

An optimisation strategy for concurrent Supply Chain Finance schemes

Abstract

The uncertainty and financial instability that has plagued companies and industries in the last decade is one of the root causes behind the development of Supply Chain Finance (SCF), a set of schemes aiming to optimise the management of financial flows at the supply chain level. Recent years have seen a proliferation of different SCF schemes, with different impacts on working capital costs and requirements throughout the supply chain. The practicality of SCF usage indicates that the concurrent adoption of multiple schemes is not only possible, but even likely. However, literature on SCF still focuses on individual SCF schemes, while the concurrent adoption of multiple SCF schemes remains largely unaddressed. Thus, the objective of this paper is to assess the tangible benefits deriving from a multi-scheme SCF strategy. Based on the analytical formulation of the benefits of three relevant SCF schemes (Reverse Factoring, Inventory Financing and Dynamic Discounting), the paper formalises a model that investigates the benefits that a buyer can achieve by onboarding suppliers onto these three schemes. The results show how working capital requirements and the cost of finance represent the key parameters to assessing the benefits of the concurrent adoption of multiple SCF schemes. Moreover, the funding limits of the SCF schemes themselves strongly affect the relevance of such strategies; strict limits will increase the relevance of having ‘alternative’ schemes available to onboard suppliers. To highlight the managerial relevance of the model, the article provides a numerical example based on a real-world application.

Keywords: Supply Chain Finance, Reverse Factoring, Dynamic Discounting, Inventory Financing, Supplier onboarding

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Introduction

In the current business context, corporations tend to compensate contractions in bank lending through increased access to trade credit, increasing payment terms available to suppliers and/or reducing settlement terms with customers, with the risk of triggering liquidity shortages further along the chain (Jinjarak, 2015; Klapper and Randall, 2011), thus propagating throughout the supply chain (Boissay and Gropp, 2007; Raddatz, 2010). This context contributed greatly to the increased awareness of the inter-organisational management of financial flows, and specifically towards Supply Chain Finance (SCF): a set of schemes which several corporations use, for example, by collaborating with a financial institution to provide additional liquidity to strategic suppliers (Caniato et al., 2016; Wuttke et al., 2013b).

Literature has, in recent years, strongly focused on SCF (Gelsomino et al., 2016). However, significant unexplored areas persist. Multiple contributions highlight how there are several different SCF schemes, such as Reverse Factoring (RF), Dynamic Discounting (DD), Inventory Financing (IF), Purchase Order Financing, and so on (e.g. Caniato et al., 2016; Martin, 2017; Wuttke et al., 2013b). Moreover, the practicalities of SCF adoption describe how different service providers offer the concurrent adoption of multiple SCF schemes by the same company

(GBI, 2016; Herath, 2015). For example, PrimeRevenue, a well-known provider in the SCF landscape, offers the concurrent adoption of RF and DD to its customers, claiming to be able to “identify the optimal mix of terms, rates, and funders within a single platform”¹. Moreover, recent practitioner reports illustrate how RF covers a limited amount of total purchase volume, usually less than 20% (Siemes et al., 2017, p. 16) and how it is aimed at the biggest suppliers, in combination with DD and other SCF schemes (GBI, 2016, p. 36). These trends lead to the reasonable assumption that large buyers might decide or have already decided to adopt multiple SCF schemes (from the same or different providers) at the same time, in the hope of increasing opportunities for working capital optimisation, the number of suppliers involved and, ultimately, the total benefits that can be achieved through SCF.

The concurrent adoption of multiple SCF schemes poses new and interesting questions, both from a theoretical and practical point of view. From a theoretical point of view, the most pressing questions relate to the level of benefits that can be achieved through the concurrent adoption of multiple schemes. Although it is relatively straightforward to expect higher benefits by adopting more than one scheme, the quantitative assessment of the total tangible benefits remains unclear. How can a buyer optimally allocate suppliers to different schemes? Should suppliers be allocated to the scheme that generates the highest benefits? And, overall, how does allocating suppliers to multiple schemes affect the total level of benefits that can be achieved? Moreover, specific parameters are known to influence the adoption of SCF: working capital costs and requirements throughout the supply chain are key factors in achieving the tangible benefits of SCF solutions (e.g. Grüter and Wuttke, 2017; Pfohl and Gomm, 2009). Parameters such as the limitation of available funding have straightforward impacts on a single-scheme adoption, but are likely to have less clear-cut impacts when simultaneously considering multiple schemes. However, it remains unclear how such influences translate to the adoption of multiple concurrent schemes and, conversely, what combination of said parameters presents the best case for the adoption of SCF schemes. Is there a combination of parameters that is more or less likely to render the concurrent adoption of multiple SCF scheme more or less beneficial, as opposed to adopting a single scheme?

From a practical point of view, managers will likely be exposed to the possibility of adopting multiple schemes. As the trend becomes more popular, it is expected to have a significant impact on the SCF strategy of large corporations. Clarity over their tangible benefits as well as the practical indications of which parameters (within the supply base, the buyer working capital features or the characteristics of the SCF schemes) are most likely to provide more tangible benefits within a specific supply chain will benefit practitioners.

Therefore, we aim to investigate the tangible benefits (defined as the increase in profit due to the adoption of an SCF scheme resulting from a reduction in working capital, a reduction in cost of goods sold and/or a reduction in interest charges) achieved by the concurrent adoption of multiple SCF schemes within a supply chain. We do so by considering a buyer in the process of evaluating the adoption of three common and relevant SCF schemes, namely RF, IF and DD. We contribute to the literature on SCF by providing a better understanding of the benefits and parameters (within the supply base and the SCF schemes) that influence the decision to adopt one or more SCF schemes.

More formally, we define two Research Questions (RQ#):

RQ1. *What are the tangible benefits generated by the concurrent adoption of multiple SCF schemes?*

RQ2. *Which parameters influence these tangible benefits?*

The results illustrate how specific parameters of the supply chain and the SCF schemes determine the relevance of a multi-scheme versus single scheme strategy, and that under proper

¹ <https://primerevenue.com/scisupplier-global-supply-chain-finance/>, accessed 24/05/2018

conditions the concurrent adoption of multiple SCF scheme can greatly increase the total benefits generated by adopting SCF, influencing the choices of the buyer in relation to supplier onboarding, providing a potential theoretical explanation for increasingly observed practices.

The rest of the paper is organised as follows: section two highlights the relevant theoretical background; sections three and four illustrate the analytical modelling of the research, formalise the problem of allocating suppliers to multiple SCF schemes and discuss its implications; the fifth section presents the numerical application of a real-world example, while the final section concludes the paper.

Literature review

SCF or, less commonly, financial supply chain management (Sugirin, 2009; Wuttke et al., 2013b), deals with schemes, solutions or products to facilitate the inter-organisation management of financial flows within supply chains (Hofmann, 2005; Pfohl and Gomm, 2009; Randall and Farris II, 2009). Literature on SCF tends to be divided into two perspectives, finance-oriented and supply chain-oriented, with two different understanding of what constitute an SCF scheme (e.g. Gelsomino et al., 2016; Pellegrino et al., 2018; Song et al., 2018). Within the former, it is usually seen as a set of (innovative) financial schemes (Chen and Hu, 2011; Lamoureux and Evans, 2011; More and Basu, 2013) focused on optimising accounts payable and receivable along the supply chain. Some authors (e.g. Chen and Hu, 2011; Wuttke et al., 2013a) and practitioner reports (Amariei et al., 2015; Demica, 2011) even identify SCF as a synonym of RF. Within the latter, it is seen as a way to optimise working capital (or even fixed assets), including inventories, and more generally improve the financial performance of a supply chain, focusing on collaborations among supply chain players rather than on financial products (Hofmann, 2005; Pfohl and Gomm, 2009; Randall and Farris II, 2009). Authors include schemes that focus on financing working capital more broadly, not only through sale of receivables but through focusing on inventory (e.g. through IF or pre-shipment financing), or on schemes that do not necessarily involve a third party financial service provider (e.g. DD) (Buatsi, 2002; Hofmann, 2009; Wuttke et al., 2013b), as well as more consolidated supply chain integration schemes (e.g. VMI) or even collaborative fixed-asset financing (Caniato et al., 2016; Hofmann, 2005; Pfohl and Gomm, 2009). This paper is grounded within the supply chain-oriented perspective and focuses on three of the most common SCF schemes: RF, IF and DD. They comprehensively cover the SCF conceptual framework defined by Pfohl and Gomm (2009, p. 151-2), presenting different configurations across the three dimensions of the conceptual framework (i.e. actors involved, objects and levers of financing), offering a clear picture of the potential impacts of different SCF schemes.

The analysis of the SCF literature allows the identification of key parameters that affect the adoption of SCF schemes, namely the difference in the cost of debt and the relevance of the working capital position of the companies involved. Literature focusing on SCF from a general point of view highlights how the difference between the credit rating of the buyer and the supplier (and, consequently, the higher cost of accessing liquidity for suppliers) is a key factor in SCF (Pfohl and Gomm, 2009). Moreover, articles confirm that the financial attractiveness of buyers is a key parameter (Caniato et al., 2016), and that the working capital position of the buyer and its suppliers (taken together as well as in relation to one another) constitute a causal condition for the adoption of SCF schemes (Wuttke et al., 2013b).

The rest of this section provides an overview of the literature on those specific schemes, whose main characteristics and key references are summarised in Table 1.

