Fintech innovation in Supply Chain Finance

Keywords: Supply Chain Finance; Fintech; Information technology; Blockchain; Internet of things; Artificial intelligence; Application programming interface.

Topic(s): Supply Chain Management

Abstract

Fintech (financial technology) adoption is on the rise. Technological innovation such as blockchain or internet of things are seen as the 'next big thing' in integrating physical and financial flows within supply chains, as well as for adopting supply chain finance (SCF) schemes. However, it remains unclear how such technologies can meet the requirements for SCF development, as well as how they impact SCF-related risks. We investigate these aspects through a case study involving 9 organisations (large buyers, technological and information providers) which shows how – although diverse in nature and impacts – all of the identified technologies have the potential to thrust SCF evolution.

Introduction and literature review

Supply Chain Finance (SCF) is a set of schemes for the optimisation of financial flows between primary supply chain members (de Boer et al., 2015; Hofmann, 2005; Pfohl and Gomm, 2009). Besides the most common schemes focused on optimising accounts payable and receivable (e.g. Reverse Factoring, as in Wuttke et al., 2013), authors often identified additional SCF includes. More specifically, this contribution focuses also on financing of inventories (Chen and Cai, 2011; Hofmann, 2009) and financing of fixed asset (Hofmann, 2005; Pfohl and Gomm, 2009). Across the different schemes, authors agree that SCF, especially in its most innovative applications, requires a significant level of technological innovation (Caniato et al., 2016). Therefore this research is positioned at the interface of innovative technologies for the financial industry, technological requirements for the evolution of SCF and SCF-related risks and mitigation procedures. The following paragraphs summarise literature for these core concepts.

Supply chain finance risks and risk mitigation procedures

SCF schemes are often financial transactions (e.g. reverse factoring, inventory financing, …) and, as such, they are characterised by a series of risks that are typical of financing operations. Clearly, not all SCF scheme is affected by the same risk. As SCF schemes are numerous (Gelsomino et al., 2016), in seek of simplicity we divided them into three categories: invoice-based financing (e.g. factoring, reverse factoring, invoice auctions), inventory financing and fixed-asset financing. The most relevant sources of risk, as emerging from the literature, are the following:

- credit risk, the risk that a borrower will default on a debt by failing to make the required payments. (Bakker et al., 2004; Berlin, 2003; Lekkakos and Serrano, 2016);
- operational risk, defined as losses resulting from inadequate or failed internal processes, people and systems or from external events. The sources of this risk considered are related to fraud, human error and system failure (Basel Committee on Banking Supervision, 2011);
- double financing risk, fraudulent practice that concerns raising funds more than once against the same asset. It is common in invoice related financing but it can be present also

in inventory financing, as well as fixed asset financing (Lycklama à Nijeholt et al., 2017);

- performance risk, which includes the risk of the supplier not fulfilling the purchase order or the buyer not paying the invoice, due to disputes caused by unmatched documents or other issues of misalignment between the goods and information flows. As such, it affects invoice financing SCF schemes (Hofmann et al., 2017);
- value and saleability inventory risk, which is typical of inventory financing, a scheme in which the financed asset is subject to market condition, logistics operations and other external effects. Moreover, in case of default the financing company typically re-enters in possession of the financed inventory, which implies that they are subject to the risk of being unable to resell it at the appropriate value (Chen and Cai, 2011; Hofmann, 2009);
- maintenance misuse and asset deterioration risk, which affect mostly fixed asset financing SCF schemes, as wear, tear, natural deterioration, asset misuse and lack of proper maintenance might deteriorate the value of an asset object of a financing scheme.

SCF risk mitigation procedures can be summarised in two categories: Know Your Customers (KYC) and Anti Money Laundering (AML) procedures and audit procedures. KYC involves the procedures of customer due diligence that financial institutions and other regulated companies have to carry out in order to verify the identity and standing of their clients and avoid doing business with customers that result to have been linked to negative practices. KYC is also used to refer to the legal regulation that steer these procedures. KYC is one of the procedure within AML, a broader set of risk mitigation procedures governed by legal regulation, designed to stop the practice of generating income through illegal actions. Audit procedures refers to the processes by which financial records, business operations, and information systems are independently verified by an internal or external auditors (BAFT et al., 2016).

