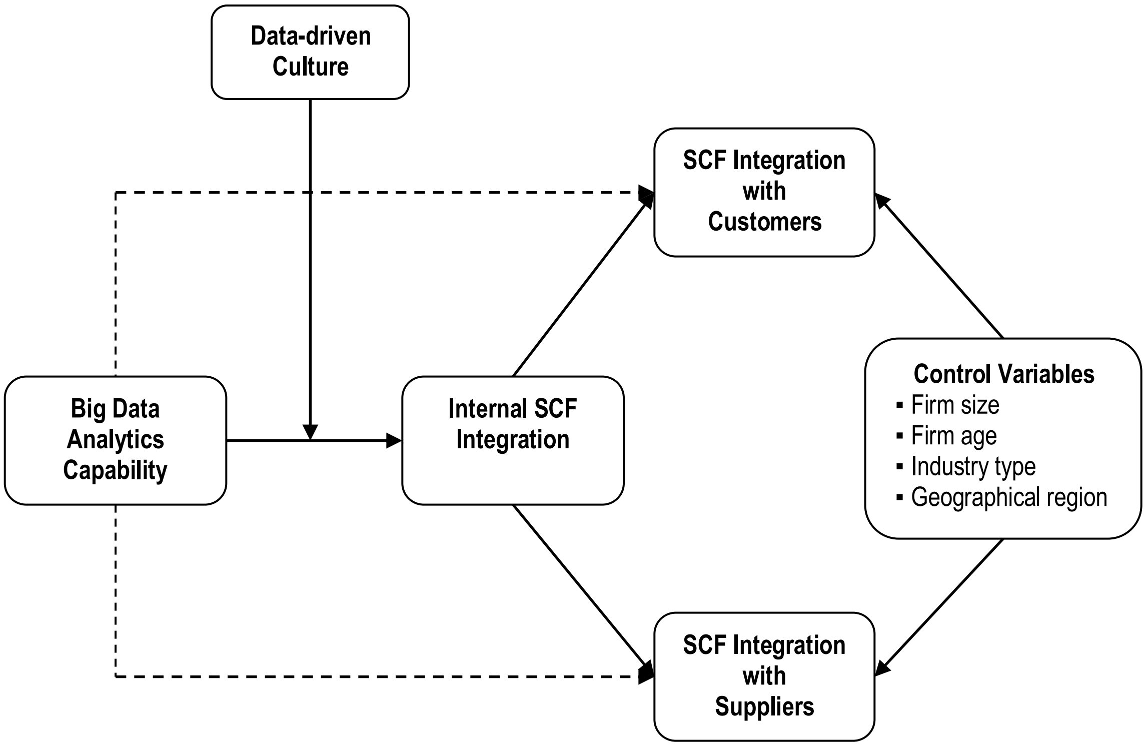


**Figure 2: Moderating effect of data-driven culture on the BDAC–internal SCF Integration relationship**