Table 1: main literature findings on the three schemes object of this contribution

====Table 1====

Reverse Factoring

RF can be defined as an SCF scheme where a large buyer facilitates early payment of its trade credit obligations to suppliers (van der Vliet et al., 2015, p. 842). It focuses on suppliers' accounts receivable and revolves around a financial institution purchasing suppliers' invoices approved by a specific and informationally-transparent high-quality buyer. The financial institution only needs to calculate the credit risk of the selected buyer (a high-quality customer), and not the risky suppliers (often small and medium enterprises, otherwise known as SMEs). This arrangement often provides low-risk financing to high-risk suppliers (Klapper, 2006). The buyer then typically extends payment terms and/or requires a discount on the purchase price in return for allowing (i.e. 'onboarding') the supplier into the programme (Grüter and Wuttke, 2017; Liebl et al., 2016; van der Vliet et al., 2015; Wuttke et al., 2013a).

RF is the most addressed SCF scheme in literature. In terms of its quantitative contributions for benefits assessment, Tanrisever et al. (2015) and Van der Vliet et al. (2015) focus their analysis on the duality between the discount and extension of payment terms, a factor qualitatively confirmed by the analysis of Liebl et al. (2016). Dello Iacono et al. (2015) analyse the adoption process of RF by a large buyer and the subsequent onboarding of suppliers. This article builds on its assessment of tangible benefits and further extends it to include the aforementioned duality between the discount and extension of payment terms.

In terms of the relevant characteristics of the supply base, most analytical contributions build on Pfohl and Gomm (2009) and highlight the key relevance of the arbitrage between the costs of the debt of the buyer and the supplier as the main trigger for the benefits of RF. Grüter and Wuttke (2017, p. 6) extend this by highlighting how the value of RF is driven by large volumes of accounts receivables and high working capital costs in relation to the cost of the programme. Different qualitative studies support this view and highlight the relevance of RF for the context in which suppliers are driven by high working capital requirements and, contextually, have high costs or difficulties accessing other forms of working capital financing, such as direct factoring. This includes, for example, SMEs with difficult access to cash (Martínez-Sola et al., 2017), suppliers in developing countries (Klapper, 2006) or small transporters in the logistics industry (de Goeij et al., 2015).

Inventory Financing

IF has long been studied as an alternative to traditional credit lines backed up by fixed assets, which are relatively more difficult to obtain for non-manufacturing companies such as startups or retailers (Buzacott and Zhang, 2004; Robert and Jerome, 2011). Current assets acting as collateral (specifically, accounts receivable and inventories) links the extension of credit to the value of specific short-term assets rather than to the overall creditworthiness of the firm (Berger and Udell, 2006). More recent contributions describe IF as an innovative SCF scheme in which a third party provider (often of logistic services, or LSP) buys goods from a manufacturer and temporarily retains legal ownership before selling them to the manufacturers' customers after a certain time (Chen and Cai, 2011; Hofmann, 2009).

Hofmann (2009) first addressed this innovative form of financing inventories, providing a conceptual explanation of the relevance and implications of the topic. The author underlines how the LSP involved in such schemes does not take on the role of wholesaler, as the fee exercised is related to the arbitration of interest rates between the buyer and the supplier and the control that the LSP exercises on the goods flow, rather than the LSP's 'marketing' capabilities. Chen and Cai (2011) analyse how a capitally constrained retailer obtaining working capital from an LSP (through IF) leads to higher profit for the entire supply chain with respect to traditional bank channel financing. Such benefit streams mainly from the control that the LSP can naturally exercise on the goods flow.

Dynamic Discounting

Despite significant attention from practitioners (e.g. BAFT et al., 2016; GBI, 2016; Gustin, 2013), in terms of academic contributions DD is the least commonly addressed SCF scheme among the three considered. DD allows the dynamic settlement of invoices in a buyer-supplier relationship: for every day of payment in advance with respect to contractual payment terms, the supplier grants to the buyer an incremental discount on the nominal invoice value (Nienhuis et al., 2013; Templar et al., 2016). This takes root from the cash-discount policy typical of trade credit practices and, through the proper use of a buyer-supplier integrated platform, allows the dynamic settlement of invoices (de Boer et al., 2015). DD first arose after it was recognised that the ‘mass application’ of static discount policies precludes the potential profits gained through the ‘customised’ application of early payment discounts (Randall and Farris II, 2009). The flexible use of cash discount policies, where buyer and supplier can settle an invoice at any given time within the standard payment terms in exchange for a proportional discount, provide, overall, more benefits to each company involved (Zhou et al., 2013). According to He et al. (2010), DD can either be buyer-initiated (i.e. the buyer declares the acceptable discount rate and the supplier reacts by accepting early payments) or supplier-initiated (i.e. the supplier suggests a competitive discount and the buyer accepts the proposal). As the benefits for the buyer rely on the discount realised, the supplier mitigates the level of uncertainty on cash flow-in, as well as increases trust and cooperation among supply chain players (Templar et al., 2016).

In conclusion, a gap persists in SCF literature, as contributions tend to: (i) focus on the general concept of SCF, without the specific focus on the scheme ultimately adopted (e.g. Pfohl and Gomm, 2009; Randall and Farris II, 2009), (ii) acknowledge the existence of multiple SCF schemes without focusing on their concurrent adoption (e.g. Caniato et al., 2016; Wuttke et al., 2013b) or (iii) dive into one specific scheme, providing insights of its benefits and characteristics, both for RF (Dello Iacono et al., 2015; Lekakos and Serrano, 2016; Liebl et al., 2016) and, more rarely, IF (Chen and Cai, 2011; Hofmann, 2009). These contributions provide a clear picture of how working capital costs and requirements, as well as the key parameters of SCF schemes, affect both their adoption and benefits. However, it is of significant importance to investigate if such considerations and insights hold in the case of the concurrent adoption of multiple schemes.

Assessing the tangible benefits of SCF schemes

The model developed comprises of four steps: (i) identify suppliers to be potentially onboarded within the three schemes; (ii) assess and collect the required data; (iii) assess the value of key parameters; (iv) determine the solution to the allocation problem and obtain the desired outputs. The notation used from here onwards is shortly summarised in the appendix of this article.

Context and assumptions

In this model, we take the perspective of a large, creditworthy buyer with $i = \{1, \dots, N\}$ captive suppliers, which is based on the following assumptions:

- D_i is the yearly demand seen by the i -th supplier and is known, deterministic and constant within the year;
- demand materialises when the buyer places an order at the i -th supplier, at time 0 of a generic trade cycle;
- as per common literature (e.g. Hofmann and Kotzab, 2010; Viskari and Kärri, 2012), DSO_i is the Days of Sales Outstanding and DIH_i the Days of Inventory Holding of the i -th supplier;
- m_i is the gross margin of the i -th supplier;
- the time value of money is negligible in the time frames considered;
- transformation and transportation lead times for the suppliers in procuring goods are null;

- the supplier procures the finished goods to satisfy the fraction of D_i of a generic trade cycle at time 0, and keeps the ownership of such goods for DIH_i days;
- DIH_i can be interpreted as the time required by LSP to transport the goods to the buyer's premises, as well as the time required for the buyer to finalise the purchase of the goods after the emission of the order;
- after DIH_i days, the buyer finalises the sale, with a consequent change in ownership;
- invoices are approved after t_a days (with $t_a < DSO_i$), an administrative time needed by the buyer for the reconciliation of the invoice with order and delivery documents (Dello Iacono et al., 2015; Perego and Salgaro, 2010);
- the buyer pays the supplier DSO_i days after the sale has been finalised.

The context of this model reflects a supply chain with a large creditworthy buyer and several small suppliers, which tend to have a higher cost of debt. Therefore, we define $r_{s,i}$ as the cost of debt of the i -th supplier and r_b as the cost of debt of the buyer, assuming $r_b < r_{s,i}$. Such a context is extremely common in literature, both when presenting empirical evidence related to RF (Klapper and Randall, 2011; Liebl et al., 2016) and as a reference context for mathematical models (Lekakos and Serrano, 2016; van der Vliet et al., 2015).

The buyer's decision concerns the allocation of suppliers to the three SCF schemes described in the literature review (identified as $j = \{1,2,3\}$). Allocating a supplier to an SCF scheme (i.e. "onboarding" the supplier) implies that the supplier is offered the possibility of using that scheme. When faced with a buyer offer to start using an SCF scheme, the supplier chooses to accept or reject it. Although their motivations for making this choice might be complex, for the sake of simplicity we adopt the common assumption (e.g. Wuttke et al., 2016) that a supplier – once aware of the availability of RF – onboard on RF when faced with a positive business case. Moreover, we assume this is also true for IF and DD. Finally, we assume that the buyer either assures the supplier a positive business case modulating the scheme parameters (a combination of discount on the invoice nominal value and extension of payment terms) or, if this does not prove to be mutually beneficial, does not offer that specific scheme to that specific supplier. Financing occurs through the involvement of a third party financier (as in RF and IF) or if the buyer invests its own means of short-term financing (as in DD). The financed assets are also different: while RF and DD reduce the suppliers' accounts receivables, IF focuses on both accounts receivables and inventory simultaneously.