Supply chain finance requirements

Literature on SCF has often focused on limitations that impede its evolution (de Boer et al., 2015; Lamoureux and Evans, 2011). Most of these limitation are technological in nature, to the point that it is possible to draw a list of requirements illustrating the most relevant features that needs to be addressed for the evolution of the SCF model (Fellenz and Augustenborg, 2009). The following paragraph provides a concise – yet exhausting – list of requirements:

- Creation of global, common or interoperable standards which recognises diversity (Fellenz and Augustenborg, 2009; Lamoureux and Evans, 2011)
- Combination of all relevant information regarding the financial and physical aspects of supply chains enables real time joint command and control of physical and financial flows (Chen and Cai, 2011; Fellenz and Augustenborg, 2009; Gelsomino et al., 2016; Hofmann et al., 2017; Hofmann and Martin, 2016)
- End-to-end electronic from purchase orders to all trade finance documentation and payments should be seamless and of minimal cost. Automation and streamline the process; improve burden of compliances checks procedures, delay in approval, thus shortening financing window of opportunity (Fellenz and Augustenborg, 2009; Hofmann and Belin, 2011; Lamoureux and Evans, 2011)
- Inclusive, accessible and scalable infrastructure oriented toward a whole ecosystem adoption (Fellenz and Augustenborg, 2009; Hofmann et al., 2017)
- Data governance in terms of Who can take what actions with what information and under what circumstances and using what methods
- A coordinating player or trusted intermediary hub (Fellenz and Augustenborg, 2009).

Supply chain finance and innovative technologies
A significant thrust to SCF technological innovation comes from the recent development in the 'fintech' domain. Fintech, portmanteau of Financial Technology, describes the connection between recent information technologies (such as cloud computing, blockchain or internet of things) and established financial services (Gomber et al., 2017). Fintech applications spans from automated information processing to ubiquitous availability of financial data. Fintech innovation is closely related to SCF: recent 'market guides' and other grey press often illustrates how fintech is at the base of significant recent advancements of SCF (Das, 2017; The Paypers, 2017). For example, several fintech startups (such as Bootz24 or debiteurenbeurs in the Netherlands or SKUchain in the US) offer typical SCF solutions that are enhanced by financial technology.

However, the link between fintech and SCF is yet to be explored and formalised in literature. With this contribution, we aim at filling this gap, by addressing the following Research Questions:

- How can innovative information technologies support the evolution of the SCF approach?
- How can innovative information technologies mitigate SCF-related risks?

To answer those research questions, five main technologies related to the fintech domain were considered: Blockchain and Distributed Ledger (BCT); Internet of Things (IoT); Artificial Intelligence (IA, including also big data analytics), and Application Programming Interfaces (APIs).

Methodology and research framework
Research on the relationship between fintech and SCF is clearly at an exploratory stage. Despite significant attention from practitioner towards fintech innovation, empirical evidence, especially in connection with SCF, is still largely missing. Thus, exploratory case studies are considered appropriate for this context, as the theoretical foundation is rather weak (Edmondson and Mcmanus, 2007). The study is based on a deductive approach, with its general constructs, variables and relationships grounded in the underlying theoretical domains (Ketokivi and Choi, 2014) – namely, SCF and IT for supply chain management. Consistently with Voss et al. (2009, 2002), we base our case study design on four phases: design, collect, analyse and report.

Thus, the first step is the design of the research framework, based on the review of relevant literature. As clear from the previous sections, the framework is composed of three main blocks: innovative technologies, SCF requirements and SCF risks (and related mitigation procedures). Each block presents a different number of macro-variables, which – when appropriate – have been further divided, at a higher level of detail, in multiple variables. Constructs leading to variable identification have been identified in the literature session. A summary of the different variables is reported in the final framework, in Figure 1. As stressed by Yin (2003), multiple-case design reinforces the results through pattern replication, increasing the robustness of the findings. Consequently, this was the approach adopted in this study. Case selection followed a mixed literal and theoretical replication logic. Heterogeneity was introduced in industry and technology adopted or investigated, as well as role in the supply chain, which included large buyers, financial service providers, IT service providers and logistic services providers. The different in the role within the supply chain is especially relevant to acquire different perspectives on the adoption and offering of SCF schemes, as technological innovation can sometimes be visible only from the specific perspective of one actor within the supply chain. Literal replication was introduced by selecting cases with a very strong buyer as focal player in the supply chain, as well as selecting cases in which one or more of the different technologies have been investigated or adopted. Overall, 9 interviews have been carried out. Table 1 and 2 summarises the sample characteristics and technology coverage.