Each scheme is characterised by the maximum level of funds available, equal to C_j . Such a limit represents the liquidity (provided by the service provider or allocated to the programme from its own funds by the buyer) available to finance the working capital of the suppliers within the generic (j -th) scheme. The limit represents the upper boundary of the amount of suppliers' working capital that can be subject to an SCF scheme and, ultimately, a cap on the number of suppliers that can be onboarded in each scheme. This parameter is scheme-dependent and is introduced in SCF schemes for multiple reasons. From the point of view of the service provider, RF and IF are credit lines, and as such are subject to a specific, distinct limitation in volume, typically dependent on the buyer's credit rating. From the point of view of the buyer, DD represents an investment of its own liquidity, and as such it is straightforward to assume that there will be a limit on the amount of liquidity that can be invested in that scheme. Moreover, an extensive use of RF might trigger the reclassification of accounts payable into short-term debt, negating the working capital benefit for the buyer and constituting a risk of decreasing key balance sheet performance indicators. For these reasons, such limits are managed independently.

The impact of the schemes on DSO_i and DIH_i is reported in Figure 1.

====Figure 1====

Figure 1: impact of the different schemes on the supplier DIH_i and DSO_i

Reverse Factoring

When the buyer onboards the i -th supplier on RF, it sets an extension of contractual payment terms equal to ΔDSO (Lekkakos and Serrano, 2016; van der Vliet et al., 2015). It is assumed in this model that such extensions are the same across suppliers and a-priori set the adoption (i.e. as a target to be achieved in negotiations with suppliers). The buyer also requires the i -th supplier to provide a discount on the invoice nominal value ($d_{i,RF}$). Therefore, assuming no relevant operational costs for the buyer, its tangible benefits over the course of one year (TBB_{ij}) arising from onboarding the i -th supplier in RF are:

$$TBB_{i,RF} = \left(d_{i,RF} + \frac{\Delta DSO}{365} \cdot r_b \right) \cdot D_i \quad (1)$$

The supplier will receive their payment from the service provider after the administrative time required by the buyer to approve the invoice (t_a days). The service provider charges a fee (proportional to the amount financed), which is deducted from the payment based on a pre-defined yearly rate of r_{RF} , equally applicable to all suppliers, based on the amount financed (i.e. on the time between the moment in which the supplier receives payment and the moment in which the buyer settles the account with the financial provider). The tangible benefits for the i -th supplier (TBS_{ij}) deriving from the adoption of RF are equal to:

$$TBS_{i,RF} = \left[\frac{DSO_i - t_a}{365} \cdot (r_{S,i} - r_{RF}) - \frac{\Delta DSO}{365} \cdot r_{RF} - d_{i,RF} \right] \cdot D_i \quad (2)$$

Consequently, the buyer will select a discount which provides the supplier with a tangible benefit of at least TS (as an annual percentage rate of the total demand):

$$TBS_{i,RF} = TS \cdot D_i \Leftrightarrow d_{i,RF} = \frac{DSO_i - t_a}{365} \cdot (r_{S,i} - r_{RF}) - \frac{\Delta DSO}{365} \cdot r_{RF} - TS \quad (3)$$

And will compare its tangible benefits resulting from such a discount with the maximum funding required if the supplier adopts RF (F_{ij}):

$$F_{i,RF} = \left[\frac{DSO_i - t_a + \Delta DSO}{365} \cdot (1 - d_{i,RF}) \right] \cdot D_i \quad (4)$$

Such funding has to be deducted from the maximum amount of funding available (C_{RF}), if the i -th supplier onboards RF.

Inventory Financing

The model is grounded in the innovative inventory finance scheme proposed by Chen and Cai (2011) and Hofmann (2009), where the scheme is offered by a solutions provider who has the means to monitor and control inventories (e.g. an LSP holding inventories in-transit or within a warehouse) and has access to capital funds at a lower cost than the average supplier (i.e. through a collaboration with a bank or a generic financier). When the buyer onboards the i -th supplier on IF, it sets a single parameter: the discount required to onboard, $d_{i,IF}$. The supplier immediately receives the payment at time 0, effectively reducing DIH_i and DSO_i to zero. Thus, the supplier provides a discount to the buyer in exchange for reduced financing costs, with a total tangible benefit of:

$$TBS_{i,IF} = \left[\frac{DSO_i + DIH_i \cdot (1 - m)}{365} \cdot r_{S,i} - d_{i,IF} \right] \cdot D_i \quad (5)$$

The contractual agreement beyond the IF scheme lies between the buyer and the service provider, which implies that the supplier immediately releases ownership of the goods at time 0. Therefore, to operate effectively, the service provider needs to establish a control mechanism

to monitor inventories on behalf of the buyer. This provides the buyer with confidence that the inventories have been effectively procured by the supplier when the order is placed. After $DIH_i + DSO_i$ days, the buyer settles their account directly with the solution provider, without the extension of payment terms. The cost of the scheme (f_{IF}) is proportional to the amount financed (i.e. it is expressed as an annual rate) and is somewhat higher than RF. The solutions provider charges the cost of the scheme directly to the buyer. Such costs are comprised of two components; the first component represents the cost at which the solutions provider accesses funds, which needs to cover the financing for $DSO_i + DIH_i$ days; the second component represents the transaction costs related to the control and monitoring of inventories. To cover the scheme costs, the buyer asks the supplier for a discount.

In summary, the buyer has to compare the operational costs of the scheme with the discount that the supplier is willing to provide:

$$TBB_{i,IF} = \left[d_{i,IF} - \frac{(DSO_i + DIH_i) \cdot (1 - d_{i,IF})}{365} \cdot f_{IF} \right] \cdot D_i \quad (6)$$

As in RF, the buyer will select the maximum discount that provides a benefit of TS to the supplier:

$$d_{i,IF} = \frac{DSO_i + DIH_i \cdot (1 - m)}{365} \cdot r_{S,i} - TS \quad (7)$$

Once more, the buyer will compare the benefit with the amount of funding required to onboard the i -th supplier:

$$F_{i,IF} = \left[\frac{(DSO_i + DIH_i) \cdot (1 - d_{i,IF})}{365} \right] \cdot D_i \quad (8)$$

Dynamic Discounting

Finally, when the buyer onboards the i -th supplier on DD, it sets a single parameter: the discount on the nominal invoice value, $d_{i,DD}$. For the purpose of this model, we assume that the buyer uses a third party IT platform to manage the DD process, and that the service provider charges the supplier with a fee (f_{DD}), proportional to the value of the invoice, every time an invoice is discounted. There are no yearly or fixed fees, and the buyer has no platform-related costs. The buyer settles invoices in advance in exchange for a discount on the invoice nominal value. In order to correctly assess the benefits resulting from the use of DD by different suppliers, the buyer needs to estimate the ratio between the early settlement period and DSO_i , namely ep_i , which represents the behaviour of the supplier in terms of the acceptance of early invoice settlements. Considering the administrative time required to approve an invoice (t_a days), a supplier discounting invoicing at the earliest possible time will have the highest possible value of ep_i , equal to:

$$ep_{i,max} = \frac{DSO_i - t_a}{DSO_i} \quad (9)$$

On the other hand, a supplier discounting invoices at the earliest possible time (i.e. a few days) will have an ep_i close to zero. The benefit of the buyer derives from the discount obtained and the additional financial charges related to the early settlement of their invoices:

$$TBB_{i,DD} = \left[d_{i,DD} - \frac{DSO_i \cdot ep_i}{365} \cdot r_b \right] \cdot D_i \quad (10)$$

While the benefit of the supplier derives from the difference between the financial charges avoided and the sum of discounts and platform fees:

$$TBS_{i,DD} = \left[\frac{DSO_i \cdot ep_i}{365} \cdot r_{S,i} - d_{i,DD} - f_{DD} \right] \cdot D_i \quad (11)$$

As in the previous schemes, the buyer selects the maximum discount which provides a benefit of TS to the supplier:

$$d_{i,DD} = \frac{DSO_i \cdot ep_i}{365} \cdot r_{S,i} - f_{DD} - TS \quad (12)$$

Consequently, the buyer compares the benefits deriving from onboarding the i -th supplier with the funds required to onboard them:

$$F_{i,DD} = \left[\frac{DSO_i \cdot ep_i}{365} \cdot (1 - d_{i,DD}) \right] \cdot D_i \quad (13)$$

Allocate suppliers to SCF schemes

Once each parameter has been assessed and each discount d_{ij} has been calculated, the buyer allocates suppliers to different SCF schemes in order to maximise the total sum of their tangible benefits. Defining x_{ij} as a binary variable that takes a value of 1 if the i -th supplier is allocated to the j -th scheme and 0 otherwise, the buyer's problem can be formally stated as:

$$\begin{aligned} \max_{x_{ij}} \quad & \sum_{j=1}^3 \sum_{i=1}^N TBB_{ij} \cdot x_{ij} \\ \text{s. t.} \quad & \sum_{i=1}^N F_{ij} \cdot x_{ij} \leq C_j \quad \forall j \\ & \sum_{j=1}^3 x_{ij} \leq 1 \quad \forall i \\ & x_{ij} \in \{0,1\} \quad \forall i,j \end{aligned} \quad (14)$$

This allocation problem is an application of the so-called General Allocation Problem (GAP)²: each SCF scheme considered constitutes a 'knapsack' to which the i -th supplier might be allocated, with the aim of maximising the tangible benefits of the buyer, with the total funding required (i.e. weights) within the funding limit set by C_j (i.e. total knapsack weight). An in-depth analysis of the exact algorithm, heuristics and solution times is available upon request.

Interpreting results

Solving this problem provides the optimal allocation of suppliers to the three SCF schemes taken into consideration. For each supplier, this includes the optimal scheme (if any) to which it should be onboarded, as well as the specific tangible benefits for the buyer as a result of such onboarding. Based on the structure of the model, only three generalised outcomes can occur:

- *The supplier is allocated to the 'best' SCF scheme:* in the optimal solution to the problem, the i -th supplier is allocated to the SCF scheme with the highest TBB_{ij} (i.e. the 'best' scheme);
- *The supplier is allocated to an 'alternative' SCF scheme:* the i -th supplier can be allocated to multiple schemes (i.e. more than one scheme provides positive tangible benefits to the buyer) but, due to the total funding constraints (C_j), in the optimal solution to the problem it is not allocated to the scheme with the highest TBB_{ij} ;

² More specifically, the problem presented in this paper allows suppliers to not be allocated to any SCF scheme. This problem is referred to as LEGAP (Martello and Toth, 1990) or the *loading problem*. However, this problem can easily be transformed to the GAP and is also NP complete (Ohlsson and Pi, 1997).

- *The supplier is not allocated to any SCF scheme:* either the supplier does not derive any positive value of TBB_{ij} or, if such value exists, the optimal solution to the problem does not involve its allocation to any scheme.

Several insights can be drawn from this. First, limits on the scheme funding (C_j parameters) strongly influence whether a generic supplier is allocated to the ‘best’ scheme. Such parameters are typically set by a third party financier as a credit limit or by the buyer itself to avoid auditing problems (such as the reclassification of trade payables into financial debt, as explained by Feenstra et al., 2017) or to limit the amount of cash available to invest in a scheme (such as in DD). Without any constraints on the total amount of financing that can be conveyed to each scheme, the second outcome would not occur for any supplier, as they would either be allocated to the ‘best’ solution or to no solution at all if they don’t provide any tangible benefit to the buyer. Instead, the introduction of caps on the total amount of funding provides the suppliers with the opportunity to be allocated to their ‘second’ or ‘third best’ schemes, or to not be allocated to a scheme at all, despite providing potential tangible benefits.

Second, the parameters of the supply base strongly influence the possibility of suppliers being allocated to ‘alternative’ schemes. This can easily be seen from a graphical point of view, as reported in Figure 2. For the sake of simplicity, the chart in Figure 2 focuses on RF and IF only: this allows the study to obtain results that can be easily interpreted from a graphical point of view. The subsequent discussion is still valid when considering more than two schemes.

===Figure 2===

Figure 2: understanding supplier allocation to RF or IF based on the analysis of DSO_i and DIH_i values

On the one hand, the buyer will be interested in onboarding the generic supplier on RF if $TBB_{i,RF} > 0$. This depends on DSO_i alone and not DIH_i , and is represented in Figure 2 as a straight line, an ‘RF threshold’^{3,4}. Above this threshold the supplier can be onboarded in RF; below this, its onboarding does not provide tangible benefits to the buyer. On the other hand, the buyer will be interested in onboarding the generic supplier on IF if $TBB_{i,IF} > 0$. As this depends on both DSO_i and DIH_i , it is represented in Figure 2 as a function, the ‘IF threshold’. If the supplier is positioned above the threshold, the combination of the two values determines a tangible benefit for the buyer and the supplier might be allocated to IF, otherwise it will not. If the DSO_i and DIH_i values position the supplier above both thresholds, the buyer is potentially interested in onboarding it in both according to the following solution: if $TBB_{i,RF} > TBB_{i,IF}$, RF is the ‘best’ solution and IF is an alternative, and vice versa. The function expressing $TBB_{i,RF} = TBB_{i,IF}$ represents the ‘RF/IF frontier’⁵ that determines, between the two schemes, which one is preferable from the point of view of the buyer.

In total, the supplier’s position in terms of its DSO_i and DIH_i can fall into five different areas, as highlighted in Figure 2:

- A. the buyer is not interested in onboarding the supplier in either RF or IF, as their tangible benefits are negative for both schemes;
- B. the buyer is interested in onboarding the supplier in RF, but not in IF;

³ This line and the following functions are all obtained in the same manner: (i) the parameters of the model (e.g. costs of debt, payment terms extension, costs of the schemes) are assessed; based on such parameters, (ii) the equation for d_{ij} is substituted into TBB_{ij} and (iii) the equation $TBB_{ij} = 0$ is solved by DSO_i . In subsequent functions, DIH_i is kept as a variable, obtaining a function in the form $DSO_i = f(DIH_i)$.

⁴ For DD the procedure would be exactly the same: obtaining a function solved by DSO_i . The resulting “DD threshold” would be higher or lower than the RF threshold based on the value of relevant parameters.

⁵ The analytical expression of these functions is not the scope of this article; however, any readers interested in these details are welcome to contact the authors.

- C. the buyer is interested in onboarding the supplier in both schemes, but RF is the ‘best’ and IF is ‘second best’;
- D. the buyer is interested in onboarding the supplier in both schemes, but IF is the ‘best’ and RF is ‘second best’;
- E. the buyer is interested in onboarding the supplier in IF, but not in RF.

Therefore, the supplier’s working capital requirements (driven by DSO_i and DIH_i) directly affect which scheme (if any) is more suitable for adoption. A generic supplier with high DSO_i and low DIH_i tends to be more suitable for RF, while a supplier with high DIH_i and low DSO_i tends to be more suitable for IF. If a supplier has both high DSO_i and DIH_i , it tends to provide tangible benefits if onboarded in any of the two schemes. The position of the thresholds in Figure 2 is also affected by $r_{s,i}$, the cost of debt of the supplier; the lower the cost of debt, the higher the position of the thresholds on the chart (i.e. the higher the value of DSO_i and DIH_i needed to provide tangible benefits to the buyer). Therefore, the higher the working capital requirements (driven by DSO_i and DIH_i) and the higher the cost to access capital to finance such working capital (driven by $r_{s,i}$) of a supplier, the higher the probability of having more than one scheme in which it can be onboarded.

Third, the previous considerations can be extended to an entire supply chain, or even an entire industry. For example, the graphical representation at the bottom of Figure 2 shows two opposite supply chain contexts: on the left (a) pursuing a combination of RF and IF seems ideal, as all of the suppliers fall within areas C and D, while on the right (b) IF appears to be the only relevant scheme. This graphical analysis is simplified and cannot substitute solving the model presented in the previous paragraphs, but it serves the purpose of illustrating the relationship between the relevant parameters and multi-scheme SCF strategies, as summarised in Figure 3: supply chains (or industries) in which suppliers tend to have high amounts of overall working capital and relatively more difficulty accessing cash will increase the possibility that suppliers can be onboarded in more than one SCF scheme. When the limits on the total funding per scheme are stringent, a multi-scheme strategy acquires more value, providing the buyer an alternative option to onboard suppliers that provide high tangible benefits but do not fit within the optimal allocation of their ‘best’ scheme. On the other hand, loose limits (i.e. very high values of C_j) allow suppliers to always be allocated to the ‘best’ solution. In this last case, a multi-scheme SCF strategy will be less relevant and only provide significantly more benefits if suppliers present different characteristics and there are distinct groups that can be onboarded to each particular scheme (e.g. one group with high average DSO and low DIH and vice versa).

====Figure 3====

Figure 3: relevance of a multi-scheme SCF strategy depending on working capital and SCF scheme features

Numerical example

As stated in the previous sections, the method described in this paper has been applied to a real-world company (anonymously referred to as Company X) and its suppliers to highlight, using a practical case, the insights provided by the model. Data from Company X were collected in the period 2013-2016 and included key information such as purchase volumes with suppliers, cost of debt, limitations in existing SCF schemes, as well as managerial expectations regarding SCF adoption.

Where necessary, data have been modified to assure anonymity without the loss of meaning to the model application. Company X is a multinational manufacturer and distributor of fast moving consumer goods. In 2016, the company’s revenue totalled more than €50 billion. The application has followed the four steps described in previous sections.

- (i) *identify suppliers to be potentially onboarded within the three schemes*

Company X has several thousand suppliers located around the world. Of these, 331 are currently considered ‘strategic’, for a total purchase volume of approximately €8 billion. Interactions with Company X management indicate that the company is willing to pursue the adoption of an SCF scheme with each of these suppliers if mutual benefit is assured.

(ii) *assess and collect the required data*

In relation to these 331 suppliers, Company X provided a valuable starting set of data, including the following variables: D_i (assumed equal to the annual purchase value of Company X towards the i -th supplier in 2015); DSO_i ; $r_{S,i}$ (periodically collected through an external service provider) and r_B (as the average cost to access short-term liquidity from the current financial institutions). Moreover, high-quality interactions with Company X made it possible to collect actual data from previously implemented schemes (RF and IF) regarding costs, parameters and targets (e.g. ΔDSO equals 30 days), as well as assessing the value of Cap_j for each of the three schemes. However, not all the data were available and some variables have been assumed by the authors: DIH_i has been randomly generated based on a normal distribution $\mathcal{N}(80; 30)$, ep_i has been randomly generated as a uniform distribution $\mathcal{U}(0, ep_{i,max})$ and, finally, m_i has been assumed to be equal to 0.1 for every supplier. Table 2 reports a summary of all the input data.