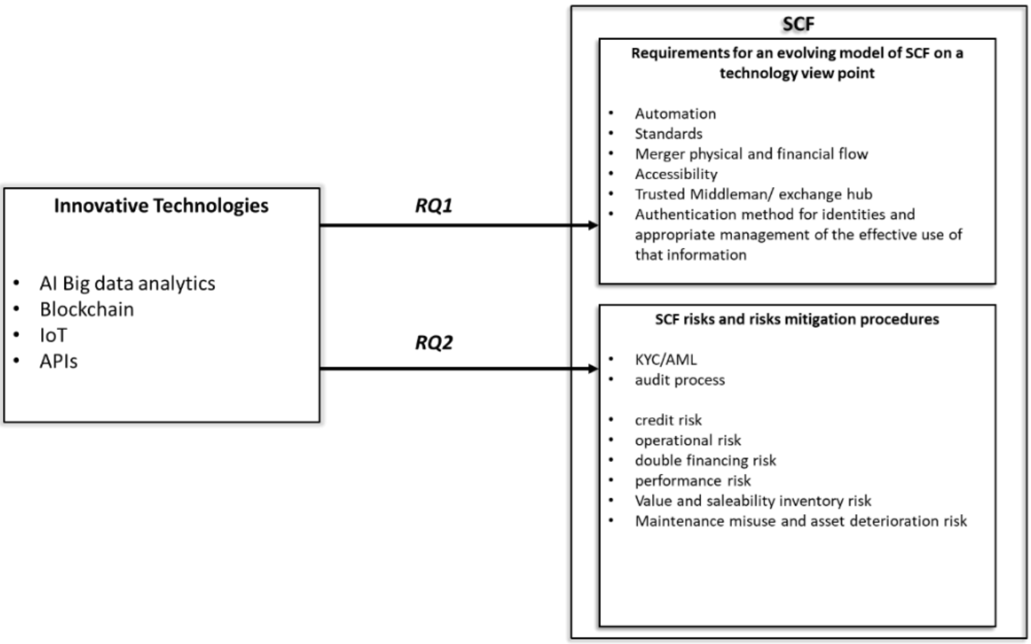

Figure 1: research framework

Table 1: sample description

Case	SC role	Industry	Headquarters	Market served	Interview role
Alpha	Focal company (manufacturer)	Agricultural	USA	Worldwide	Supply chain director and material manager leader
Beta	Fintech	Financial services and IT	Netherlands	Worldwide	Founder
Gamma	Financial Institution	Financial services and IT	Netherlands	Worldwide	Program manager and blockchain project leader
Delta	Fintech	Financial services and IT	Netherlands	Europe	Owner and founder
Epsilon	Logistics service provider (air)	Logistics (air cargo)	Netherlands	Worldwide	IT specialist
Zeta	Logistics service provider (forwarder)	Excise goods, chemicals and hazardous goods	Netherlands	Worldwide	General manager and IT engineer
Eta	IT service provider	IT, logistics and ports services	Netherlands	Netherlands	Innovation consultant
Theta	Focal company (manufacturing)	Transportation	Sweden	Worldwide	Manager engineering and senior project leader
Iota	Focal company (wholesaling)	Electrical, technical installation and home appliances	Netherlands	Netherlands	Logistics director

Table 2: cases coverage of technologies (legend: P/T pilot/trial, O opinion provided, I commercial implementation, W willingness to implement, investigation of implementation or feasibility studies are undergoing)

Case	Blockchain	IoT	APIs	AI and BD analytics
Alpha	P/T	O		O
Beta	O			I
Gamma	I	O		O
Delta	I	O	I	O
Epsilon	O	W	I	
Zeta	I	W		
Eta	O	O	I	W
Theta		I		I
Iota		O		O

A standard semi-structured interview protocol has been developed as basis for the interviews. Although common in structure, it has been slightly modified to take into consideration the different role in the supply chain of the interviewed companies. All the 9 companies were directly contacted by email and a protocol summary was shared beforehand. Interviews lasted between 60 and 120 minutes, were transcribed afterwards and their content summarised. The third step included the code phase, necessary to analyse the data, pinpointing recurring concepts and findings within the sources, coherently with the developed research framework. Beside the content of the interviews, additional information from the interviewees and secondary sources were used to triangulate data. Coding has been performed on the data, followed by both a within-case and cross-case analysis, as suggested by Eisenhardt (1989). Crossing cases in table based on the variables identified within the research framework allowed to highlight patterns and relationships between variables, that constitute – with their generalisation – the core content of the next section.