Table 2: main values used in the real-world application

====Table 3====

(iii) *apply the analytical model determining the value of the key parameters*

Using all the variables defined in the previous step, it was possible to determine the value of d_{ij} , as per equations (3), (7) and (12). Overall, this first step already highlights how the C_j values are considered ‘strict’: for RF and IF, in fact, onboarding all suppliers providing a positive tangible benefit would require total funding that is, respectively, 2.4 and 3.3 times higher than their limits. For DD, as few suppliers have positive tangible benefits, the limit on funding is not considered strict.

(iv) *run the algorithm and obtain the output*

Overall, the concurrent adoption of RF, IF and DD would bring Company X a total of €24.29 million of tangible benefits. Figure 4 reports the optimal result for single-scheme problems (RF, IF or DD only), obtained solving a single-scheme simplified problem (i.e. a problem in which, instead of the concurrent adoption of multiple schemes, the buyer investigates the adoption of a single scheme). The result shows how the concurrent adoption of the different SCF schemes results in a higher performance overall: the benefits resulting from the concurrent adoption of the three schemes are 1.6 times higher than the benefits of adopting only RF, 1.3 times higher than only adopting IF and 5.7 times higher than only adopting DD.

====Figure 4====

Figure 4: the sum of the tangible benefits for the buyer in the case of single- and multi-scheme(s) SCF strategies

Approximately 70% of the total benefits for the buyer are provided by IF, 29% by RF and the remaining 1% from DD. IF onboards a total of 91 suppliers, RF onboards 60 and DD onboards just 10. The poor performance of DD is to be found in its relatively high cost, which generates few suppliers with positive tangible benefits to begin with and, consequently, few suppliers are allocated to this scheme. RF and IF exhaust their funding limit and could potentially onboard additional suppliers; most of the suppliers that were not given a place in the optimal allocation among RF or IF see DD as too costly and, as a result, are not allocated to any scheme.

The analysis of key parameters in this numerical application provides additional insights. As reported in Table 3, the largest group of suppliers provides positive tangible benefits for both

RF and IF, but negative tangible benefits for DD. Another significant group provides benefit for all of the three schemes; 55% of suppliers can potentially be onboarded in at least two schemes, rendering a multi-scheme strategy relevant for this supply chain. Moreover, the relatively strict C_j values highlight the possibility of the supplier being allocated to ‘alternative’ solutions. Consequently, the concurrent adoption of multiple SCF schemes provides more tangible benefits than a simple adoption of RF or IF. Surprisingly, this is a straightforward result, as a single scheme adoption model is limited by C_j , which (as in the case of Company X) is introduced internally to avoid excessive reliance on a single financial product. A second and third SCF scheme introduces additional funds and allows more suppliers to be onboarded in an SCF scheme. An increased number of suppliers onboarded implies a higher value of financial flows subjected to an SCF scheme, and therefore a higher total value of benefits.

Table 3: number of suppliers providing positive (Y) and negative (N) tangible benefits, as per each scheme

===Table 3===

The results of the numerical application illustrate the considerations summarised in Figure 3. First, it can be said that the suppliers present high working capital costs and requirements, considering that 70% of them have parameters that allow a positive tangible benefit for at least one SCF scheme. There are no specific features strong enough to render a multi-scheme SCF adoption irrelevant per se, as more than 100 suppliers could be allocated to more than one scheme; however, most suppliers present the highest tangible benefit values for RF. Despite this RF prevalence, the optimal allocation presents more suppliers within IF than RF. This is due, clearly, to the presence of strict C_j values. In fact, as represented in Figure 5, with higher funding limits each supplier would be allocated to the solution that generates the highest tangible benefits. The solution to the problem would then be straightforward: 149 suppliers for which RF is the best solution would be allocated to RF and 49 suppliers for which IF is the best solution would be allocated to IF. As no supplier presents optimal benefits for DD, no one would be allocated there. The evaluation of the buyer would, in this case, be limited to assessing if the benefits streaming from such ‘ideal’ allocations are significant enough to justify pursuing this strategy. Solving the analytical problem would be redundant and, as described in Figure 3, a multi-scheme strategy might be less relevant.

However, as limits on funding become stricter, the number of suppliers that are not allocated to the ‘ideal’ scheme increases. In the specific case of Company X, this leads to an increase in the number of suppliers allocated to IF, to the point that, with the levels of C_j used for the numerical application, IF onboards more suppliers than RF.

This result illustrates how the concurrent adoption of multiple SCF schemes, under specific conditions, generates complex and nontrivial solutions. More specifically, strict C_j limits on funding in the presence of high working capital costs and requirements increase the number of suppliers that are not allocated to the ‘best’ scheme, with an optimal allocation of suppliers that can be identified through solving the problem presented in this article.

===Figure 5===

Figure 5: sensitivity analysis on C_j values.

To summarise the numerical application, results show that Company X and their suppliers would strongly benefit from the concurrent adoption of RF and IF, while DD (with the costs and adoption process delineated in the previous section) is unlikely to provide enough value to be worth pursuing its adoption.

On a more general note, this application shows how a prospective user of this model can define an SCF strategy in terms of choosing between different SCF schemes that would potentially be beneficial for the supply chain and allocating suppliers to them. Compared to a single SCF scheme approach, simultaneously adopting multiple schemes has the potential to generate non-trivial solutions whilst achieving higher levels of benefits, increasing the average benefit provided to suppliers and their cash flow profile and, in general, improving the management of financial flows in the upstream supply chain.

Conclusion

Despite the recent proliferation of literature around SCF and SCF schemes, the topic of the concurrent adoption of multiple SCF schemes has not yet been addressed. This topic is becoming increasingly pressing among practitioners, considering how several non-banking SCF providers are offering multiple SCF schemes to the same buyer at the same time and within the same platform. This article provides a contribution aiming at filling this gap.

To answer the first RQ, this article has developed an analytical formulation of the tangible benefits deriving from the onboarding of a supplier in three SCF schemes: RF, IF and DD. Starting with RF, this article grounded its analytical benefit formulation and assumptions on the existing literature, and especially on the mathematical formulation presented by Dello Iacono et al. (2015, pp. 291–2). This formulation was then extended to both IF and DD. For IF, the existing literature provided further support to develop a more complex set of assumptions that could allow the formulation of analytical expressions for its tangible benefits. For DD, the scarceness of the existing literature required a more significant effort to develop the analytical formulation of its tangible benefits.

The answer to the question was achieved using the formulation of an optimisation problem that represents the behaviour of a buyer in onboarding suppliers and provides insights on the total level of tangible benefits that can be achieved using a multi-scheme strategy.

The second RQ is grounded in SCF literature. Several contributions to the SCF literature illustrate how the arbitrage of costs of capital, as well as working capital requirements, are the cornerstones of this approach (e.g. Liebl et al., 2016; Pfohl and Gomm, 2009). We built on these results, extending them to the context of the concurrent adoption of multiple SCF schemes. First, our results show, unsurprisingly, how working capital costs and requirements maintain their relevance in the presence of multiple schemes. However, a prominent working capital feature of suppliers (such as when DIH is significantly higher than DSO) will reduce the total benefits of such a strategy. Moreover, strict limits on available funding (C_j) will increase the probability that an increasing number of suppliers might be onboarded in an ‘alternative’ scheme rather than in their ‘best’ scheme. This last result shows how the optimal allocation of suppliers in a multi-scheme strategy might be non-trivial and require the solution of the optimisation problem presented in section 4 of this article. Even as in the case of Company X, where the ‘best’ scheme for most suppliers is RF (which might suggest that a single strategy is the most ideal), the combination of working capital costs, requirements and limits on funding means that, overall, a multi-scheme strategy is preferable.

Theoretical and managerial implications

The first theoretical contributions relate to the quantitative assessment of the benefits of SCF schemes. The formulation presented in this article builds on the existing quantitative assessments by extending the formulation of Dello Iacono et al. (2015, pp. 291–2), which presents the benefits of RF and encompasses discounts on purchase price, as described in the literature (e.g. Grüter and Wuttke, 2017; Liebl et al., 2016). We extend such a formulation to IF and, more significantly, to DD, which has received significantly less attention in literature, particularly from a quantitative point of view. Our formulation casts a light on its tangible benefits.

Second, we address the topic of the concurrent adoption of SCF schemes by developing a model that investigates a buyer in the process of adopting three SCF schemes with its supplier base. This model represents the first step in this line of research, illustrating how the concurrent adoption of multiple SCF schemes requires the solution of an optimisation problem to identify the optimal allocation of suppliers to the schemes.

Third, the analysis of the developed model reveals how key parameters influence the benefits of the concurrent adoption of multiple SCF schemes. Working capital costs and requirements, which are known to strongly influence the benefits of SCF schemes, affect the concurrent adoption of multiple SCF schemes as well. However, the consideration of funding limits provide additional insights on the importance of multi-scheme strategies. Such limits (either introduced by the financier as a credit limit or by the buyer themselves as a limit to preclude accounting issues) are neglected by existing literature, likely because their impact, when evaluating a single scheme, is straightforward: they simply reduce the number of suppliers that can be onboarded. However, under strict funding limits, the presence of ‘alternative’ schemes can greatly increase the total benefits of SCF.

From a managerial point of view, the paper’s contributions rely on the practical value of the developed tool. As highlighted by the real-world numerical application, even with a relatively limited set of data, practitioners can determine the optimal allocation of suppliers to different SCF schemes, identifying which SCF scheme is relevant for their supply chain and taking steps towards the definition of an SCF strategy.

The model developed is relevant for large buyers either developing for the first time or revisiting their existing SCF strategy, as well as for SCF providers offering multiple-scheme platforms. They can support their customers in identifying the best strategy or, in a pre-contractual phase, highlight the (potential) value of a multi-SCF scheme in comparison to a single SCF scheme approach.

Moreover, considerations made in this paper in relation to key parameters and the relevance of multi-scheme SCF strategies (e.g. the one reported in Figure 3) are of interest to practitioners, supplying them with high level insights on the suitability of such approaches within their own supply chain context.

Limitations and directions for future research

Limitations of this article lie firstly in the analytical definition of its tangible benefits, which can be enriched with more sophisticated assumptions (e.g. bankruptcy risk, inventory obsolescence, reconciliation errors or failures, stochastic distribution of demands, fluctuation of credit risk). This is particularly true for DD, which does not benefit from a developed literature stream; the assumptions and design decisions can be considered limiting. Further development in this direction will surely increase the accuracy of the developed model. For example, more complex assumptions on the distribution of ep_i (especially if streaming from empirically observed behaviours) would surely improve the analytical formulation of the benefits of DD.

At the same time, although the three schemes considered in this model are a good representation of the SCF landscape, they do not exhaust the panorama of existing schemes. It would be of interest to tackle new schemes within the same methodological approach. Moreover, this paper takes into consideration a two-stage supply chain. As SCF could be applied downstream as well as upstream or, in its broader definition, even to multiple supply chain echelons, future research could, for example, extend the current model to three-stage supply chains (e.g. evaluating a buyer’s choice of pursuing both first- and second-tier financing) and expose it to even more complex and less explored schemes (e.g. the joint financing of a warehouse, such as in Hofmann, 2005, p. 11). Including upstream, working capital-focused SCF schemes requires limited effort (essentially only formulating the tangible benefits in a similar way to the one presented in this article). However, due to the design choices in the problem formulation,

extending the model to non-working capital-focused schemes or to other tiers in the supply chain requires a significant revision of the proposed model.

Finally, and more generally, onboarding a supplier in an SCF scheme involves a mix of qualitative and quantitative considerations (Caniato et al., 2016; Wuttke et al., 2013b) and cannot be exhausted by considering the tangible benefits alone. In this sense, this contribution should be considered to be the first step towards the identification of a suitable combination of SCF schemes for a specific supply chain, followed by more in-depth analyses that can benefit from its insights. Future research will hopefully build in this direction, providing additional insights into the definition of an optimal SCF strategy and focusing on aspects that are not covered in this article. For example, an additional qualitative, empirically-based investigation focused on the reasons and motivations why funding limits are introduced in SCF would provide additional value to this first investigation.

A more complete framework for the definition of an SCF strategy, with a joint qualitative and quantitative effort, would greatly benefit both academia and practitioners, and provide a further step towards generating a more complete theory of SCF.

Bibliography

- Amariei, M., Avram, T., Barbuta, I., Cristea, S., Lupu, S., Mihaila, M., Nita, A., Screpniceanu, A., 2015. B2B Payment , Supply Chain Finance & E-Invoicing Market Guide 2015, Report.
- BAFT, Euro Banking Association, Factors Chain International, International Chamber of Commerce, International Trade and Forfaiting Association, 2016. Standard Definitions for Techniques of Supply Chain Finance.
- Berger, A.N., Udell, G.F., 2006. A More Complete Conceptual Framework for SME Finance. *Journal of Banking and Finance* 30, 2945–2966. <https://doi.org/10.1016/j.jbankfin.2006.05.008>
- Boissay, F., Gropp, R., 2007. Trade Credit Defaults and Liquidity Provision by Firms. Rochester, NY.
- Buatsi, S.N., 2002. Financing Non-Traditional Exports in Ghana. *Journal of Business and Industrial Marketing* 17, 501–522. <https://doi.org/10.1108/08858620210442848>
- Buzacott, J.A., Zhang, R.Q., 2004. Inventory Management with Asset-Based Financing. *Management Science* 50, 1274–1292. <https://doi.org/10.1287/mnsc.1040.0278>
- Caniato, F., Gelsomino, L.M., Perego, A., Ronchi, S., 2016. Does Finance Solve the Supply Chain Financing Problem? *Supply chain Management: An International Journal* 21, 534–549. <https://doi.org/http://dx.doi.org/10.1108/SCM-11-2015-0436>
- Chen, X., Cai, G., 2011. Joint logistics and financial services by a 3PL firm. *European Journal of Operational Research* 214, 579–587. <https://doi.org/10.1016/j.ejor.2011.05.010>
- Chen, X., Hu, C., 2011. The Value of Supply Chain Finance, in: Habib, M.M. (Ed.), *Supply Chain Management-Applications and Simulations*. Intech, pp. 111–132. <https://doi.org/10.5772/19208>
- de Boer, R., van Bergen, M., Steeman, M.A., 2015. *Supply Chain Finance, its Practical Relevance and Strategic Value*, 1st ed, The Supply Chain Finance Essential Knowledge Series. Zwolle.
- de Goeij, C.A.J., Onstein, A.T.C., Steeman, M.A., 2015. Impediments to the Adoption of Reverse Factoring for Logistics Service Providers, in: Zjim Henk, Klumpp Matthias, Clausen Uwe, Hompel Ten Michael (Eds.), *Logistics and Supply Chain Innovation*. Springer International Publishing, Cham, pp. 261–277. <https://doi.org/10.1007/978-3-319-22288-2>
- Dello Iacono, U., Reindorp, M., Dellaert, N., 2015. Market adoption of reverse factoring. *International Journal of Physical Distribution & Logistics Management* 45, 286–308. <https://doi.org/10.1108/IJPDLM-10-2013-0258>
- Demica, 2011. *Chain Reaction - Growth Trends in Supply Chain Finance: The Views of Europe's top 40 Banks*. London.
- Feenstra, B., Engbers, A.R., Steeman, M., 2017. *Supply Chain Finance and its Accounting Treatment*. Amsterdam.
- GBI, 2016. *2016 State of Supply Chain Finance Industry - Entering a New Era of Maturity*, Report.
- Gelsomino, L.M., Mangiaracina, R., Perego, A., Tumino, A., 2016. Supply Chain Finance: A literature Review. *International Journal of Physical Distribution & Logistics Management* 46, 348–366.
- Grüter, R., Wuttke, D.A., 2017. Option matters: valuing reverse factoring. *International Journal of Production Research* 7543, 1–16. <https://doi.org/10.1080/00207543.2017.1330564>
- Gustin, D., 2013. *Vendor Positioning Grid - 2013 Working Capital Technology Guide*.
- He, M., Ren, C., Shao, B., Wang, Q., Dong, J., 2010. Financial supply chain management, in: *Proceedings of 2010 IEEE International Conference on Service Operations and Logistics, and Informatics*. IEEE Xplore, pp. 70–75. <https://doi.org/10.1109/SOLI.2010.5551613>
- Herath, G., 2015. *McKinsey on Payments Supply-chain finance: The emergence of a new competitive landscape*,