Results

Technological requirements for an evolving model of supply chain finance

Lack of standards in managing financial flows hinders communication between buyer, suppliers and financial institutions. The proliferation of platforms for accounts-payable related solutions provides significant opportunities for companies to tailor financing needs to the features of their supply chain. However, the lack of proper standards increases the cost per users and the complexity of managing multiple platforms. There does not seem to be a single unique technological solution to the lack of standards, except for the indirect use of APIs. Potential solutions comes from three sources: (i) regulatory efforts, such as for payments in the Euro area; (ii) system integrators that provides interoperability services among existing standards, such as for e-invoicing standards in Europe or (iii) a third-party open protocol that provides a common platform for the identification of parties and the granting of specific rights and access, without standardising the exchange of information in itself, such as the i-share protocol in the Netherlands.

Integrating information about goods and financial flows together enhanced the overall management of the supply chain. Among the four technologies identified, BCT and IoT directly impact the technological requirement, while API and AI provides an indirect effect on it. IoT enables the real time access to information on the physical status and location of goods in the supply chain, providing access to physical "triggers" of potential financial solutions. This is often combined with the security and integrity of blockchains, for example in smart contracts. APIs indirectly affect this requirement by facilitating the access to data to different parties, which usually have different systems and data structure. AI, on the other side, indirectly facilitate the integration by providing quicker and easier interpretation of existing data collected.

One of the key requirements of for bridging together physical and financial supply chain is automation. There are essentially two aspects in which the identified technologies can support the bridging of physical and financial supply chains: the complete overcome of manual processes in order to "transform" them into automated ones, or the use of automation to bridge paper-, manual-based phases with digital ones within the same process. The first is supported by technologies such as blockchain and IoT. The smart contract is, again, a good example of this: smart contracts triggered by IoT and grounded into a blockchain automate the process of financing reducing its costs and increasing the timeliness. AI, on the other side, can play a direct role in bridging manual and digital processes together. An example of this is AI-enhanced OCR for trade financing. When a paper bill of lading is provided to a financial institution, it has to manually enter its information in the ICT system, an activity that can potentially take up to one hour per single bill of lading, with a risk of data entry errors. AI-enhanced OCR can scan the bill of lading and, through a learning mechanisms based on a database of existing bills of lading scanned and validated by humans, can learn where and what each field on the bill is, providing a “mask” in a matter of seconds. At that point, the human simply need to validate the received information and approve it. Finally, similarly to the previous requirement, APIs can facilitate the access and sharing of data.

Accessibility drives inclusiveness, which is paramount in a true bridge between physical and financial supply chains: financial solutions that, for example, do not allow small, remote or non-strategic suppliers to access proper financing will limit the integrability of the physical and financial supply chains. Therefore, systems that aim at better align goods and finance flows in supply chain should focus on being inclusive and scalable, so to be open to adoption to an entire ecosystem, rather than targeting specific players within it. BCT has a direct but unclear impact on this: on one side, decentralisation and cryptography improve accessibility, making it theoretically accessible to all authorised players, without the need for a central authority that check and protects data. On the other side, the recent proliferation of private blockchains hinders the accessibility of this technology, which in those cases is specifically designed to not be accessible. Moreover, several actors indicates how currently blockchain has scalability issues, which limits its theoretical level of accessibility. API, on the other side, have a very direct and positive effect on this requirements: API versatility strongly increase accessibility by allowing players to access data and information without necessarily adapting their information systems.

Data governance is needed to ensure safe and effective information sharing among partners, through identity authentication and information management techniques. An effective link between physical and financial supply chains has to rely on trustworthy identity management that can trace who has provided specific information at what specific time. For example, one of the most relevant limitation that is still impeding the digitalisation of bill of lading is mainly related to the legal unclarity regarding the uniqueness of digital bill of lading in case of double financing. In this sense, BCT has a direct positive impact on this: its combination of cryptography, digital signatures and immutability provides a safe environment to trace who has submitted what information at what time. The same level of security can be achieved through the proper APIs, which allow to check identity and manage access. Negatively affecting this requirement is IoT, which in itself is structurally unable to provide secure identity management and has weak data ownership.