- mckinsey on payments. London.
- Hofmann, E., 2009. Inventory financing in supply chains: A logistics service provider-approach. *International Journal of Physical Distribution & Logistics Management* 39, 716–740. <https://doi.org/10.1108/09600030911008175>
- Hofmann, E., 2005. Supply Chain Finance: some conceptual insights, in: *Logistik Management - Innovative Logistikkonzepte*. pp. 203–214.
- Hofmann, E., Kotzab, H., 2010. A Supply Chain-Oriented Approach of Working Capital Management. *Journal of Business Logistics* 31, 305–330. <https://doi.org/10.1002/j.2158-1592.2010.tb00154.x>
- Jinjarak, Y., 2015. Supply chains, global financial shocks and firm behaviour towards liquidity needs. *World Economy* 38, 425–444. <https://doi.org/10.1111/twec.12202>
- Klapper, L., 2006. The role of factoring for financing small and medium enterprises. *Journal of Banking and Finance* 30, 3111–3130. <https://doi.org/10.1016/j.jbankfin.2006.05.001>
- Klapper, L., Randall, D., 2011. Financial Crisis and Supply-Chain Financing, in: *Chauffour, J.-P., Malouche, M. (Eds.), Trade Finance during the Great Trade Collapse*. World Bank Publications, Washington, D.C., pp. 73–86.
- Lamoureux, J.-F., Evans, T., 2011. Supply Chain Finance: A New Means to Support the Competitiveness and Resilience of Global Value Chains, SSRN Report. <https://doi.org/10.2139/ssrn.2179944>
- Lekakos, S.D., Serrano, A., 2016. Supply Chain Finance for Small and Medium Sized Enterprises: The Case of Reverse Factoring. *International Journal of Physical Distribution & Logistics Management* 46, 367–392. <https://doi.org/http://dx.doi.org/10.1108/IJPDLM-07-2014-0165>
- Liebl, J., Hartmann, E., Feisel, E., 2016. Reverse Factoring in the Supply Chain: Objectives, Antecedents and Implementation Barriers. *International Journal of Physical Distribution & Logistics Management* 46, 393–413. <https://doi.org/10.1108/02656710210415703>
- Martello, S.S., Toth, P., 1990. *Knapsack Problems: Algorithms and Computer Implementations*, 1 edition. ed. Chichester; New York.
- Martin, J., 2017. Suppliers' participation in supply chain finance practices: predictors and outcomes. *International Journal of Integrated Supply Management* 11, 193. <https://doi.org/10.1504/IJISM.2017.086242>
- Martínez-Sola, C., García-Teruel, P.J., Martínez-Solano, P., 2017. SMEs access to finance and the value of supplier financing. *Revista Espanola de Financiacion y Contabilidad* 46, 455–483. <https://doi.org/10.1080/02102412.2017.1345196>
- More, D., Basu, P., 2013. Challenges of supply chain finance: A detailed study and a hierarchical model based on the experiences of an Indian firm. *Business Process Management Journal* 19, 624–647. <https://doi.org/10.1108/BPMJ-09-2012-0093>
- Nienhuis, J.J., Cortet, M., Lycklama, D., 2013. RealTimeFinancing: Extending E-Invoicing toward Real Time SME Financing. *Journal of Payments Strategy & Systems* 1–13.
- Ohlsson, M., Pi, H., 1997. A Study of the Mean Field Approach to Knapsack Problems. *Neural Networks* 10, 263–271.
- Pellegrino, R., Costantino, N., Tauro, D., 2018. Supply Chain Finance: A supply chain-oriented perspective to mitigate commodity risk and pricing volatility. *Journal of Purchasing and Supply Management*. <https://doi.org/10.1016/j.pursup.2018.03.004>
- Perego, A., Salgaro, A., 2010. Assessing the benefits of B2B trade cycle integration: a model in the home appliances industry. *Benchmarking: An International Journal* 17, 616–631. <https://doi.org/10.1108/14635771011060611>
- Pfohl, H., Gomm, M.L., 2009. Supply chain finance: optimizing financial flows in supply chains. *Logistics Research* 1, 149–161. <https://doi.org/10.1007/s12159-009-0020-y>
- Raddatz, C., 2010. Credit Chains and Sectoral Comovement: Does the Use of Trade Credit Amplify Sectoral Shocks? *The Review of Economics and Statistics* 92, 985–1003.
- Randall, W.S., Farris II, M.T., 2009. Supply chain financing: using cash-to-cash variables to strengthen the supply chain. *International Journal of Physical Distribution & Logistics Management* 39, 669–689. <https://doi.org/10.1108/09600030910996314>
- Robert, M., Jerome, M., 2011. Asset-Based Financing Basics. *Journal of Accountancy* 40–44.
- Siemes, D., Extra, W., Dellermann, S., Gelsomino, L.M., Kortman, R., Oosterhuis, M., Monagan, L., 2017. *SCF Barometer 2017*. Amsterdam.
- Song, H., Yu, K., Lu, Q., 2018. Financial service providers and banks' role in helping SMEs to access finance. *International Journal of Physical Distribution & Logistics Management IJPDLM-11-2016-0315*. <https://doi.org/10.1108/IJPDLM-11-2016-0315>
- Sugirin, M., 2009. Financial supply chain management. *Journal of Corporate Treasury Management* 2, 237–241.
- Tanrisever, F., Reindorp, M., Cetinay Hande, 2015. Reverse Factoring for SME Finance.
- Templar, S., Findlay, C., Hofmann, E., 2016. *Financing the End-to-end Supply Chain, A Reference Guide to Supply Chain Finance*. KoganPage.
- van der Vliet, K., Reindorp, M.J., Fransoo, J.C., 2015. The price of reverse factoring: Financing rates vs. payment delays. *European Journal of Operational Research* 242, 842–853. <https://doi.org/10.1016/j.ejor.2014.10.052>
- Viskari, S., Kärrä, T., 2012. A model for working capital management in the inter-organisational context. *International Journal of Integrated Supply Management* 7, 61–79.

- <https://doi.org/10.1504/IJISM.2012.051051>
- Wuttke, D.A., Blome, C., Foerstl, K., Henke, M., 2013a. Managing the Innovation Adoption of Supply Chain Finance-Empirical Evidence From Six European Case Studies. *Journal of Business Logistics* 34, 148–166. <https://doi.org/10.1111/jbl.12016>
- Wuttke, D.A., Blome, C., Henke, M., 2013b. Focusing the Financial flow of Supply chains: An Empirical Investigation of Financial Supply Chain Management. *International Journal of Production Economics* 145, 773–789. <https://doi.org/10.1016/j.ijpe.2013.05.031>
- Wuttke, D.A., Blome, C., Sebastian Heese, H., Protopappa-Sieke, M., 2016. Supply Chain Finance: Optimal Introduction and Adoption Decisions. *International Journal of Production Economics* 178, 72–81. <https://doi.org/10.1016/j.ijpe.2016.05.003>
- Zhou, Y.-W., Zhong, Y.-G., Wahab, M.I.M., 2013. How to make the replenishment and payment strategy under flexible two-part trade credit. *Computers & Operations Research* 40, 1328–1338. <https://doi.org/10.1016/j.cor.2012.12.013>

Appendix

Summary of notations

Variable	Unit	Description	Variable	Unit	Description
Assessment of tangible benefits					
D_i	€/year	Annual demand between the buyer and the i -th supplier	TBS_{ij}	€/year	Tangible benefits for the i -th supplier deriving from onboarding in the j -th scheme
DSO_i	days	Days of Sales Outstanding of the i -th supplier	TBB_{ij}	€/year	Tangible benefits for the buyer deriving from onboarding the i -th supplier in the j -th scheme
DIH_i	days	Days of Inventory Holding of the i -th supplier	r_{RF}	%/year	Annual interest rate of the RF programme
m_i	%	Margin of the i -th supplier	ΔDSO	days	DSO extension required by the buyer to all suppliers onboarded in RF
t_a	days	Administrative time to approve invoices by the buyer	f_{IF}	%	Fee paid to the service provider in IF (proportional to amount financed)
$r_{s,i}$	%/year	Cost of debt of the i -th supplier	ep_i	%	Average early settlement period of invoice in DD for the i -th supplier
r_b	%/year	Cost of debt of the buyer	f_{DD}	%	Fee paid to the service provider in DD (proportional to invoice nominal value)
d_{ij}	%	Discount on the invoice nominal value exercised by the buyer while onboarding the i -th supplier in the j -th scheme	TS	%	Minimum level of benefits (threshold) for the supplier to onboard in an SCF scheme (as % of D_i)
General allocation problem					
TBB_{ij}	€/year	Tangible benefits for the buyer deriving from onboarding the i -th supplier in the j -th scheme	x_{ij}	N/A	Binary variable assuming value 1 if the i -th supplier is onboarded in the j -th scheme
F_{ij}	€/year	Funding required to onboard the i -th supplier in the j -th scheme	C_j	€/year	Cap on the total amount of funding that can be allocated to the j -th scheme

Figures and tables

Table 1

	Reverse Factoring	Inventory Financing (innovative)	Dynamic Discounting
Main benefit for buyer	Reduction of working capital through combination of longer payment terms and discount	Costs of goods sold reduction through discount	Costs of goods sold reduction through discount
Impact on supplier working capital	Reduction through early payment of invoices	Reduction through lower inventory levels and (possibly) early payments of invoices	Reduction through early payment of invoices
Main cost for supplier	Has to directly pay the service provider and possibly provide the buyer with a discount or extension of payment terms	Has to provide the buyer with a discount covering at least the cost of the solution	Has to provide the buyer with a discount
Direct involvement of third party financier	Always	Always	Not compulsory
Service provider fee charged to	Supplier (interest charges proportional to amount financed)	Buyer (within re-sell price, proportional to amount financed)	Supplier (proportional to invoice value)
Key references	Klapper, 2006; Wuttke et al., 2016; Wuttke et al., 2013a; Dello Iacono et al., 2015	Hofmann, 2009; Chen and Cai, 2011	More and Basu, 2013; Templar et al., 2016