Finally, an effective bridge between the physical and financial supply chains require significant level of trust in third parties: IT service providers, financial institutions and any other actor willing to achieve a coordination role in this field has to acquire trust from primary members of the supply chain. So far, there are no centralised trust systems in supply chain that can help in support exchanges, especially regarding financial flows (e.g. no paypal for companies in supply chains). This trend is mostly addressed in relation to BCT. On one side, blockchain databases provide several features that positively impact this technological requirement: digital signatures, decentralised architecture, cryptography and immutability. However, BCT in itself cannot substitute trust with third parties and, in some cases, might even negatively affect it: the lack of a centralised authority and the removal of all middleman might create contexts in which more trust in third parties is required. In this sense, APIs can again provide an indirect positive impact on this requirement, through a secure system of authentication and authorisation that can support the actual exchange of data effectively reducing the total amount of trust required.

Table 3: technological requirements for an evolving model of SCF and innovative information technologies

Technological requirements	**Blockchain**	**IoT**	**API**	**AI**
Standards	No impact	No impact	Indirect impact	No impact
Integrated joint control of goods and financial flows	Direct (+)	Direct (+)	Indirect	Indirect
Automation	Direct (+)	Direct (+)	Indirect	Direct (+)
Accessibility	Direct (unclear)	None	Direct (+)	None
Data governance	Direct (+)	Direct (-)	Direct (+)	None
Trusted third party / exchange hub	Direct (unclear)	None	Indirect	None

Supply chain finance-related risks and risks mitigation procedures

In terms of credit risk, blockchain and AI present the strongest cases for improving risk assessment. On one side, blockchain provides better profiling through wider and more secure data sources. Information such as transaction history can be registered in the blockchain, providing more security to providers that need to assess credit risk. Similarly, AI has the potential to use algorithm to improve credit scoring and help actors in better scoring the risk of specific assets, such as invoices or inventories.

Operational risk is positively affected by all technologies object of this contribution, which contributes to reducing its impact on SCF schemes. First of all, the immutability of a BCT database virtually eliminates every possibility of tampering with data that has already been recorded. Moreover, the use of cryptographic keys assure that unauthorized accesses to the database are limited to a minimum. Finally, the use of smart contracts limits the human error factor of operational risk. IoT can also strongly reduce this specific risk; sensors can provide information on location, weight, humidity and other physical conditions of assets. For example, one of the most pressing problems of Episolon is weighting of pallets, which is both time and resource consuming as well as a potential source of errors, misunderstanding or fraudulent behaviour from customers. Technological innovation in weighting of pallets would be a priority for them. In similar way adaptive analytics (including optical character recognition – OCR – and natural language processing - NLP) make AI efficient in reducing risks related to operational risk. The same emerges from APIs which ability to prevent unauthorised and/or unauthenticated access to information or starting new financing operations greatly reduces this type of risk.

Double financing risks is primarily affected by BCT and AI, while IoT provides support in its reduction, limited to its occurrence in inventory- or fixed-asset related SCF schemes. For reasons mentioned above, BCT provides security a level of security and immutability that – almost naturally – mitigates double financing risks. However, it should be noticed that this applies only if a significant critical mass of financiers is part of the same blockchain platform. AI can work in a similar way, with the introduction of machine learning algorithms that can spot similarly between documents and recurring patterns that suggest the presence of a double financing operations at the origin of the data entry from the financial institution side. Finally, regarding IoT, data show how it can control and guarantee the existence, position and other relevant statuses of a physical asset. This can support double checks from financial institutions

that are in the process of financing, for example, physical inventory.
Performance risk is a very significant component of SCF and is mostly affected by BCT and IoT, which support decisions makes in better assess the risk. The former provides significant support because a blockchain database typically registers key information such as the transfer of ownership of documents or progression in operations object of the financing (e.g. delivery). Similarly, IoT can intercept issues in the physical status of goods that can generate financial performance issues (e.g. low quality of goods). Finally, APIs can support this process by facilitating the data exchange between parties.
Value and saleability is a SCF-related risk that affects almost exclusively inventory-based SCF schemes. Due to its peculiar nature, linked to the physical flow of goods, from the cases only a link with IoT emerges. In a similar manner as for double financing risk, tracking and tracing conditions of goods improves the assessment of its saleability risk.
Finally, cases illustrate how maintenance, misuses and deterioration risk can be reduced by IoT and AI. The former can provide information on the current status of the asset in question (e.g. fixed assets). This allows to intercept asset deterioration (whether expected or unexpected) and pre-emptively intervene. The latter supports this process through analytical models that can prevent failure of assets.