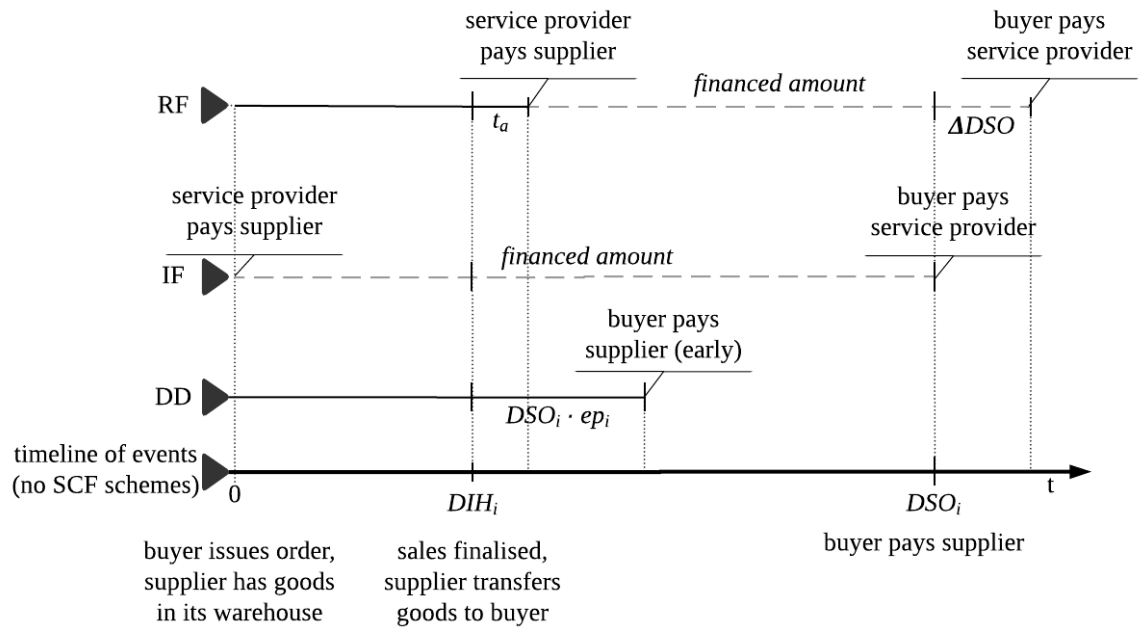
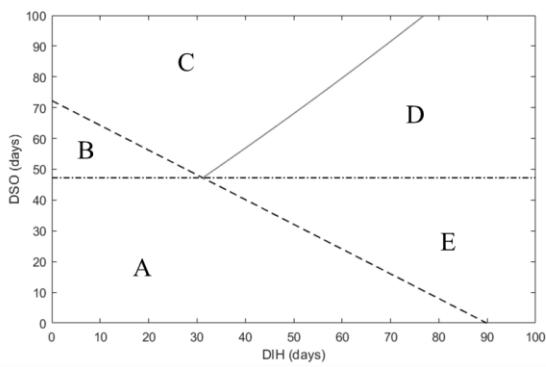


Figure 1

Table 2

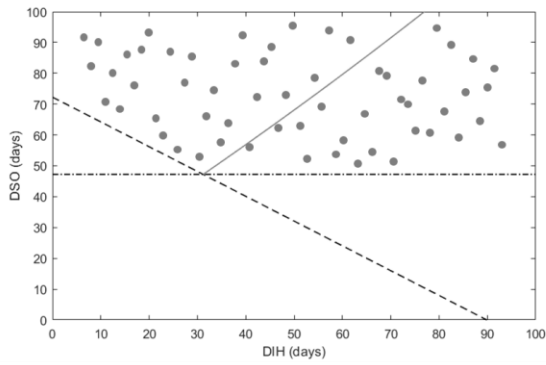
<i>Variable</i>	<i>Value</i>	<i>Variable</i>	<i>Value</i>
ΔDSO	30 days	f_{IF}	0.03
t_a	5 days	r_B	0.005
f_{DD}	0.005	C_{RF}	500 M€
m	0.1	C_{IF}	700 M€
TS	0.001	C_{DD}	500 M€
r_{RF}	0.01		



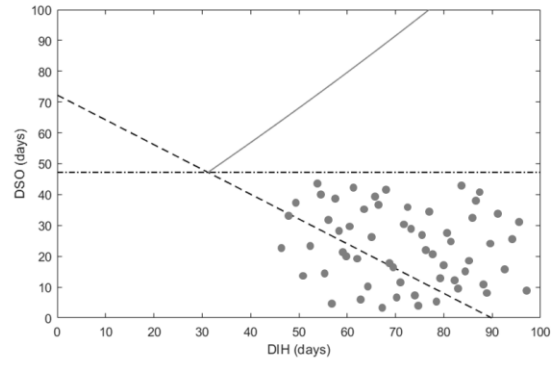
Legend:
 - - - RF (or DD) threshold
 - - - IF threshold
 — Frontier between schemes (RF and IF in this example)
 • supplier

Parameters used to generate the charts:

$f_{if} = 0.05$ $t_a = 5 \text{ days}$
 $r_s = 0.1$ $\Delta DSO = 30 \text{ days}$
 $m = 0.1$ $r_{RF} = 0.01$
 $TS = 0.01$ $r_b = 0.005$

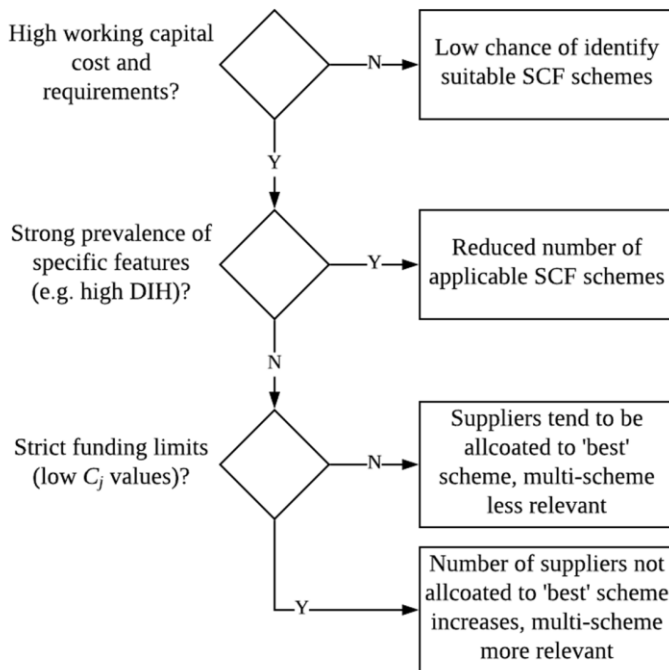


(a)

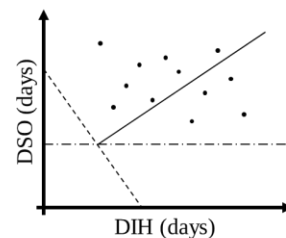
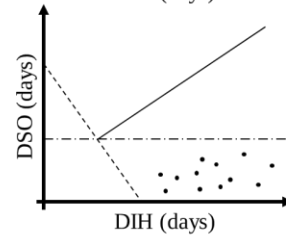
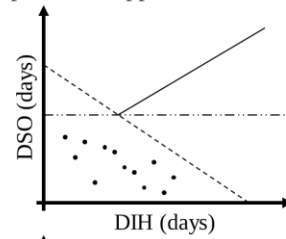


(b)

Figure 2



Graphical representation of potential suppliers distributions



Legend:
 - - - RF or DD threshold
 - - - IF threshold
 — Equal benefit frontier
 • supplier

Figure 3

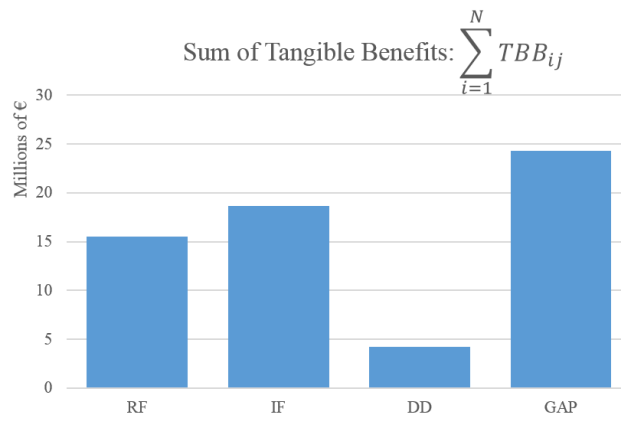


Figure 4

Table 3

RF	IF	DD	Number of suppliers	% of suppliers
Y	Y	Y	51	15%
N	Y	Y	0	0%
Y	N	Y	0	0%
N	N	Y	0	0%
Y	Y	N	130	39%
N	Y	N	1	0%
Y	N	N	52	16%
N	N	N	97	29%

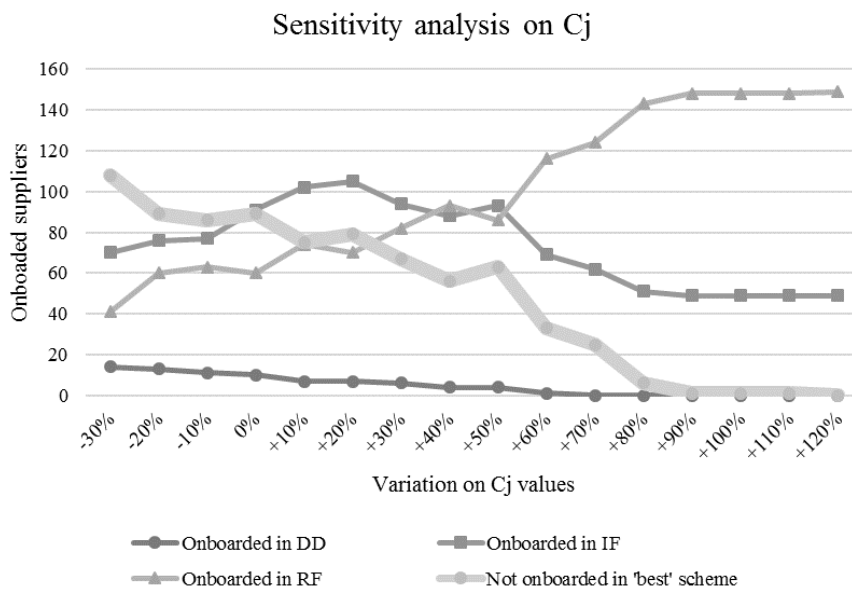


Figure 5