As regards risk mitigation procedures, KYC and AML represent key financial processes that greatly affect SCF. Several of the cases carried out, triangulated with information from secondary sources, point out how KYC procedures are often critical for effective adoption of SCF, and how new SCF providers sometimes compete with traditional ones (i.e. banks and other large financial institutions) directly on the efficiency of their KYC and AML procedures. Penalties for KYC incompliance are significant and banks greatly invest to avoid them. As such procedures become more and more critical for providers, they also highlight the lack of a clear guidance: KYC is not a standardised process and, for this reason, banks are reluctant to disrupt it with the introduction of new technologies. Moving away from a safe KYC or AML process might even so slightly increase the likelihood of incurring in very large penalties.
In this sense there is a clear support role from BCT towards KYC and AML, which does not affect significantly the time and resources required to carry out the procedures, but help in streamline them. For example, storing KYC checks in a blockchain might avoid duplication of activities within the same bank, for example by confidently sharing the same check on the same customer between different branches. However, as highlighted by Beta, sharing of KYC procedures between banks in the blockchain will not be adopted, as the incompliance risk is extremely high. In a similar way, AI can support AML procedures by integrating pattern recognition techniques within existing AML processes. This will allow banks to reduce their costs, without however having a truly disrupting impact on the procedure itself.

Similarly, auditing procedures are equally relevant in SCF. As reported in literature, for SCF schemes such as Reverse Factoring, auditing – when leading to reclassification of trade payables – has the potential to strongly reduce benefits for the adopter (Feenstra et al., 2017). More in general, auditing – especially in large organisations – can be a lengthy and costly process. Similarly to KYC and AML, BCT and AI have the potential to support this process. As explained by Delta, the most relevant application of blockchain in auditing is in avoiding the double entry accounting procedure typical of a buyer-supplier relationship. Typically, every supplier books an account receivable for accrued revenues which have not been collected yet, while the buyer does the same with its account payables; with BCT, this accounting information is not recorded separately but rather is updated in the same shared database. This information is cryptographically protected, rendering virtually impossible to delete or falsify it, facilitating a seamlessly reconciliation of trade process documents by auditors. However, evidence collected show how it is unlikely that the blockchain will disrupt and completely transform audit processes (at least in the short term), while it will very likely support them and reducing their costs. The reason for this is related to the necessity of preserving a trustable audit trail for activities that do not happen to be recorded in the blockchain. The origin (and, sometimes, custody) of documents before they are registered in the blockchain have to be audited as well. In this sense, proper use of AI can support this process. Audit checks can be supported by AI technology (e.g. OCR digitalisation of document with AI pattern recognition), which can therefore reduce the cost to perform audit procedures.

Table 4: technolgoeis, SCF risks and risk mitigation procedures

SCF risk mitigation procedures	**Blockchain**	**IoT**	**AI**	**API**
KYC/AMC	Support	No impact	Support	No impact
Audit procedures	Support	No impact	Support	No impact
SCF related risks				
Credit risk	Better risk assessment	No impact	Better risk assessment	No impact
Value and saleability inventory risk	No impact	Better risk assessment	No impact	No impact
Double financing risk	Reduction	Support	Reduction	No impact
Operational risk	Reduction	Reduction	Reduction	Reduction
Performance risk	Better risk assessment	Better risk assessment	No impact	Support
Maintenance, misuses and deterioration risk	No impact	Reduction	Reduction	No impact

Conclusions

This paper investigates how innovative information technologies (more specifically, blockchain technology, internet of things, artificial intelligence and application programming interfaces) support the development of SCF by meeting technical requirements that limits its evolution, reduce or support a better risk assessment or support existing procedures for the mitigation of risk. From a theoretical point of view, this paper contributes to literature by exploring the connection between innovative information technologies and SCF. This allows to bridge SCF with fintech literatures, two fields which have significant overlap, which however have not been significantly investigated so far. From a practical point of view, this paper casts a light on practical adoption of technologies in the field of SCF. Practitioners can find relevant information related to how specific technologies an help them in their own supply chain, helping them in integrating physical and financial supply chains. In terms of limitations, despite an in-depth literature review, it is possible that the framework does not include all the SCF technological requirements or the SCF risks (and mitigation procedures) currently used by companies. Moreover, relationship between technologies and other constructs should be evaluated in further explanatory settings to cast a light on the intensity of specific relationships.

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